HOUSEHOLD ENERGY USE AND DETERMINANTS OF ADOPTION OF SOLAR (PV) ENERGY TECHNOLOGY IN HAWZEN DISTRICT OF TIGRAI, ETHIOPIA

M.Sc. THESIS

BERHANE HIDARU WELDEKRISTOS

HAWASSA UNIVERSITY, WONDO GENET COLLEGE OF FORESTRY AND NATURAL RESOURCE, WONDEGENT, ETHIOPIA

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BERHANE HIDARU WELDEKRISTOS

THESIS SUBMITTED TO THE

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

OCTOBER, 2019

ADVISORS'APPROVAL SHEET

This is to certify that the thesis entitled "**Household Energy Use and Determinants of Adoption of Solar (PV) Energy Technology in Hawzen District of Tigrai, Ethiopia**" submitted in partial fulfillment of the requirements for the degree of Master's in specialization Renewable Energy Utilization and Management, the Graduate Program of the Department of Environmental Science, and has been carried out by **Berhane Hidaru ID.No. REUM/Roo4/10** under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department

Zerihun Demrew (Ph.D.) ____________________ __________________

Signature Date

Yemiru Tesfaye (Ph.D.) __________________ ___________________

Signature Date

OCTOBER, 2019

We, the undersigned, members of the Board of Examiners of the final open defense by **Mr. Berhane Hidaru Weldekristos** have read and evaluated his thesis entitled " **Household Energy Use and Determinants of Adoption of Solar (PV) Energy Technology in Hawzen District of Tigrai, Ethiopia**" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

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Name of the Chairman person	Signature	Date
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Name of Major Advisor	Signature	Date
_____________________	____________________	______________
Name of Internal Examiner	Signature	Date
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Name of External examiner	Signature	Date
_________________________	____________________	______________
SGS Approval	Signature	Date

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Berhane Hidaru Weldekristos

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled " **Household Energy Use and Determinants of Adoption of Solar (PV) Energy Technology in Hawzen District of Tigrai, Ethiopia**" in partial fulfillment of the requirements for the award of the degree of Master of Science and submitted to the School of Graduate Studies, Wondo Genet College of Forestry and Natural Resource, Hawassa University is an authentic record of my own work carried out during the period from October, 2018 to October 2019 under the supervision of Zerihun Demrew (Ph.D.) Assistant Professor, Hawassa University and Yemiru Tesfaye (Ph.D.) Associate professor, Wondo Genet.

The work contained in this thesis has not been previously submitted for similar or for other purpose at any higher institution or elsewhere to the best of my knowledge.

Berhane Hidaru Weldekristos ___________ ____________

Signature Date

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ACRONYOMY AND ABBREVIATIONS

A:	Agree
AC:	Alternating current
CdTe:	Cadmium Telluride
CH_4	Methane
CO_2:	Carbon dioxide
CO_2eq	Carbon dioxide equivalent
CRGE:	Climate Resilient Green Economy
CSP:	Concentrated solar power
D:	Disagree
DC:	Direct current
DOI:	Diffusion of Innovation
EEPCO:	Ethiopian Electric Power Corporation
FGD:	Focus Group Discussion
Fit:	Feed-in Tariff
GHG:	Energy-related greenhouse gas
GTP-2:	Growth and Transformation plan Two
GW:	Global Warming
GWP:	Global Warming Potential
Ha:	Hectares
HHS:	Household Heads
IPCC:	Intergovernmental Panel on Climate Change
IR:	Infrared Ray
IRENA:	International Renewable Energy Agency
Kg:	Kilogram
KWh:	Kilo Watt Hours
MJ:	Mega Joule
MoWIE:	Ministry of Water, Irrigation and Energy
N:	Neutral
N_2O:	Di nitrous oxide
Ppm:	Particle per million
PV:	Photovoltaic
REF:	Rural Electrification Fund
RET:	Renewable Energy Technology
S.D:	Standard Deviation
S.E:	Standard Error
SHS:	Solar Home System
SMFE:	Small and Medium Forest Enterprises
SPSS:	Statistical Package for Social Science
TAM:	Technology Acceptance Model
TJ:	Tera Joule
TRA:	Theory of Reasoned Action
UV:	Ultraviolet-visible

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ABSTRACT

The clean energy source for domestic consumption has been increasing globally. Ethiopia is in the equator experiences enough solar energy which provides an excellent opportunity for solar energy utilization. Despite the huge potential of solar energy in the study area, adoption of the technology is limited by different factors. Hence, the purpose of the present investigation was to explore the household energy use pattern in the study area and determine the factors that affect the adoption of solar energy technologies for domestic usage at the household level. Random sampling techniques were employed to identify the sample households for data collection using semi-structured questionnaires. Three hundred thirty-eight households were from a target population of 3,640 households. Descriptive and separate regression equations were used to investigate the influence of household head characteristics and economic factors on the adoption of solar power technology. The result revealed that households were consumed large proportion of 228,540Kg year^{-1} animal dung, 111,488Kg year^{-1}firewood, and 56,940 Kg yaer^{-1}charcoal source for baking and cooking purposes while 168.27Kg year^{-1}crop residues were the least used and most households use the solar lantern for lighting. The findings indicate that the adoption of solar energy technology is very low with only 6.2% of the household uses a solar home system in the three study Kebeles. The result revealed that households with age, number of families, cash income, and number of livestock owned showed statistically (+) effect. On the other hand, Kerosene user and the price of technology influence negatively to solar energy technology adoption in the study area. The study revealed that there is a lack of technically skilled person, lack of solar energy technology availability, and spare parts, off-grid rural dwellers, back to dark. It is recommended that government officials, government, NGOs and concerned stakeholders should focus on creating awareness, create incentives and subsidies, and support the government in building capacity to the dwellers in using solar energy and integrating it with biogases technology for domestic consumption.

Keyword: Energy consumption, off-grid solution, Renewable, solar home system, Tigrai

1. INTRODUCTION

1.1. Background

Access to energy has been associated with improving human development. However, 1.3 billion people, which are equivalent to 10% of the world's population, lack access to electricity. From this percentage, 22% are those living in developing countries with almost 97% of this percentage without access to electricity living in sub-Saharan Africa, and the primary source of energy globally is from coal, fossil fuel, oil, and natural gas causes 4 million deaths per year from breathing emission (Asumadu-Sarkodie and Owusu, 2016; Wagh and Walke, 2017; Watkins *et al*., 2017). Due to the rise in temperature the climate, physical appearance to change in different parts of the world and the main gases that cause climate change are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which account for 99 % of total greenhouse gas emissions (Janssens-Maenhout *et al*., 2017; Yang *et al*., 2017). Approximately more than 600 million people in sub-Saharan Africa alone are without electricity access (Lee *et al*., 2016; Stojanovski *et al*., 2017; Trotter *et al*., 2018). Hence, Sub-Saharan Africa is said to be the most energy-poor region on the planet with electrification rates which are much lower than the rest of the developing world (Kachapulula-Mudenda *et al*., 2018). However, among the renewable energy technologies (RETs), solar PV energy technology is one of the most common solutions to solve the lack of modern energy access in remote rural areas globally (Naah, 2018).

The Ethiopian energy faces a twofold challenge of limited access to modern energy and highly depends on traditional biomass energy sources (firewood, charcoal, animal dung and agricultural residues) to meet growing demand. However, the expansion of energy supply, in the urban areas (87%) of the population has access to electricity, while in rural areas electricity access remains extremely low at about 2%. While 83% percent of the population lives in rural areas, mainly relying on traditional biomass energy sources for baking, cooking, and kerosene and dry cell batteries for lamps and electronic media. Consequently, per capita electricity consumption was 23 kWh in 2000 and increased to about 41 kWh by 2008 and 86 kWh by 2015. However, this level is extremely below the average level of per capita energy consumption across all African countries (500 kWh per capita). Due to the dependence on biomass for cooking, CO_2 emissions in Ethiopia have increased from 5.1 million tons in 2005 to 6.5 million tons in 2010. On a per-capita basis, this amounts to 0.06 tons of CO_2 in 2005, 0.075 tons in 2010, and 0.19 tons in 2015 (Mondal *et al*., 2018; Warkaw Legesse and Chawla, 2016; Woldesilassie and Seyoum, 2017).

Ethiopia receives solar radiation levels ranging from 4.5 kWh per m^2 to 7.5 kWh per m^2 per day (Abubakar Mas'ud *et al*., 2016; Kammen *et al*., 2015; Mondal *et al*., 2018; Salam and Khan, 2018). On average, the country obtained about 6.0 kWh per square meters per day, corresponding to 2,200 kWh per m^2 per year. The average sunshine hours per day in Ethiopia is 6.6 hours (Abubakar Mas'ud *et al*., 2016; Schelling *et al*., 2010). Even if Ethiopia is one of the naturally given countries with a large array of renewable energy resources, it remains one of the energy poorest nations in the globe and the main sources of light in homes and small businesses, particularly in the rural community are kerosene lamps and candles (Alfa Hailemariam *et al*., 2013; Kassahun Yimer *et al*., 2014; Schelling *et al*., 2010). Therefore, electric lighting creates conditions conducive to study by reducing indoor air pollution and health hazards caused by kerosene lamps. Solar energy saves time spent on fuel collection, thereby freeing time to study and enabling people, especially women who work during the day to study in the evenings. Thus, access to clean energy could positively impact women's education, health, and livelihoods. Hence, access to modern energy contributes to improved education and gender equality (Kumar, 2018).

Most people in the rural villages of the study area use a solar lantern, dry cell batteries and kerosene lantern for lamp electronic media, diesel for water pumping and flour mills, firewood, animal dung and agricultural residues for cooking. Hence, the households that live in the rural villages of the study area are suffering from lack of modern electricity. Due to the cultural belief, women are forced to do their day-to-day domestic activities such as baking and cooking, using firewood, animal dung and agricultural residues which lead to a rapid rate of deforestation. Therefore, village electrification is a vital step in improving the socioeconomic conditions of rural areas and crucial for the country's overall development (Hailu Kebede and Bekele Beyene, 2018).

As the customer list of EEPCO (2018), in the Tigrai regional, state, in northern Ethiopia, the entire customer's on-grid electricity is 230,000 households only and approximately 4,000 solar home systems were installed in the entire region. Therefore, the rest over 1.03 million households are without access to modern energy sources. Due to the high transmission and distribution costs in the study area, many households are not connected to the national electricity network. Hence, the adoption of solar energy reduces poverty and helps economic development by enhancing the health, education, and water supply needs of the rural population (Kabir *et al*., 2017).

1.2. Statement of the Problem

Published study reports indicate that rural households in Ethiopia spent, on average USD 2 per month for 3 hours of lighting each night (Harrison *et al*., 2016). It is being reported that after purchasing a solar light, it is found that 71 % of families reduced their lighting spending, primarily on kerosene. Of those households, which were using kerosene for lighting before purchasing a solar lantern, 69 % eliminated kerosene use. After solar light ownership, families saved USD 60 per year, spending on average just 2 % of their household income on lighting. Thus, Tigrai regional, state, in northern Ethiopia off-grid inhabitants is facing energy poverty. This energy poverty is a key obstacle to improve social, environmental, economical, and well-being among the poorest household. Therefore, a lack of modern energy access negatively affects many households in their daily life. Consequently, energy poverty leads to a lack of access to acceptable health care because of the lack of electricity. Energy poverty also hinders the educational opportunities for children in many parts of the rural off-grid inhabitants, including in Hawzen district of Tigrai, as well as affecting's educational quality and equity. Using kerosene, the main source of lighting in many rural households causes childhood injuries or even deaths.

In rural Tigrai, as kerosene in Ethiopia is often imported its availability is limited. People who rely on kerosene must, therefore, limit the amount of time that children can make a study or family members can make products to sell after dark to conserve fuel (Alfa Hailemariam *et al*., 2013; Schuetzeichel, 2015).

Clean solar power technology is one of the best weapons to fight energy poverty. Ethiopia, being at the equator, has a higher potential of solar power than many other nations. On the other hand, the Government of Ethiopia is looking for alternative energy sources to address the energy needs of the rural people living in dispersed villages. As a result, solar energy is currently used to electrify public sectors and installing the solar home system in rural areas, where there is no access to the national grid (Natei Ermias and Getachew Tadesse, 2017). Due to the lack of awareness and information, the total exploited solar (PV) energy technology by household in Ethiopia and the study area looks insignificant, the energy demand being addressed through these solar (PV) energy technology installations is vital, serving remotely located rural households, with badly needed electricity services, that otherwise would not have been served.

In the study area, the solar lanterns and the solar (PV) energy for social institutions were begun dissemination earlier, while the solar home system for household use was started later. This study is therefore aimed at investigating the household energy consumption pattern and the determinant factors in adoption solar (PV) energy technology for domestic purposes, in Hawzen district in the Tigrai regional, state.

1.3. Objectives of the Study

1.3.1. General Objective

The general objective of the proposed study was to assess the household energy use and determinants of solar (PV) energy technology adoption in Hawzen district of Tigrai.

1.3.2. Specific Objectives

- To analyze the contribution of socioeconomic characteristics for household energy technology adoption.
- To investigate household energy demand for lighting.
- To asses household energy consumption for baking and cooking and carbon dioxide equivalent emission.
- To assess the determinants of adoption of solar (PV) energy technology for domestic usage.

1.4. Research Questions

- How socioeconomic characteristics influencing household energy source preference?
- What are the household sources of energy used for the lighting system?
- What is the major household energy consumption for baking and cooking and their carbon dioxide equivalent emission?
- What are the major determinants of adoption of solar (PV) energy technology for domestic usage?

2. LITERATURE REVIEW

2.1. Global Overview of Solar Energy

Energy is the lifeblood of the global economy as it interacts with all other goods and services that are essential for economies (Mukami, 2016). Thus, the sun is the most abundant energy source for the earth (International Energy Agency, 2010). Completely wind, fossil, hydro and biomass energy have their origins in solar radiation. Solar radiation falls on the surface of the earth at a rate of 120 petawatts[1], (1 petawatt = 10^{15} Watt). This means all the solar radiation received from the sun in one day can satisfy the whole world's demand for more than 20 years. According to Energy Balance for World Report (2010) provided by the International Energy Agency (IEA) around 30 % of the total energy produced is consumed by electricity generation sectors with an efficiency rate of 42.6 %. The PV is a commercially obtainable and reliable technology with a significant potential for long-term growth in nearly all world regions. In the IEA solar PV roadmap vision, PV is projected to provide 5 % of global electricity consumption in 2030, rising to 11 % in 2050 (International Energy Agency, 2010).

According to Sampaio and González (2017), the photovoltaic market is rapidly growing. Thus, during the period between 2000 and 2015, the growth rate of photovoltaic installations was off 41%. It is observed that in China and Taiwan since 2006 have been increasing the photovoltaic industry with strong growth rates. At the end of 2015, it is market share was about 71% of global sales. Europe contributed 40 % of the total cumulative PV installations in 2015 (in 2014 it was 48%). The facilities in China and Taiwan accounted for 21% of the total cumulative installations (in 2014 was 17%). In 2015, Germany accounted for about 16 % (39.6 GWp) of cumulative installed PV capacity worldwide (242 GWp). In 2015, the recently installed capacity in Germany was about 1.4

[1] Peta means 1.2×10^{17} Watts.

GW_P; in 2014 it was 1.9 GW_p. In total, 1.5 million photovoltaic systems were installed in Germany. The altered rates of technological advancement of photovoltaic technologies affect the dynamics of the market. The photovoltaic technology based on crystalline silicon accounted for about 93% of the total production in 2015. The participation of multi-crystalline silicon technology was about 69 % of total production. Among the thin-film technologies in 2015, CdTe cells led with an annual output of 2.5 GW_p. To 2015, the participation of all thin-film technology markets amounted to about 7% of the total annual production (Sampaio and González, 2017).

According to IRENA (2018), Off-grid renewable energy capacity has been deployed across a wide range of end-use sectors providing electricity services. Of the 6.6 GW of off-grid capacity in 2017, the industry sector dominates, followed by mixed-use and commercial/energy needs through self-generation. As the economic situation for renewable supports, islands in Oceania as well as in the Caribbean are expected to see a stronger transition towards renewable-based power systems. The Community Services, around 1.5 GW of off-grid capacity serves unknown sector(s) due to the lack of end-use disaggregated data. The biomass energy accounts for the majority share of industrial off-grid capacity with feedstock depending on local conditions, including agricultural and forestry residues. Solar photovoltaic (PV) accounts for the majority of users in the commercial and public sectors, as well as in residential and agriculture/forestry. Within commercial and public uses, most solar PV use is for powering telecommunication infrastructure, followed by schools, street lighting, health centers, and water pumping.

The modular and distributed nature of solar PV enables it to be adapted to a wide range of off-grid applications, and several programs and initiatives have been launched to accelerate deployment. Solar pumps offer an attractive option to provide affordable and sustainable modern energy for meeting water pumping needs for irrigation and drinking water supply and are increasingly being deployed (IRENA, 2016). Another area of growing interest is the use of solar PV for powering rural health care centers.

2.2. Overview of Ethiopian Energy Statuses

According to Mondal *et al.* (2018), Ethiopia launched the "Light to All" National Electrification Program in November 2017 to provide electricity access to all by 2025. Hence, alternative policy scenarios are developed in line with government goals for universal electrification, energy efficiency improvement, and mitigation of GHG emissions in the energy sector (Mondal *et al*., 2018). The country has a final energy consumption of around 4.57 GW; somewhere of 93 % are consumed by household utilization, 4 % by transport and 3 % by industry (Benka-Coker *et al*., 2018). Most of the energy about 70-80% household energy supply comes from biomass, although the demand for it is still higher than the supply (Benka-Coker *et al*., 2018; Gebrecherkos Gebregiorgis, 2015). The produced electricity of ~ 9000 GWh per annum is mainly generated by hydro energy (96%) followed by wind energy (4 %), whereof in total, 11 % get exported. In opposition to the major share of energy supply for transport is imported in the forms of oil, Ethiopia is gifted with renewable energy sources. These are hydro first, but also wind, geothermal, solar as well as biomass. Only a small share of the potential is harnessed today. Due to its fast economic growth, the energy demand is increasing enormously. Therefore, it is expected to rise by a rate of (10 -14) % per year till 2037.

2.3. Determinant Factors for Solar (PV) Energy Technology Adoption

2.3.1. Socioeconomic Factors of Solar (PV) Energy Technology

Studies revealed that the cost of a PV solar system is a major barrier in the diffusion of the solar system in homes. It also reflects the financial constraints in terms of the high cost of PV system which further intensify the absence of subsidies and incentive from the government side (Khalil *et al.*, 2017). According to Abate Warkaw and Chawla (2016), and Assefa Admassie and Gezahegn Ayele (2011), solar technology adoption increases as age and distance to the market center decrease. Awareness, farmers' contact with extension agents, literacy and income increase. Whereas decreasing with increases farming occupation. Remoteness agriculture extension center and market service, time are taken to collect of firewood and frequency of cooking meals and with increased availability of charcoal, household size and Farm size, increase the adoption of renewable energy decision. Location of charcoal collection, increase the time taken for charcoal collection decrease adoption.

According to Kabir *et al.* (2017), and Khan and Khanam (2017), higher installation cost, with the occurrence of rural poverty, less developed country, the adoption of the solar home system wants to address the lower purchasing power of the rural client. One of the key challenges that need important consideration in this sector is to decrease the high upfront cost of the solar system. Research Studies have shown that discount in price by 10 % would inspire 61% of non-solar home system households to wary of adopting the solar home system. Savings in energy costs, solar power technology makes the households' worried simple and reduce expenses for candle and kerosene for lighting purpose.

Solar power technology supports the rural household within the business to increase their income and output by extending the working time after sunset and access to information, the usage of electronic home appliances like; Television, radio, computer and mobile phone increases access to information about the market price of materials and energy condition. Thus, employment generation, solar power technology for domestic production of solar component types such as lamps, charge controller and inverters create job chances for technicians and local jobless youth in solar in the solar industry. Solar power technology in rural off-grid areas create solar installation job and also improved health and safety conditions: as solar power technology is environmentally friendly, the growing implementation of solar power technology in the rural off-grid household reduces emission kerosene lantern, accordingly, adds health improving and harmless situation among the most susceptible groups. Improved educational opportunities: benefits of solar electricity to student with extended study hour after dark and the quality of performance of education and gender equity are promoted, thus, revealed positive correlation between rural electrification and education enrollment ratios, gender aspects: in rural village, empowering rural labor force, especially young women to become technicians and Entrepreneurs give women's to adopt solar electricity has improved their social-economic significant in the rural household and supports women empowerment

2.3.2. Level of Knowledge and Awareness on the Technology

According to Khan and Khanam (2017) and Kabir *et al.* (2017), lack of knowledge and awareness about solar energy technology still founds a small share in developing the country's energy generation portfolio. Currently, the mounted renewable energy generation capacity is 2.89 %. Thus, the lack of knowledge and awareness of adopting solar technology requires demonstration of it to the rural inhabitance to create the benefits of solar technology well-known to people through the media and via applied demonstrations.

2.3.3. Availability of Alternative Sources

According to Khan and Khanam (2017), lack of availability of better quality system components; research studies have shown that low availability of better quality solar home system components like batteries and charge controllers affects customer's attitudes and durability of the system. Therefore, the sustainability of the solar home system program also needs, the availability of solar equipment in the off-grid rural areas so that customers can purchase them easily when required.

2.3.4. Government Policy on the Adoption of Solar (PV) Energy Technology

According to Khan and Khanam (2017), and Assefa Admassie and Gezahegn Ayele (2011), low after-sales service support and need for technician training: Client fulfillment and impact assessment studies have shown that in some cases, the customer of the solar home system has shown experience lack of regular and reasonable maintenance service from the suppliers. Accordingly, trained local technicians will yield better results. Hence, skilled service employees can reach consumers on the right usage and maintenance of the solar home system, which may avoid expert demands and increase system reliability. Research studies declared that the lack of integrated hard work from the shareholders is obvious to stimulate the commercialization of renewable energy. There are difficulties in the organization of a dispersed technical system on a one to one basis between service supplier on the ground and the customer (household or enterprise). Similarly, it should strengthen its quality control and inspections to ensure the quality and benefits of solar home system installations.

The change in import duty can be the outcome of rising costs and move solar energy schemes, which have previously been scheduled and are being established. In this context, the high upfront cost of increasing the national electricity grid to the off-grid rural areas of the country is an acute limitation in rural electrification and increases access to credit increases the adoption of technology.

2.3.5. Environmental Factors of Solar (PV) Energy Technology

Hemmen (2011) and Khan and Khanam (2017), reported that a reduction in greenhouse gas emission, growing economy, like developing countries, solar home systems deliver cost-effective chances to implement low carbon growth electrification without negotiation the hard work in endless progress of living standard. Thus, about 11 % of people in rural off-grid areas have recognized solar power technology, which is a significant potential for ever greater diminution of harmful GHG.CO_2 emissions per capita was not a monetary consideration but were heavily influenced by the waiting monetary variable of average income. Also interesting are the especially high correlations with the awareness, alternatives of bounded rationality.

It appears that levels of awareness might be even better indicators of solar energy adoption than monetary considerations. This is evidenced by the lower correlations of solar adoption with the payback period as compared to more visible monetary considerations such as system price and the presence of incentives. Interpretation of the strong correlations of system price and average income as compared to the other monetary variables would also lead to two primary conclusions. First of all, likely, many people do not have available funds for the upfront costs, which prevents them from solar adoption altogether. Secondly, it may indicate that nonmonetary factors are at play with those that do have the funds. At the counterbalance, it might be concluded that Fits stimulate solar adoption particularly well. However, in this case, it must also be considered that Fit platforms might put in place where solar adoption is particularly popular due to political motivations, or that Fit platform is used in countries that are mainly well equipped to adopt solar. Overall, it proved to be difficult to judge the influence of government incentives since the direction of the relationship between incentives and solar adoption is unclear.

2.4. Household Energy consumption and their carbon dioxide emission

2.4.1. Fuel Stacking Theory

Fuel stacking theory corresponds to multiple fuel use patterns where households choose a combination of fuels from both lower and upper levels of the ladder. Indeed, modern fuels may serve only as partial, rather than perfect substitutes for traditional fuels (Muller and Yan, 2018). Multiple fuel use arises for several reasons, such as, occasional shortages of modern fuels, high cost of appliances associated with using exclusively modern fuels, fluctuations of commercial fuel prices and preferences inducing households not to fully adopt modern fuels.

According to Solomon Ayele and Demel Teketay (2018) currently, over 2.5 billion people around the world depend on biomass fuels for cooking and heating. Although all people have a legitimate right to and need for energy services, which are affordable, healthy, reliable and sustainable, energy issues are particularly challenging for developing countries where higher energy costs exert tremendous pressure on fragile economies that have little capacity to adapt or change.

According to Lp (2016) firewood (cooking, lighting, heating bath water, and heating space), charcoal (cooking, ironing, heating bath water and heating space), kerosene (lighting and cooking), electricity (lighting and cooking), gas (cooking), solar (lighting), petrol (transport and powering generators for light) and diesel (transport and powering generators for lighting). Reducing the current pressure on biomass resources, increasing land productivity and reducing the ill effects of indoor air pollution, understanding the determinants of adoption, as well as the speed of adoption, can provide information that policymakers can use to increase the speed of adoption, generally (Beyene and Koch, 2013).

According to Kus *et al*. (2017) energy consumption based CO_2 emissions is examined, heating and hot water energy consumption have the highest emission amount (4.34 tons) per household. Electricity consumption related CO_2 emissions ranks second (1.69 tons), followed by private car usage and auxiliary heating energy consumption emissions. It was aimed to determine the amount of CO_2 emissions due to the energy consumption in the residential sector in Ankara and the factors that affect the energy consumption at homes.

2.5. Theoretical Background on the Diffusion of Solar (PV) Energy Technology

"Diffusion of Innovation" (DoI) as a main theory to understand the diffusion of clean energy innovations. Address its benefits and shortcomings, and pay special attention to specific technology related and socio-cultural dimensions (Elmustapha *et al.*, 2018)

DoI is considered an academic milestone in the field of novel technology adoption diffusion. Argues that opinion leaders and change agents play an influential role in diffusing innovation within communities through their social network. In addition, this theory explained that when innovations are presented to the public, the public will experience uncertainty when deciding whether to adopt or not. As a result of this uncertainty, potential adopters will engage in information seeking behavior to assess the necessary factors (innovation characteristics or social factors) before adopting. This is contested by scholars who argue that sharing information alone is not sufficient to initiate behavior change in communities

2.5.1. Limitations of the Diffusion of Innovation Theory

In various studies DoI was used as an analytical framework focusing on innovation-diffusion of energy efficient systems in residential sector communities and in the industry and built environment. Although widely used, the DoI theory is not without limitations. An important limitation is when major socio-cultural factors in the value system of end users and technology specific constraints are not considered (Elmustapha *et al.*, 2018)

2.5.2. Technology Attributes

Studies have shown that the high initial cost is a barrier which is declared by all respondents, regardless, of their category (user or non-user) (Elmustapha *et al.*, 2018; Khalil et al., 2017). The installation of the PV system will be complex task or simple. It has been shared that government is providing loans through a state bank, but usually not providing any subsidy on the solar panel. While another barrier like hard accessibility is not a significant barrier. For a complete assessment of complexity attribute, an aspect of maintenance and routine services is also requested high demand for maintenance. Observability and Trialability features are hard to access. Researches showed that both play positively in the diffusion of the solar system to households (Elmustapha et al., 2018). According to Feng (2012), Maina and Rotich (2016) and Qureshi *et al.* (2017), both attitude and subjective norm are important determinants of people's intention to adopt and use technology in enterprises. Further, the intention to adopt and to continue using technology is influenced by one's attitude. Using the theory of reasoned action (TRA), the technology acceptance model (TAM) Elmustapha *et al*. (2018) is the second important factor, the last factor was the acceptance of innovation and they were found that the income wasn't the significant variables. Likewise, it won't have to affect the attitude toward to use the technology.

The resource-based theory states that the basis for the competitive advantage of a firm lies primarily in the application of the bundle of valuable resources at the firm's disposal, including technology such as solar technology. According to Feng (2012) and Maina and Rotitch (2016) firm`s ability to reach a competitive advantage when different resources are employed and these resources cannot be imitated by competitors. The theory of innovation diffusion further considers the adopter classes as an influence on the rate of adoption of new technologies. Adopters of a given new technology can be classified into five with its own % age shares, i.e. Innovators (2.5%), early adopter (13.5%), early majority (34%), late majority (34%) and laggards (16%) respectively (Elmustapha *et al*., 2018; Hemmen, 2011; Rogers, 1995).

2.6. Conceptual Framework

The conceptual framework in Fig. 2.2 demonstrates the relationships that existed between the dependent and independent variables under investigation. The dependent variable performs of solar energy technologies. The independent variables that were investigated to establish their level of influence on the dependent variable were: Determinant of solar energy adoption for demotic usage, environmental factors, and socioeconomic characteristics, government policy factors, technology characteristics, attitude and how they influence on the adoption of solar energy technologies.

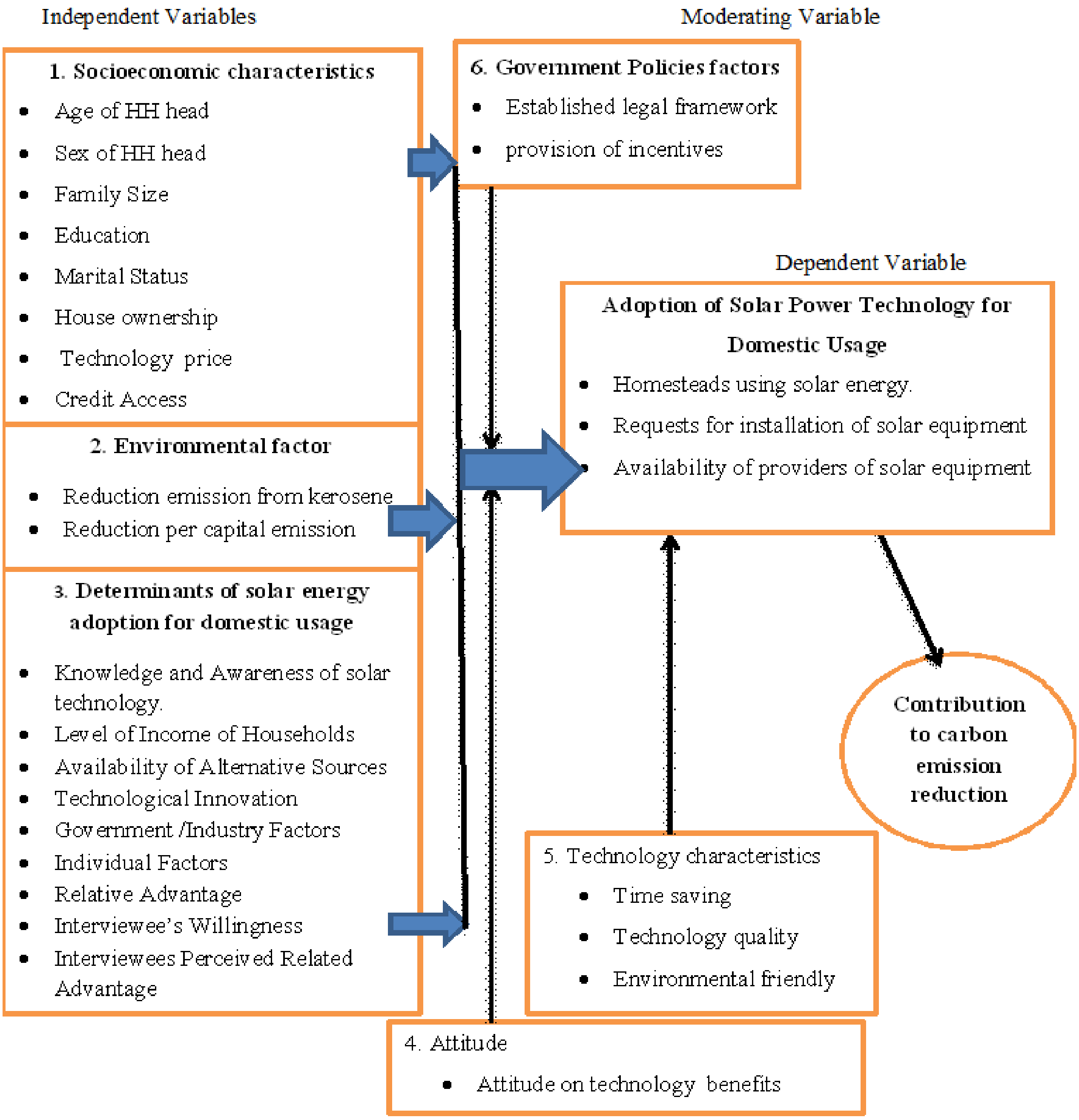

Fig: 2.2. Conceptual Framework of Variables (Kanangire et al., 2016)

The conceptual framework indicates that determinants of adoption of solar energy technology for demotic usage (i.e. Knowledge and awareness, availability of alternative of solar power sources, level of income of household head, technology innovation, individual factor, relative advantage, Interviewee's willingness, and Interviewee's perceived relative advantage). Environmental factors (i.e., Reduced emission from kerosene and reduction per capita emission). Socioeconomic characteristics (i.e. Age of household head, educational level of household head, sex of household head, family size, marital status, house ownership, credit access), governmental policy (i.e. Established legal framework and provision of incentives). Attitude on technology benefits and technology characteristics could affect the adoption of solar (PV) energy technology adoption.

3. MATERIAL AND METHODS

3.1.Description of the Study Area

3.1.1. Location

The study was carried out in Hawzen district, Eastern zone of Tigrai, regional, state. It is one of the seven districts of the Eastern zone of Tigrai, regional, state. Geographically, it is located between 13.50° to 14.175°N latitude and 39.20° to 39.55°E longitudes (Fig. 3.1).

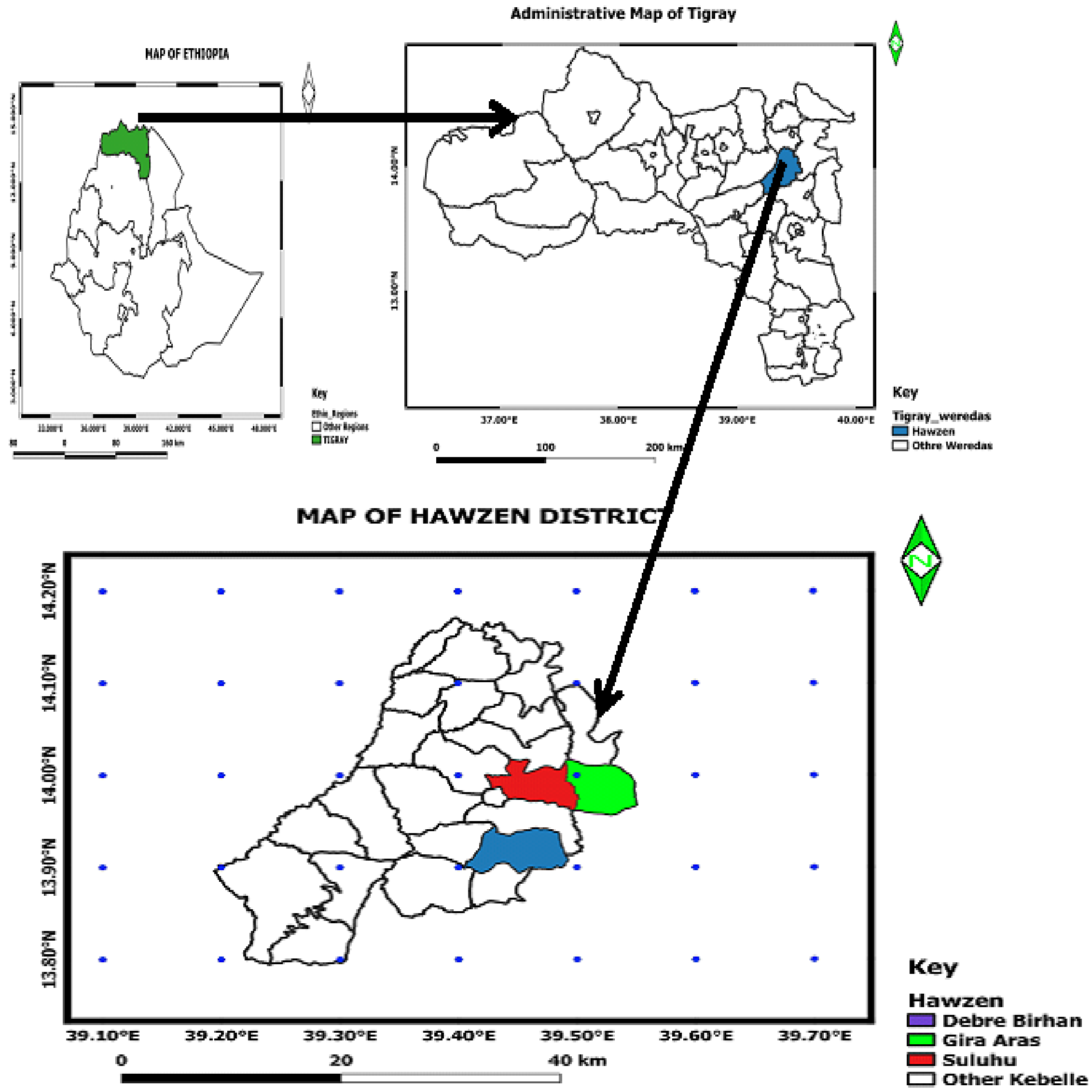

Fig: 3.1.Map of the Study Area

The district is bordered by Saesie-Tsaeda Emba, Wereleke, Kilteawlaelo and Ganta-ofeshim districts to the east, west, south, and north, respectively, and has 24 Kebeles. The district is located at a distance of 78Km away from Mekelle, the regional capital city and 861 km away from Addis Ababa (Luchia Tekle and Hadush Hagos, 2018).

3.1.2. Topography and Climate

According to Luchia Tekle and Hadush Hagos (2018), Hawzen district has a total area of 1,892.69 square kilometers and characterized by three agro-ecological zones (Dega, Woina Dega, and Kola). More than 60% of the areas are categorized as Woina Dega (i.e., Midland areas). The main rain lasts from mid-June to mid-September, with temperature ranging from 12°C to 28°C. The annual rainfall ranges between 500-700 mm with altitude ranging from 1500- 2450 meters above sea level. The temperature of the area ranges from 12°C to 28°C. February, March, and May are the hottest months, while November and December are the coldest months with the rainy season extended up to six months.

3.1.3. Population

According to Luchia Tekle and Hadush Hagos (2018), Hawzen district has a population of 129,681 (62,787 males and 66,894 females). Based on the 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA), a total of 25,067 households was living in this district. The average number of family members in a single house in the rural part of the Tigrai regional, state is 4.71 people (Wikipedia, 2017). It is the second-most densely populated districts of the Eastern zone next to the Atsbi Wonberta district (Luchia Tekle and Hadush Hagos, 2018).

3.1.4. Land Use and Socioeconomic Activities

According to CSA[2] (2007), 21,582 farmers are living in the district with an average of landholding of 0.77 ha per household. Of the total 16,580hectares of private land, 77.92 % were under cultivation, 12.64 % is used as a pasture, 5.1% as fallow, 0.78 %is woodland, and 4.03 % were devoted to other uses. For the land under cultivation in this district, 62%

[2] CSA means Central Statistics Agency

was planted with cereals, 13.2% pulses, 0.96% oilseeds, and 7 ha covered with vegetables. The total area planted in fruit trees was 372 ha, while 13 were planted in Gesho[3]. Seventy-four percent of the farmers both raised crops and livestock, while 22.35% only grew crops and 3.65% only raised livestock. Land tenure in this district is distributed amongst 95.49% owning their land, 3.37% renting, and 1.02 % holding their land under other forms of tenure.

3.2. Selection of Study Area

The district has traditionally Dega[4], Woina[5]Dega and Kola[6]agro-ecologies and has all the signs of the scarcity of firewood hence the need for alternative energy sources. For the present investigation, three sample Kebeles[7] were selected out of 24 Kebeles in the district purposefully based on the dissemination of the solar home system.

3.3. Sample Population

According to the rural electrification information, the amount of solar home system, disseminated in the whole region has found to be 3,384 households since 2013/2014. The sample households were categorized into adopters and non-adopter households of solar technology. Since the numbers of adopters of solar technology are expected to be less in number, and the researcher also has an interest to know on the adopter households in three sample Kebeles were included in the investigation. The targeted sample population was 3,640 household heads from both types.

[3]"Gesho" means a type of plant used to make the local drink (Tela)
[4]"Dega" means the coldest area and denser population.
[5]"Woina Dega" means middle temperature and lesser denser.
[6] "Kola" means the hottest area.
[7] Kebele is the smallest administrative unit of Ethiopia.

3.4. Sampling Design

3.4.1. Sampling Techniques

The households in the three Kebeles were categorized into adopters and non-adopters of a solar home system based on the information from the respective Kebele administration office and the existence of the technology in the compound. Random sampling techniques were employed to identify the sample households from both adopters and non-adopters of the technology.

3.4.2. Sample Size Determination

The total sample size of the target population was determined by using a simplified formula provided by Yamane (1967) and reviewed by Israel (2012).

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

Where "n" is the sample size, "N" is the population size of sample Kebeles, and "e" is the level of precision or sampling error (e: from 5%-10%). According to the district actual report (2018), 1,331 and 1,117 and 1,192 households are found in Debere-birhan, Gira-Aras, and Suluh Kebeles, respectively.

$$n = \frac{N}{(1+N(e)^2}, \quad \frac{3{,}640}{(1+3{,}640(0.06)^2)} \approx 260$$

As shown in Table 3.1 the sample size in each sample Kebele was determined proportional to their respective total number of households. For those who adopt the technology is small in number, adopter and non-adopter households were given an equal chance to be selected. For this purpose list of all adopter households in each sample, Kebeles were taken from the respective kebele administration offices and to compensate non-response questioner, 30% was added and the total sample size was 338. The total number of samples was equally split between adopters and non-adopter households.

Table: 3.1. Proportional sample size determination

S/n	Keble name	Number of Households	Sample Size				Total %
			Adopter	30%	Non-adopter	30%	
1	Debre-birhan	1,331	47	14	47	14	36.09
2	Gira-Aras	1,117	40	12	40	12	30.77
3	Suluh	1,192	43	13	43	13	33.13
Total		3,640	130	39	130	39	100

Source: own result, 2019

3.5. Data Collection Method

Both qualitative and quantitative approaches were employed due to the mixed nature of activities in the study. These include structured and semi-structured interviews, checklists for key informants, focus group discussion and field observations. The use of a combination of methods in data collection is due to the diversity of information that was requiring achieving the objective of the study. Secondary information from published and unpublished journals, books, conference proceedings, reports, etc. were also collected after they screened for their reliability and suitability on top of primary data to strengthen the overall data and achieve the targets of the study.

3.5.1. Household Survey

This study was employing a mixed quantitative and qualitative cross-sectional research design (sometimes called survey design). Because it is a popular design that is widely used by researchers, it allows the collection of data on different groups of respondents at one point at a time. It has a greater degree of accuracy and precision in social science studies than other designs, its flexibility and its simplicity in collecting many types of information related to the use of various data collection methods. It is also economical in terms of costs and time. It consisted of major parts, they are: Information on household socioeconomic characteristics and availability of important household energy demand for lighting purpose, collect information on solar power technology determinants in the study area and experiences from solar adopters and gender involved in related activities, and Information relating to a policy environment particularly government involvement in the promotion of solar technology. Both structured and Semi-structured interviews were used with the aid of open and closed-ended questions.

3.5.2. Field Observation

It was used to evaluate the existence of a solar home system, solar lantern, household fuel consumption, SHS installation types, orientation (SHS installation to which face) and condition of shading and also to confirm the functioning of solar technology and household fuel consumption. Thus, this was helping to study some massage expressions, signs and other behaviors during interviews. When the SHS did not have well managed (cleaning, protects the cable from eating of rats, and exposed to contact). The soil, which installed the panel, was eroded and the panel will be in danger. If we assembled our solar system within the mud roof, cleaning would need frequently than installed in a metal steel roof but both not done.

3.5.3. Focus Group Discussion and informant

FGD is useful in verifying and clarifying information and in filling in gaps of information caused by inadequate information gathered from the interviews and observations.

The FGD was conducted in three Kebeles from a district. The focus groups comprised more than 5-8 participants who were selected with consideration of all social group representations, in the Kebele and civil leaders. From these, qualitative information such as general opinion, awareness of solar technology was collected. The checklist was also prepared to conduct focus group discussions.

3.6. Data processing, Analysis, and Presentation

3.6.1. Data Processing

The data were collected and entered into Excel sheets, then entered into the Statistical Package for Social Sciences (SPSS), IBM statistics Version-20 was used. Data cleaning was done with running frequencies of individual variables and later analyzed; the continuous variables were cleaned with descriptive statistical explorer and analyzed. All the calculations were done in Excel sheet, then interred to the SPSS softer for analysis

3.6.2. Data Analysis

Both qualitative and quantitative techniques were used to analyze the data. A substantial part of the analysis was based on descriptive statistics. Calculation of average annual energy consumption of the particular fuel per Household, the energy consumption per household has two distinct parts: primary energy consumption and end-use energy consumption. The calculation of the primary energy consumption per household was calculated by using the data collected, usually in units of the kilogram, liter, per year and then converting to energy using by multiplying this quantity with the LHV (MJ/kg) and converting it to the annual energy intensity. Afterward, the amount is multiplied by the Lower heating value (LHV) of the fuel to obtain annual energy consumption.

$$\mathbf{E_p} = \frac{\mathbf{m_f} * \boldsymbol{LVH_f}}{\mathbf{3.6}} \text{---} \quad (2)$$

$E_{P=}$ household's primary annual energy consumption from a fuel (kWh/ year)

$m_{f=}$amount of the annual fuel consumption by mass (kg/year)

LHV_f=the Lower heating value (LHV) of the fuel (MJ/kg)

The calculation of average household energy consumption of fuel also called energy intensity is conducted by adding all the energy consumption of the sample households and dividing it with the number of the sample households.

$$\mathbf{E_{p.ave}} = \frac{\mathbf{E_1^n} * \mathbf{E_{pi}}}{\mathbf{n}} \text{---} \quad (3)$$

Where

$E_{p.ave}$=average household energy consumption (kWh/year)

E_{pi}= primary annual energy consumption of household i (kWh/year)

n= number of sample households

The per capita energy consumption is calculated by dividing the average energy consumption of a fuel ’p’ calculate above in (2) with the average family member.

$$\mathbf{E}_{\mathbf{p,per\ capita}} = \frac{E_{p,ave}}{n_{fam}} \text{--} (4)$$

Where

$\mathbf{E}_{\mathbf{p,per\ capita}} =$ average per capita energy consumption of a fuel ‘p’ (KWh/year)

n_{fam}=average number of family per household

In cases of standard efficiency measurement, different biomass energy sources have different degrees of efficiency. For example, "heating value and consumption factors can be used to compare the efficiency level of different kinds of biomass fuel categories" (Guta, 2012). Fuel efficiency can be measured in terms of Mega Joules (MJ) per unit of the Kilogram of giving energy consumed. Therefore, the thermal value of different fuel resources can be measured and compared using standard units (MJ/Kg). Fuel efficiency is measured based on the input-output approach. This indicates how much Joules of energy is gained as output from a given amount of biomass fuels consumed. It also denotes heat values and conversion factors of biomass fuels (Guta, 2012). According to the MOWIE of Ethiopia, the heat value/efficiency/ measures of biomass and other household energy sources are herein below.

Table: 3.2. Thermal values of biomass and other household energy sources

Fuel type	Thermal values
Air dried firewood	15.5 MJ kg^{-1}
Air dried branches, leaves and twigs (BLT)	15.5 MJ kg-1
Charcoal	29.0 MJ kg^{-1}
Air dried crop residue	15.0 MJ kg^{-1}
Air-dried dung to fuel	13.8 MJ kg-1
Electricity	3.6 MJ kWh^{-1}
Kerosene	43.8 MJ L^{-1}

Sources: MWE (Dawit Diriba Guta, 2012)

3.6.3.1.Descriptive Statistics

Descriptive statistics such as frequencies and cross-tabulations and Correlation coefficients were used to determine the responsiveness characteristics, their knowledge, and awareness towards solar technology, factors influencing adoption and non-adoption of solar technology; and the adequacy of strategies for promoting adoption of solar technology in the study area. The logistic regression model was used to determine the determinants of adoption and non- adoption of solar technology. A chi-square test and an independent sample t-test were employed to identify variables that vary significantly between adopters and non-adopters. Furthermore, the chi-square test was used to show the association between two categorical variables of adopter's household heads and non-adopter's household heads. The t-test was used to check whether they are statistically significant in the mean difference or not of adapter's household heads and non-adopter's household heads to continuous variables, for instance, age and family size of household heads.

3.6.2.2.Estimation of GHG Emission

The GHG emission from stationary fuel combustion was calculated by multiplying the amount of fuel consumed by the corresponding emission factor. The fuel consumption data in mass or volume units was first converted into the energy content of these fuels (Garg and Pulles, 2006). In this study, only the three important gases such as CO_2, CH_4, and N_2O

were considered in the GHG emission estimation. The GWP of these three gases over a 100 years' time horizon is 1, 25, and 298 respectively (IPCC, 2007). To estimate the GHG emission from the combustion of a given fuel type ‘of' by the adopter or non-adopter households will be calculated using the IPCC guideline tair1 method as follows.

$$\boldsymbol{E_{f} = \sum_{i=1}^{n}(A_i * EF_i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where E_f =GHG emission in Kg from the burning of fuel type ‘f’; n= total number of sample household; A_i= amount of fuel consumed by sample household ‘i’; Ef= default emission factors for gas type ‘i’

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

$$\boldsymbol{E_{CO_2}eq = \sum_{i=1}^{n}(A_i * EF_i * GWP_i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Where GWP_i= the global warming potential of gas type ‘i’.

3.6.2.3. Logistic Regression Model

To identify the factors affecting the household's decision on the adoption of solar power technology, and household fuel consumption for lighting, a logistic regression model was employed. This model applies maximum likelihood estimation after transforming the dependent variable into the binary logistic variable and estimates the odds of a certain event occurring. The dependent variable in this study was a binary variable with values 1 for adopter and 0 otherwise. The model can be written mathematically as follows(Alazar Alehegn, 2019; Ameli and Brandt, 2015; Mukwaya, 2016)

$$P = E\,(Y = 1|Xi) = a + bx \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where Y= 1 means a given household adopts solar power technology, x is the explanatory variable, ‘a' and ‘b' are parameter's to be estimated.

$$\boldsymbol{P} = \mathbf{E}(\mathbf{Y} = \mathbf{1}|\boldsymbol{x_i}) = \frac{\mathbf{1}}{\mathbf{1}+\boldsymbol{e}^{-(\boldsymbol{a}+\boldsymbol{bx})}} = \frac{\mathbf{e^{a+bx}}}{\mathbf{1+e^{a+bx}}} \quad \textbf{(8)}$$

As P is the probability of adopting solar power technology, 1-P is the probability of not adopting solar power technology. Therefore,

$$\mathbf{1} - \boldsymbol{p} = (\boldsymbol{Y} = \mathbf{0}|\boldsymbol{x_i}) = \frac{\mathbf{1}}{\mathbf{1+e^{a+bx)}}} \quad \textbf{(9)}$$

Where Y = 0 is the non-adopter. Therefore, dividing equation (8) by equation (9) we can write the model mathematically as follows.

$$\frac{p}{1-\mathrm{p}} = e^{a+bx} \quad \textbf{(10)}$$

Where $\frac{p}{1-p}$, Is an odds ratio of certain events to have occurred which is the ratio of the probability of a given household to adopt solar power technology to the probability of that will not be adopted. By taking the natural logarithm of equations (10) on both sides, one can derive an equation to forecast the probability of certain events to have occurred as follows:

$$Ln\left(\frac{p}{1-\mathrm{p}}\right) = Ln(e^{a+bx}) = a + bx \quad \textbf{(11)}$$

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

$$\mathrm{logit}(Y) = \ln\left(\frac{p}{1-p}\right) = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \varepsilon_i \quad \textbf{(12)}$$

Where βo is a constant term, X_1, and X_2……? X_k is explanatory variables that will be expected to affect the probability of adopting solar power technology and $\beta_1, \beta_2, .. \beta_k$Are the parameters that will be estimating cross bonding to each explanatory variable and ε_i is the error term.

3.7. Description and Measurements of variables

Table: 3.3. Description of Explanatory variables and their measurement

Variables	Type	Measurement	Expected
Age of household	Continuous	Age in year	+/-
Marital status	Categorical	1.Married,2.Single,3.Divorced,4.Widower,5.Separat	
Education level	Categorical	1. Illiterate, 2. Read and write, 3. Primary school, 4. Secondary school, 5.Certificate, 6.Some degree and above	+/-
Family size	Continuous	Number of people in the household	+/-
Yearly cash income	Continuous	Annual income in Eth Birr	+
Land Size	Continuous	Land size in ha	+
Roof suitable to install SHS	Categorical	1. Yes, 2.No, 3.Needs some modification, 4.total roof will be replaced	+
Kerosene User	Continuous	Number of households used kerosene	-
Livestock number	Continuous	Number of cattle's	+
Price of technology	Categorical	1. Expensive, 2.cheap, 3. Medium, 4. Not available	-

3.8. Data Presentation

Finally, Cross-tables and figures such as histograms and pie-chart were used to present data for different study variables. Concluding remarks, recommendations and discussions were based on computed frequencies, percentages, and logistic regression analyses.

4. RESULTS AND DISCUSSION

4.1. Socioeconomic Characteristics to adoption

The socioeconomic characteristics of households like gender, age, number of families, level of education, marital status, house ownership, and access to the national grid, access to credit, technology price, income, and main occupation were assumed. The relations of those characteristics with solar energy (PV) technology adoption in the study area were also studied.

4.1.1. Age of the Household Heads

Table 4.1 showed that the overall average age of the household heads was 51.81 years. The average of the adopter's household heads was 53.40 years while the non-adopters 50.07 years. This implied that elder household heads were more interested in adopting solar (PV) energy technology. The variation of adopting the technology with age might be the fact that younger age, household heads are at the initial stage of their career and therefore, they may not have the asset for such investment. The result also showed that household heads over 65 years old were less likely to adopt solar technologies as compared to household heads with younger age. The result was in line with the report of Ameli and Brandt (2015). According to the World Bank Report (2018), Ethiopia is with a rapidly rising working-age population that presents both opportunities and challenges (more than 60 percent of the population is below 25 years of age). This also supported by study Melaku Berhe *et al*. (2017); Miassi and Dossa (2018), this age is an active labor force.

4.1.2. Family Size and Landholding of the Households

The average family size of adopters was larger than the non-adopters (Table 4.1). It implies that as the family size increases, there is a tendency to adopt the technology. This might be associated with the higher demand for energy resources in large family size. Similarly, a family with larger landholding observed to adopt energy-saving technologies as compared to a family of less landholding (Table 4.1). The household with large landholding might have a better income and then a stronger economic background that enables to install the solar technology in his compound. The result was supported by a studying Ameli and Brandt (2015); Haftu Etsay *et al*. (2017); Melaku Berhe *et al*. (2017), the probability of household adopting increases with an increasing number of family members.

Table: 4.1. Socioeconomic characteristics of the households (continuous)

Variables	SHS				Overall mean	T-value	P-value
	Adopters (n=163)		Non-adopters (n=149)				
	Mean	S.D	Mean	S.D			
Age (year)	53.40	9.733	50.07	12.448	51.81	2.611	0.010
Family size (number)	6.11	0.183	5.03	0.245	5.60	6.436	0.000
Land Size (ha)	0.54	0.266	0.48	0.2949	0.51	1.881	0.061
Yearly Income (ETH Birr)	13920.40	7717.77	9098.56	5447.57	11617.66	6.417	0.000
Livestock number own (number)	10.67	6.758	5.60	4.159	8.25	8.056	0.000

Source: own result, 2019

4.1.3. Income and Livestock Ownership of the households

The mean income of the adopter and the non-adopter household in the study area is given in (Table 4.1). It revealed that a household with better income was adopting the technology than with fewer income households. It's also associated with the economic potential to have the technology. This result was supported by studying Abate and Chawla (2016); Ameli and Brandt (2015); Frederiks *et al.* (2015), the probability of a household adopting technology increases with increasing household income. By the same token, household heads with higher livestock observed to adopt the technologies as compared to a household of lower livestock ownership (Table 4.1). The household with more livestock ownership have better income as compared to a household with least economy, which enable to install the solar energy technology in his/her compound. This result was supported by a studying Abdullah *et al.* (2017); Frederiks *et al.* (2015), the probability of a household adopting technology increases with increasing household having a high number of livestock households were reported better in adopting.

4.1.4. Sex and Marital Status of the Household Heads

As shown in Table 4.2, 89.57% of adopters and 77.18% of non-adopter households were male-headed. This result showed that male-headed households easily adopt technology as compared to female-headed households in the study area. The result was similar to a study of Zhou and Abdullah (2017) in Pakistan, farming considered only a male job and females are not allowed to do work in the field openly with the male, although some older women do work in remote areas, their contribution to agricultural productivity is far less than the males. On the other hand, 87.73% of adopters and 82.25% of non-adopter households were married (Table 4.2). It means a household with a married head showed to be a more adopter than an unmarried headed household. It might be also associated with increased demand for household energy resources in a married family. This result was supported by a study of LP (2016); Tewelde Gebre *et al.* (2017), in the adoption of technology most of the adopters were married.

4.1.5. Educational Level of Households

Frequency descriptive analysis indicates that, about 33.74% of adopter household heads can at least read and write, while more than 34% of the non- adopter household heads were Illiterate in the study area (Table 4.2). It indicates that the educational level of the household head had an impact on the adoption of solar energy technology adoption. It might be associated with better awareness of the technology, less conservative more exposed to information, knowledgeable, and environmentally aware of the risks of fossil fuel use on family health, and environment. The result was supported by a studying Frederiks *et al*. (2015); Kelebe *et al.* (2017); Miassi and Dossa, 2018), the level of education increases the sense of adopting innovation, skill, and ease of appraising new technologies.

Table: 4.2. Socioeconomic Characteristics (Category)

Variables		Adopter (n=163)		Non-adopter (n=149)		chi2-value	P-value
		Frequency	%	Frequency	%		
Sex	Male	146	89.57	115	77.18	8.738	0.003
	Female	17	10.43	34	22.82		
Marital Status	Married	143	87.73	123	82.55	2.099	0.835
	Single	3	1.84	5	3.36		
	Divorced	5	3.07	7	4.70		
	Widow	9	5.52	10	6.71		
	Widower	2	1.23	2	1.34		
	Separated	1	0.61	2	1.34		
Educational Level	Illiterate	36	22.09	51	34.23	9.751	0.083
	Read And Write	55	33.74	44	29.53		
	Primary school	51	31.29	31	20.81		
	Secondary School	15	9.20	18	12.08		
	Some Certificate	6	3.68	4	2.68		
	Some Degree and Above	0	0.00	1	0.67		

Source: own result, 2019

4.1.6. Main Occupation of Households

Nonsignificant (P > 0.05) 99.39% adopters and 97.99% of non-adopter households, both having a farming occupation (Table 4.3). This result reflects that the number of adopters was more than non-adopter households. It might be associated with the educational level, an interest, and the study was carried out within farmers.

4.1.7. House of Households Connected to the National Grid

As revealed by the investigation, 76.07% of adopters and 83.22% of non-adopters, have not access to the national grid (Table 4.3). It showed that adopters have ware of on the accessibility to grid than non-adopter households. It is associated with the development of the entire nation, settlement patterns of the dwellers, and less energy demand in rural households. The result was similar to reported of (Frederiks *et al*., 2015).

4.1.8. House ownership of the households

The present exploration showed that, 93.25% of adopters and 87.92% of non-adopters household in the study area live in their own houses (Table 4.3). It revealed that most of the adopters and non-adopters live in their own home. This is associated with household income. This result supports by studies Ameli and Brandt (2015); Frederiks *et al*. (2015); Uppal *et al*. (2017), a household's house owned improvements to increase energy efficiency, purchase of new technology and energy-saving devices than those living in rental housing.

4.1.9. The house roof of households

As being seen the descriptive the highest frequented 94.48% of the adopters and 95.97% of the non-adopter households were suited their house roofs to install a solar home system (Table 4.3). As it has been observed, the house of adopters and non-adopters were suitable for installation solar home system. It is associated with household income, house ownership, and attitude. This result was supported by a study Yared Alazar (2019) house quality and income levels (socioeconomic factors) have a significant effect on the adoption of solar PV energy technologies.

Table: 4.3. Socioeconomic Information

Variables		Adopter (n=163)		Non-adopter (n=149)		chi^2-value	P-value
		Frequency	%	Frequency	%		
Main Occupation	Civil Servant	1	0.61	2	1.34	1.539	0.463
	Farmer	162	99.39	146	97.99		
	Mason	0	0.00	1	0.67		
House connected to the grid	No	124	76.07	124	83.22	9.342	0.009
	Connection In progress	18	11.04	20	13.42		
	Nor the hope of accessing electricity power soon	21	12.88	5	3.36		
House owner	Yes	152	93.25	131	87.92	6.529	0.038
	No	11	6.75	15	10.07		
	Rent	0	0.00	3	2.01		
Roof suitable for SHS installation	Yes	154	94.48	143	95.97	1.926	0.382
	No	9	5.52	5	3.36		
	Rent	0	0.00	1	0.67		
Access credited service	Yes	163	100	128	85.91	24.631	0.000
	No	0	0.00	21	14.09		
Technology Price	Expensive	61	37.42	30	20.13	32.799	0.000
	Cheap	10	6.13	40	26.85		
	Medium	85	52.15	78	52.35		
	Not Available	7	4.29	1	0.67		

Source: own result, 2019

4.1.10. Access to Credit Service

The current household survey revealed that all (100%) adopters were having access to credit in the study area (Table 4.3). Nevertheless, 85.91% of non-adopter households have access to credit services (Table 4.3). The result showed that most of both adopters and non-adopters household having access to credit service. It is associated with the interest rate of the loan provider, collateral, household income, the upfront cost of the technology, and accountability for credit. The result was similar to reported by Ameli and Brandt (2015); Frederiks *et al*. (2015), solar energy is an investment, thus, investment needs money for those who have money it is easy and for those who haven't need credit access.

4.1.11. Technology Price

More than fifty-two (52.15%) of adopters and 52.35% of non-adopter households, both understood that prices of technology have a medium price (Table 4.3.). It revealed that adopters and non-adopter households were actually supposed the cost of the technology. It is linked to reliability (timely delivery of desired quantity), quality product and affordability of the technology (access by the poor). This result was in line with studies by Kabir *et al*. (2017); Khan and Khanam (2017), the price of solar home system technology was considered one of the main obstacles for its use.

4.2. Energy Consumption of Households

The mean variation of energy demand for baking "Injera" or Bread in kWh per household per year of the adopter and non-adopter households of the study area (Table 4.4). It revealed that of adopters were more consumed than non-adopter households. It might be connected with higher income, higher family size, and higher energy demand for baking. This result was similar to reported by Asfafaw Haileselassie *et al*. (2014); Dino Adem *et al*. (2019), 180-220 ^{o}C heat is needed for baking "Injera" and 563W power. Similarly, the average per capita energy demands for Baking "Injera" or Bread in kWh per year per person of adopters and non-adopter households (Table 4.4). It revealed that of adopters were less consumption than non-adopter households. It might be related to the technology type used, and family size. This result was supported by a study Getamesay Bekele *et al*. (2015), the old age, household heads may have more a family member than the younger households, therefore, lower family size has higher per capita.

The door to door survey outcome revealed that, mean deviation of energy demands for cooking in kWh per household per year of adopters and non-adopter households (Table 4.4). It showed that of adopters were consumed more than non-adopter households. It might be associated with higher income, higher family size, and higher energy demand. This result was similar to a study (Abate Warkaw and Chawla, 2016). According to G. Tucho and Nonhebel (2015), Ethiopian rural households required about 5-7 GJ of useful energy annually for cooking (Baking and cooking) this is typical in most of the rural areas in developing countries. In the same way, significant ($P < 0.001$) mean, variant per capita energy demand for cooking in kWh per year per person of adopters and non-adopter households shown (Table 4.4). It revealed that adopters were less than non-adopter households. It might be associated with energy demand (consumption) and family size. This result was similar to a study (Abate Warkaw and Chawla, 2016). According to G. Tucho and Nonhebel (2015), Ethiopian rural households required about 5-7 GJ of useful energy annually for cooking (Baking and cooking) this is typical in most of the rural areas in developing countries

The current investigation result revealed that, mean difference energy demand for lighting in kWh per household per year of adopters and non-adopter households showed in (Table 4.4). It revealed that of adopters were more consuming than non-adopter households. It might be associated with energy demand, technology type used, and economic status. Likewise, significant ($P < 0.001$) mean variation per capita energy demand of adopters and non-adopter households for lighting in kWh per person per year given in (Table 4.4). It revealed that of adopters were more than non-adopter households. It might be associated with the fact that SHS technology has higher energy than the solar lantern, higher energy demand, better economic status, and have a better awareness. This result was supported by studies (Kabir *et al*., 2017; Khan and Khanam, 2017).

Table: 4.4. Household Energy Demand

Variables	SHS				Overall mean	T-value	P-value
	Adopters (n=163)		Non-adopters (n=149)				
	Mean	S.D	Mean	S.D			
Energy for baking (kWh per year)	4362	1456.31	4334.11	1196	4348.68	0.185	0.853
Energy for cooking (kWh/year)	3719	1212.44	3685.04	1077.21	3702.69	0.261	0.795
Energy for lighting (kWh/year)	85.41	17.23	28.47	15.75	116.30	30.374	0.000
Per capita for baking (kWh/year)	831.84	594.05	1089.80	699.20	955.03	-3.496	0.002
Per capita for cooking (kWh/year)	749.81	627.27	1012.02	862.57	875.03	-3.047	0.003
Per capita for lighting (kWh/year)	33.31	23.86	17.46	19.14	25.74	6.432	0.000

Source: Own results, 2019

S.D= Standard Deviation

4.2.1. Households fuel preference and use pattern

In the rural household study, approximately ninety-eight percent (97.55%) adopters and approximately ninety-nine percent (98.66%) of non-adopter households in the study area were enclosed traditional Tigrai type stove user for baking (Table 4.5). It revealed that adopters and non-adopter households had both a major lack of awareness of improved cooking and baking stoves. It might be associated with culture and values, awareness and information on the emission from the stove, lower energy demand, and economic status. According Miftah Fekadu *et al*. (2019), the problems in dissemination of Mirt stoves were due to unaffordable cost of stoves, lack of training in using improved stoves and inappropriate size plates. In the same way, 65.03% of adopters and 55.03% of non-adopter households were used firewood and cow dung fuel combination for backing (Table 4.5). It showed that adopters were consuming more than non-adopter households. It is associated with higher fuel demand, higher economic status, and higher family size. This result was supported by a study Abate Warkaw and Chawla (2016); Serrano-Medrado *et al*. (2019), in many developing countries, biomass for baking and cooking accounts for more than 90% of household energy usage.

All adopters and non-adopter households were electric energy choices for baking "Injera" or Bread (Table4.5). It revealed that adopters had the same concern with non-adopter households. It is associated with clean energy, highest heat value, time saves during baking, household income, house ownership, educational level, and lower cost of bile. This result was supported by a study of LP (2016), Socioeconomic and demographic factors have effects on household fuel choice. Correspondingly, nearly half of the adopters (49.69%) and nearly two-thirds (59.73%) of non-adopter households had three baking "Injera" sessions per week per household (Table 4.5). It revealed that of adopters and non-adopters household had an equal time of the baking session. It is related to family size, age variation, and household income. This result was in line with reported by (Kabir *et al*., 2017; Khan and Khanam, 2017). According to Yared Alazar (2019), lighting from Solar PV is the major pattern of use.

Table: 4.5. Types of stoves, types of fuels, choice of energy source and baking session

Variables		SHS				Chi^2-value	P-value
		Adopter (n=163)		Non-adopter (n=149)			
		Frequency	%	Frequency	%		
Stove type use for baking	Tigrai type stove	159	97.55	147	98.66	0.51	0.475
	Tigrai type stove and Mirt stove	4	2.45	2	1.34		
Type of fuel for Baking 'Injera'	Firewood	7	4.29	5	3.36	20.94	0.000
	Dung	47	28.83	39	26.17		
	Firewood-Dung and crop residue	2	1.23	3	2.01		
	Firewood – Dung	106	65.03	82	55.03		
	Dung- Crop residue	1	0.61	20	13.42		
Energy choice for baking	Electric	163	100	149	100	20.95	0.000
Baking sessions week	1 Session	2	1.23	7	4.69	8.085	0.044
	2 Session	56	34.36	36	24.16		
	3 Session	81	49.69	89	59.73		
	4 Session	24	14.72	17	11.41		

Source: Own result, 2019

4.2.2. Firewood consumption for baking "Injera"or Bread

The analysis of mean of firewood consumption for baking "Injera" or Bread in kg per household per year showed that adopters and non-adopter households were having a difference in the study area (Table 4.6). The overall sum firewood consumption is 111,488Kg per year. It showed that of adopters were more than non-adopter households in terms of firewood consumption. It is associated with higher income, higher family size, and higher energy demand. This result was supported by studies Miftah Fekadu *et al*. (2019; Serrano-Medrado *et al*. (2019); Tesfa Worku *et al*. (2018) the total annual fuel wood consumption in rural part of Ethiopia is higher for baking consumption. Similarly, animal dung consumption for baking "Injera" or Bread in Kg per household per year of adopters and non-adopter households were also having variation in their average consumption (Table 4.6). It revealed that adopters were less than non-adopter households. It is associated with lower income, less family size, lower livestock owned, and lower energy demand, which might harm the crop production, soil fertility, and environment. This result was similar to reported of Tesfa Worku *et al*. (2018), clearing of forest and degradation of land is interrelated with the use of firewood and cow dung as a domestic energy source, which are the most serious environmental problems for the country. The overall sum animal dung consumption is 228,540Kg per year. In the same way, the average crop residue consumption for baking "Injera" or Bread in Kg per household per year of adopters and non-adopter households (Table 4.6). The overall sum crop residues consumption is 56,940Kg per year. It revealed that of adopters were less than non-adopter households. It might be associated with lower income, less family size, and lower energy demand, which might harm the soil fertility and crop production.

Table: 4.6. Fuel consumption for Baking

Variables	SHS				T-value	P-value
	Adopters (n=163)		Non-adopters (n=149)			
	Mean	S.D	Mean	S.D		
Firewood	380.59	313.64	331.89	302.22	1.394	0.164
Cow dung	710.13	336.72	756.97	296.78	-1.298	0.193
Crop residues	0.28	1.23	0.82	1.98	-1.306	0.004

Source: Own result, 2019

4.2.3. Types of stove and fuel for cooking

The rural household survey analysis revealed that more than eighty-three percent (83.44%) of adopters and 85.91% of non-adopter households were both used metal stove and enclosed traditional mud made stove (Fig.4.1). The result has shown that adopters and non-adopter households were both used similar traditional stoves. It might be associated with awareness of the emission, economic status, and lower energy demand, which might harm fuel-saving and on the health of women and children, and the environment. In the same way, less than half (42.33%) of adopters and more than one-third (34.90%) of non-adopter households were all used charcoal, firewood, and dung cake on mixed (Fig.4.1). The overall consumption of 87,143.75kg firewood, 56,940kg charcoal and 83,831kg dung for cooking per year respectively. It revealed that of adopters and non-adopter households use the same source. It might be associated with family size, economic status, age difference, and higher energy demand, which might harm the natural resource and environment. According to Miftah Fekadu *et al*. (2019); Serrano-Medrado *et al*. (2019), in many developing countries, biomass for cooking accounts for more than 90% of household energy usage.

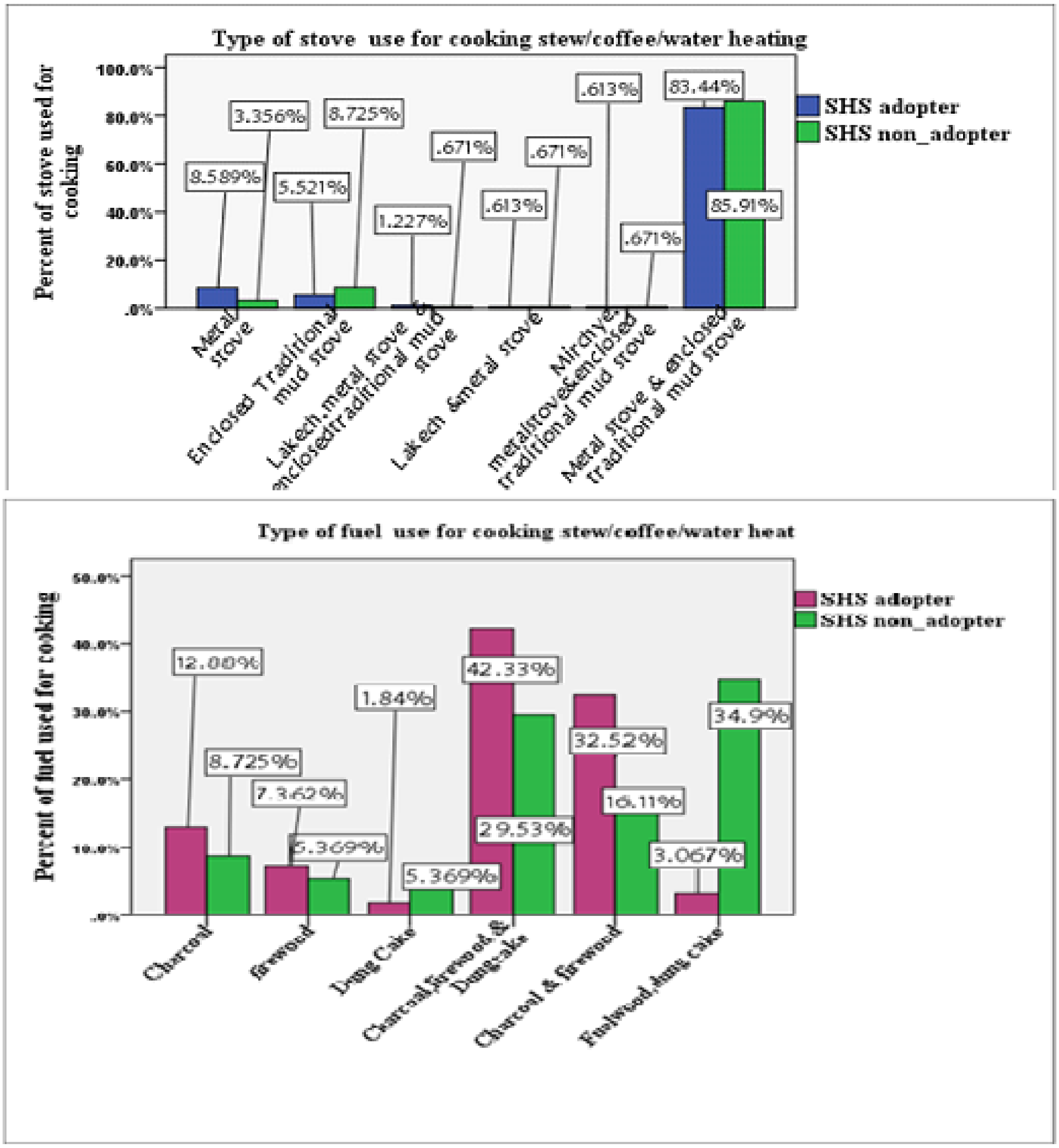

Fig: 4.1. Types of stove and fuel for cooking

4.2.4.Green House gas (GHG) Emission from Fuel burring

The result of household survey revealed that the average CO_2 equivalent emission from firewood, dung and crop restudies consumption for baking "Injera" or Bread in Kg per household per year of adopter and non-adopter is shown in (Table 4.7).The overall CO_2eq emission from baking fuel 518,666.28 kg per year. It showed that of adopters and non-adopter households were a significant difference in emission releasing. It might be associated with several families, age variation, economic status, and higher energy consumption. This result was supported by a study of Yu *et al*. (2015), the total CO_2 emissions display similar trends with energy consumption. Correspondingly, the analysis of divination of CO_2 equivalent emission per capita from "Injera" or Bread in kg per person per year in the study area (Table 4.7). It revealed that adopters and non-adopter households had differing per capita emissions. It might be observed that since fewer families and more energy per capita. This result was similar to a study by Chindo *et al*. (2015) the employment ratio causes real GDP per capita in the short run. Whereas the difference in mean of CO_2 equivalent emission from fuel (charcoal, firewood, and dung cake) consumption for cooking in kg per household per year of the adopter and non-adopter households in (Table 4.7).The overall sum of CO_2eq emission is 459,986.48kg per year. It showed that of adopters and non-adopter households were having a significant variation in emission releasing. It is due to the fact that, several families, income level and age differences. This result was similar to the study of Yu *et al*. (2015), the total CO_2 emissions display the similar trends with the energy consumption. So, the variance result revealed that per capita CO_2 equivalent emitted from cooking adopters and non-adopter households in the study area (Table 4.7). It showed that adopters were and non-adopter households were seeing great difference. It is observed that because of fewer families and more energy per capita. This result was similar to a study by Chindo *et al*. (2015), CO_2 per capita or energy consumption per capita cause real GDP per capita, but the employment ratio causes real GDP per capita in the short run.

Table 4.7 depicts an analysis of the result revealed that, CO_2 equivalent emission from the energy source for lighting in Kg per household per year adopter and non-adopter households. It revealed that adopters and non-adopter households were having a great difference. The overall sum of CO_2eq from lighting fuel (firewood and kerosene) consumption is 736.26kg per year. It might be associated with the fact that SHS and solar lantern have an impact on the reduction of emission. Furthermore, mean variation CO_2 per capita equivalent emission energy sources for lighting in Kg per person per year adopters and non-adopter households (Table 4.7). It revealed that of adopters and non-adopter households were highly difference between them. It might be associated with the fact that type, technology, and energy sources used. This result was similar to a study with Mesele Negash and Girma Kelboro (2014), the motivation to invest in renewable energy like solar energy sources prevent electricity supply problems, such as frequent power outages, high power cost and lack of connection to the national grid, environmental concerns.

Table: 4.7. Carbon dioxide Equivalent Emission from Energy Demand

Variables	SHS				Overall mean	T-value	P-value
	Adopters (n=163)		Non-adopters (n=149)				
	Mean	S.D	Mean	S.D			
Baking CO_2eq emission (kg per year)	1671.63	570.25	1652.32	473.95	1662.40	0.326	0.745
Cooking CO_2eq emission (kg per year)	1493.26	467.44	1453.59	411.65	1474.32	0.797	0.426
Lighting CO_2eq emission (kg per year)	0.0012	0.01274	4.94	1.0032	2.36	-60.08	0.000
Per capita CO_2eq baking (kg per year)	318.51	228.39	412.63	259.42	363.50	-3.388	0.001
Per capita CO_2eq cooking (kg per year)	300.74	248.28	398.03	335.62	347.20	-3.047	0.003
Per capita energy for lighting (kg per year)	0.000	0.000	1.387	1.25	0.66	6.432	0.000

Source: Own result, 2019

4.3.Household Energy Demand for Lighting

The energy source of the rural dweller on the study area was identified SHS, solar lantern, kerosene, dry cell, and firewood. Average energy demands for the lighting of adopters and non-adopter households are given in (Table 4.8). It revealed that of adopters and non-adopter households were used different energy sources. It is associated with family size, income level, educational level, awareness of SHS technology. This result was supported by a study Gosaye Shegenu and Abrham Seyoum (2017), there was a considerable saving adopter over non-adopter households by significantly firewood per year, per household. Correspondingly, mean difference per capita energy demand for lighting in kWh per year per person (Table 4.8). It showed that of adopters were more demanding than non-adopter households. It is associated with the technology type used and economic status. The result was similar to reported of Kabir *et al*. (2018); Stojanovski *et al*. (2017) is stated as it improves the children's study environment at night, higher ranges on solar PV "energy ladder" involves of still larger solar home system that can power radio, TVs, and even energy-efficient refrigerators for the largest model. There is a considerable saving of kerosene per year per household of the adopters over non-adopter households in the study area (Gosaye Shegenu and Abrham Seyoum, 2017)

Table: 4.8. Energy demand for lighting

Variables	SHS				Overall mean	T-value	P-value
	Adopters (n=163)		Non-adopters (n=149)				
	Mean	S.D	Mean	S.D			
Energy demand for lighting	169.39	34.50	31.60	2.59	116.30	-29.59	0.000
Energy Per capita for lighting	33.31	23.86	17.46	19.14	25.74	-6.43	0.000

Source: Own result, 2019

4.3.1. Energy for Lighting and Electric Media

In Table 4.9 demonstrated that, more than three-fifth (61.35%) of adopters and 95.97% of non-adopter households were both used dry cell batteries for electronics-media in the study area. It revealed that adopters and non-adopter households were used unclean energy sources for their electronic media. It is associated with household income, lack of awareness, and availability. This result was reported by Deshmukh *et al*. (2018); Karakaya and Sriwannawit (2015).

As the topical household survey analysis revealed that more than three-fifth (61.96%) of adopters and more than half (53.69%) of non-adopter households were electricity energy choice for lighting (Table 4.9). It revealed that of adopters and non-adopter households were having a choice the same energy source for lighting. It is associated with the roof of household, house ownership, reliability, access for all, technology price, interest rate loan providers, lack of availability of skilled technical person, lack of spare parts. This result was supported by a study by Schillebeeckx *et al*. (2012), reliability is a combination of quality, service level and sufficiency (timely delivery of desired quality).

Table: 4.9. Energy For lighting and Electric Media

Variable		SHS				Chi2-value	P-value
		Adopter (n=163)		Non-adopter (n=149)			
		Frequency	%	Frequency	%		
Electronics-Lighting	Solar for lighting	63	38.65	6	4.03	54.18	0.000
	Dry cells for Media	100	61.35	143	95.97		
Energy Choice for lighting	Solar	62	38.04	69	46.31	2.19	0.139
	Electricity	101	61.96	80	53.69		

Source: Own result, 2019

SHS: Means Solar Home System

4.3.2. Types of fuel for Lighting

The resulting analysis of descriptive analysis revealed that 84.05% of adopters solar home system users for lighting. On the other hand, two-fifth (40.27%) of non-adopter households use solar lantern in the study area (Fig 4.2). It revealed that of adopters and non-adopter households were the only clean energy source used for lighting. This is due to the fact that, several families, income level, attitude, educational level, and awareness. According to Naah and Hamhaber (2015) local people depended on several traditional energy sources such as lanterns, flashlights, candles, generators and oil-cotton mixed lamps for lighting before the solar PV systems were installed in the studied districts.

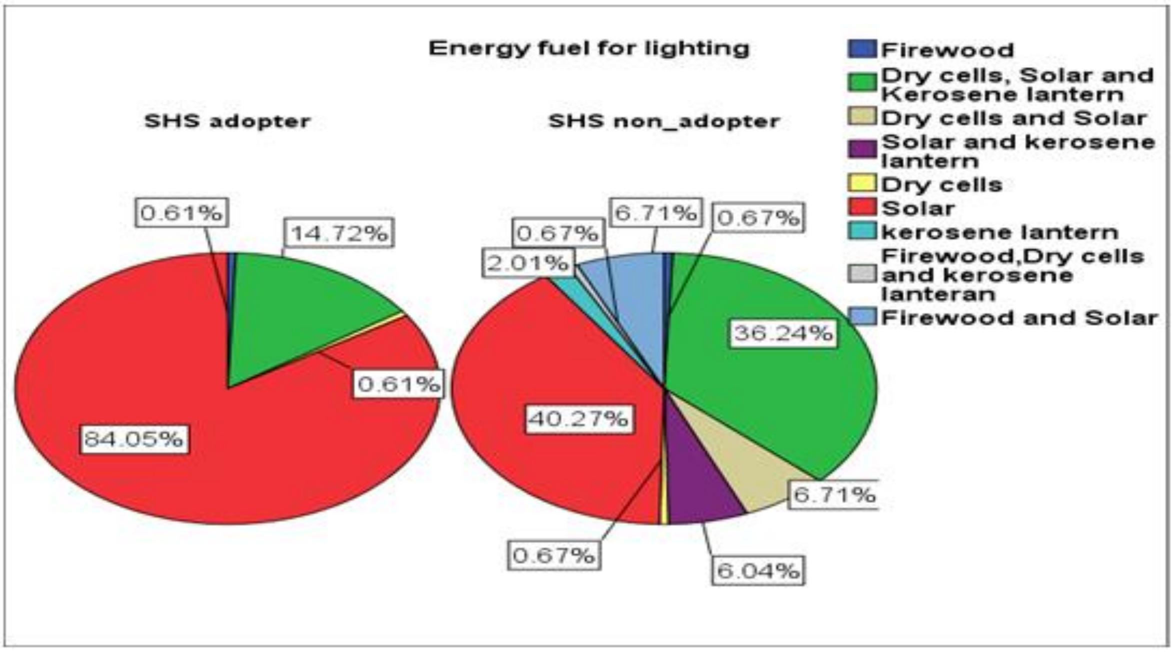

Fig: 4.2. Energy fuel for lighting (Source: own result, 2019)

4.3.3. Household opinion on solar energy technology adoption

This was aimed to fill gaps after the quantitative questionnaire was completed. The Households were asked for their opinion on solar energy technology adoption. The majority household head's opinion solar energy technology adoption said that "there was the high-interest rate of the micro-finance, lack of skilled technician for the after-sale service provider, black market and non-quality products in the market". This implies that the regulation and standardization of the import of the country are loosening or not, have police structure to control and also for renewable energy adopter households there are not supported like subsidies and encouragement to adopt solar energy technology. This is supported by studies (Abdullah *et al*., 2017; Kabir *et al*., 2017; Khan and Khanam, 2017)

Fig: 4.3.Administrations, Experts and Kebele dweller discussion

4.4.Determinants of Solar (PV) Energy Technology

To be see smart the table, the researcher changed the 1-5 value of the Likert scale to 1-3 value. Therefore, the negative answer (i.e., strongly disagree and disagree changes to disagree), and the positive answer (i.e. strongly agree and agree changes to agree) and the neutral as it is.

4.4.1. Level of knowledge and awareness

The resulting descriptive analysis revealed that less than half (45.40%) of adopters were agreeing that there was a high-level of solar power in use per installation, e.g., Charging a phone or in any other use. Nevertheless, less than three-fifth (61.75%) non-adopter households were disagreeing in the study area (Table 4.10). It showed that of adopters and non-adopter households were having a difference in awareness of the technology. It observed to be linked to the awareness of the environmental benefits, interest in new technology, socioeconomic status, seeing the technology on working and touch has an impact on technology adoption. This result was similar to reports by Feron (2016); Kabir *et al*. (2017); Nygaard *et al*. (2017), environmental sustainability demands that civil society to be aware of environmental issues, such as environmental norms and regulations define "knowing of the impact of human behavior on the environment". Likewise, the descriptive analysis result showed that, significant ($P < 0.001$) more than half (53.37%) of adopters agreed many households have solar systems installed. However, more than three-quarters (78.52%) of non-adopter households have disagreed (Table 4.10). It showed that adopters and non-adopter households were having a greater difference awareness of the different solar energy technology types. It is due to the fact that, lack of awareness of the technology, and lower economic status. This result was supported by a studding (Nygaard *et al*., 2017). According to Khan and Khanam (2017), the high installation cost and lower purchasing power of the rural households make difficulty in technology diffusion, especially in developing countries.

Nonsignificant ($P > 0.05$) variations on the descriptive frequency analysis showed that more than half (55.83%) of adopters and more than three-fifth (61.75%) of non-adopter households were together disagreeing that households have been getting formal and informal training on solar systems. It revealed that of adopters and non-adopter households had unsatisfied on with how to operate solar energy technology. It might be associated with the interest of the trainee, greediness, lack of awareness on the impact of the technology. By the same token, non-significant ($P > 0.05$) result analysis revealed that more than two-fifth (41.72%) of adopters have disagreed that there were accessible solar technology Providers in their area. Conversely, less than half (46.98%) of non-adopter households were neutral (Table 4.10). It revealed that of adopters and non-adopter households were having negative responded about the technology suppliers. It might be associated with a lack of interest (thrust) of the sellers, lack of awareness of the business, and scarcity of foreign currency, lack of government subsidies. This result was supported by a study Abdullah *et al*. (2017), the government can enhance the development of SHS by providing various incentives (subsidies).

From the overall households survey analysis result revealed that significantly ($P < 0.001$) less than a half (47.85%) of adopters agreed that their household would consider acquiring a solar household system. However, more than three-quarters (77.85%) of non-adopter households were disagreed (Table 4.10). It revealed that of adopters and non-adopter households were having a difference in the use of the technology. It might be associated with economic status, lack of interested in the new technology, awareness of the technology, and non-functioning of the technology has an impact on the adoption of the technology. This result was supported by a studding (Simpson and Clifton, 2017). As well, significantly ($P < 0.01$) more than three-quarters (76.68%) of adopters have disagreed that households were used other forms of energy for lighting to a large extent, i.e., Kerosene, firewood or dry cells. Even so, approximately two-fifth (39.60%) of the non-adopter households were neutral (Table 4.10). It showed that of adopters and non-adopter households were having answered a similar concern. It might be associated with the solar lantern use, kerosene, firewood or dry cells were used to a smaller extent. This result was supported by studies (Kabir *et al*., 2017; Khan and Khanam, 2017; Schillebeeckx *et al*., 2012; Tucho and Nonhebel, 2015).

Table: 4.10. Knowledge and Awareness

Factors Under consideration	Likert Scale	SHS				Chi²-value	P-value
		Adopters (n=163)		Non-adopters (n=149)			
		Frequency	%	Frequency	%		
There is a high Level of solar power in use per installation? E.g. Charging a phone or in any other use	D	24	14.72	92	61.75	18.768	0.000
	N	65	39.88	33	22.15		
	A	74	45.40	67	44.97		
Many households have Solar systems installed	D	21	12.88	117	78.52	140.59	0.000
	N	55	33.74	21	14.09		
	A	87	53.37	11	14.09		
Households have been given formal and informal training on Solar systems	D	91	55.83	92	61.75	4.277	0.118
	N	51	31.29	48	32.21		
	A	21	12.88	9	6.04		
There are Accessible Solar Technology Providers in the area	D	68	41.72	70	46.98	3.507	0.173
	N	60	36.81	59	39.60		
	A	35	21.47	20	13.42		
Your household would consider acquiring a solar household system	D	65	39.88	116	77.85	49.653	0.000
	N	20	12.27	13	8.72		
	A	78	47.85	20	13.42		
Households use other forms of energy for lighting to a large extent? I.e. Kerosene, firewood or dry cells	D	125	76.68	35	23.49	88.596	0.000
	N	17	10.43	59	39.60		
	A	21	12.88	55	36.91		

Source: Own result, 2019

4.4.2. Level of Income influences on solar energy technology adoption

The result of frequency analysis showed that significant ($P < 0.001$) nearly half (49.69%) adopters and nearly half (49.66%) of non-adopter households, both disagreed that there was a high level of investment in a solar system in the study area (Table 4.11). It revealed that of adopters and non-adopter households, both were having negative concerning in the investment of the technology. It might be associated with a lack of trust in the business, lack of foreign currency exchange, governmental procreate on importing the technology, and lack of subsidies from the government side, lack of government regulation and standardization, and subsidizes other alternative sources of energy like fossil fuels. This result was supported by a study (Abdullah *et al.*, 2017). Just as, frequented difference analysis showed that non-significant ($P > 0.05$) 81.59% of adopters and 87.25% of non-adopter households, both disagreed that employment of people, mainly on a monthly salary or savings in (Table 4.11). It revealed that of adopters and non-adopter households were having opposed the question on solar energy engagement. It might be associated with a person's employment with farming and animal production.

Significantly (P < 0.001) more than three-quarters (76.07%) of adopters and more than three-quarters (76.07%) non-adopter households have equally disagreed that there was a high-level of people with a regular income in the study area (Table 4.11). It revealed that of adopters and non-adopter households were not supported having a regular income. It might be associated with no regular income, animal sale income, serial sale income, fruits and vegetable sale income, butter sale income, Haney sale income. Similarly, significant (P < 0.001) more than three-fifth (43.56%) of adopters and 67.11% of non-adopter households were in cooperation disagreed that high extent of involvement in "Ekkub" that contribute money (Table4.11). It revealed that of adopters and non-adopter households were not having the traditional contribution of money except the farmer's cooperative. It might be associated with no high extent of involvement in "Ekkub" that contribute money, cooperative sharing a small amount of money a year for offering agricultural inputs, such as improved seeds and artificial fertilizers. This result supported by a studding (A. Husen *et al*., 2017).

From the complete survey, the analysis showed that, significant (P <0.001) descriptive frequented over half (53.99%) of the adopters agreed that, the high extent of borrowing loan for anything in the bank or with any micro-finance institute. On the contrary, less than three-fifth (59.06%) of the non-adopter households disagreed (Table 4.11). It showed that adopters and non-adopter households were having differences concerned with the borrower or loan providers. It might be associated with the only loan provider in kebele level was Dedebit Saving and credit micro-finance, lack of information, concern on the loan.

Similarly, less than a half (47.85%) of adopters and more than three-quarters (75.84%) of non-adopter households significantly (P < 0.001) were both disagreed that high degree of involvement in shares with any kind of capital authority shares in (Table 4.11). It showed that of adopters and non-adopter households were having variations in any money share occupation. It might be associated with no shares with any kind of capitalist authority, but might be Iddir, Ekkub, and member of the farmers' cooperative. This result was supported by a study of A. Husen *et al*. (2017), the justification for these findings was that in India and Ekkub, the source of money or the farmers´ periodic contribution is from the farmers' themselves, unlike credit.

Table: 4.11. Level of income of households

Factors Under consideration	Likert Scale	SHS				Chi^2-value	P-value
		Adopters (n=163)		Non-adopters (n=149)			
		Frequency	%	Frequency	%		
There is a high level of investment in a solar system	D	81	49.69	74	49.66	12.706	0.000
	N	55	33.74	29	19.46		
	A	27	16.56	46	30.87		
Employment of people, mainly on a monthly salary or savings	D	133	81.59	130	87.25	0.298	0.298
	N	8	4.91	7	4.69		
	A	22	13.49	12	8.05		
There is a high level of people with regular income	D	124	76.07	118	76.19	18.51	0.000
	N	19	11.66	18	12.08		
	A	20	12.27	13	8.72		
High Extent of involvement in "Ikkub" that contribute money	D	71	43.56	100	67.11	18.51	0.000
	N	67	41.10	39	26.17		
	A	25	15.34	10	6.71		
High Extent of borrowing loan for anything in the bank or with any microfinance institute	D	29	17.79	88	59.06	68.086	0.000
	N	46	28.22	38	25.50		
	A	88	53.99	23	15.43		
High Degree of involvement in shares in any kind of Capital Authority shares	D	78	47.85	113	75.84	29.950	0.000
	N	40	24.54	25	16.78		
	A	45	27.61	11	7.38		

Source: Own result, 2019

4.4.3. Availability of Alternative Sources of solar energy

Current descriptive frequency investigation revealed that, significantly ($P < 0.01$) more than half (55.83%) of adopters and less than three-quarters (73.83%) of non-adopter households were equally disagreed that there was an availability of electricity near their through schemes like ERA (Rural electrification authority) in the study area (Table 4.12). It showed that of adopters and non-adopter households were having the same knowledge of grid access. It might be observed that adopters and non-adopter households were having a completely off-grid settlement. This result was supported by a studying Abdullah *et al*. (2017), many respondents claim that some obstruct them from using SHS which includes, high cost of solar panels, lack of information and trust on solar panel providers. Similarly, non-significant ($P > 0.05$) approximately two-fifth (39.88%) of adopter households and more than two-fifth (44.97%) of non-adopter households were both neutral that there was a high level of usage of alternative energy sources that can be available to them (Table 4.12). It revealed that of adopters and non-adopter households were having either they did not aware of the technology type or not exists. It might be associated with the only biomass (cow dung, firewood) and solar technology. There were no other alternatives to using but naturally have like wind and water. This result was supported by a studying LP (2016), poor people without access to clean and affordable energy spend a large share of their scarce income on expensive and unhealthy forms of energy, which provides unsafe service e.g., Dry cell, charcoal, and candle.

As in Table 4.12 depicts, descriptive frequency result inquiry showed that significantly ($P < 0.001$) more than half (50.31%) of adopters and more than four-fifth (82.55%) of non-adopter households were mutually disagreed that there was high accessibility of vendors who sell wood, charcoal, and other wood-based fuels from their home high. It revealed that of adopters and non-adopter households were not buy fuel from the market except dry cell and kerosene. It might be associated with the fact that they were used from their plantation and homemade sources. Harmoniously, significant (P < 0.001) more than two-fifth (43.56%) of adopters have disagreed that there was near grid electricity near households. On the other hand, more than two-fifth (42.95%) of non-adopter households agreed in (Table 4.12). It revealed that adopters and non-adopter households were having devotion in the electricity future. It might be associated with economic status, scattered living conditions, difficult to distribute electricity to each household and the Geo-special problem itself, educational level and better awareness. This result was supported by studying Simpson and Clifton (2017) financial incentives will increase the adoption of an innovation by increasing the relative advantage of the technology.

Table: 4.12. Availability of alternative sources of power

Factors Under consideration	Likert Scale	SHS				Chi^2-value	P-value
		Adopters (n=163)		Non-adopters (n=149)			
		Frequency	%	Frequency	%		
There is an availability of electricity near you through schemes like REA? (Rural Electrification authority)	D	91	55.83	110	73.83	12.419	0.002
	N	46	28.22	30	20.13		
	A	26	15.95	9	6.04		
There is a high level of usage of alternative energy sources that can be available to you	D	64	39.26	60	40.27	1.434	0.488
	N	65	39.88	67	44.97		
	A	44	26.99	32	21.48		
There is a high accessibility of vendors who sell wood, charcoal, Others wood-based fuels from your home high	D	82	50.31	123	82.55	36.224	0.000
	N	57	34.97	20	13.42		
	A	24	14.72	8	5.37		
There is close proximity to Grid electricity near household	D	71	43.56	29	19.46	20.773	0.000
	N	42	25.77	56	37.58		
	A	50	30.67	64	42.95		

Sources: Own Results, 2019

4.4.4. Factors Influencing Adoption of Solar Energy

4.4.4.1. Characteristics of Technological Innovation

The existing descriptive result analysis revealed that significant (P < 0.01) 81.60% of adopters and 89.93% of non-adopter households were mutually agreed that solar energy technology was fully compatible with their household needs in the study area (Table 4.13).

It revealed that adopters and non-adopter households were having awareness of the technology benefits. It might be associated with economic status, lower energy demand, solar energy use mainly for lighting and mobile charging, fully compatible (cost, social norms, habits and routines, and household residence). This result was similar reports by a studying Hai *et al*. (2017), they describe as having a very positive attitude towards solar energy. Similarly, significant ($P < 0.01$) 72.39% of adopters and 92.62% of non-adopter households were together agreed that solar energy technology is easy to use (Table 4.13). It revealed that adopters and non-adopter households were having thought the technology operate or manage easily. It might be associated with knowledge of technology, operation and maintenance operate, unforeseen troubles, know-how to use, and know-how to manage. This result was supported by studying (Qureshi *et al*., 2017). According to Elmustapha *et al*. (2018; Khalil *et al*. (2017), among perceived attributes, there were significant differences between adopters and non-adopters in relative advantage, compatibility, complexity, Trialability, and Observability are determinants by the attributes for the (PV) systematic adoption.

The descriptive frequency analysis result on house survey revealed that significant ($P < 0.05$) 72.39% of adopters and 81.88% of non-adopter households were mutually agreed that the positive results of using solar energy technology are visible (Table 4.13). It revealed that adopters and non-adopter households thought solar energy have relative advantages. It might be associated with environmental friendless, free maintenance and non-pollutant. This result was supported by a studies Hai *et al*. (2017); Simpson and Clifton (2017), some of the perceived solar energy as a more suitable and environment-friendly source of energy than nuclear energy. Likewise, significant ($P < 0.05$) 95.71% of adopters and 91.28% of non-adopter households were together agreed that it has more advantageous to use solar energy technology than kerosene and firewood for lighting in

(Table 4.13). It revealed that adopters and non-adopter households have known the benefits of studying by solar energy and kerosene cause fire hazards. It might be associated with the negative impact of using kerosene and firewood, which might headache to study, eye disease, economy, and environment. This result was supported by (Schelling *et al*., 2010), SHS is small scale, which makes it significantly easier to install for both the customer and the provider, a stand-alone SHS requires less maintenance than large-scale PV installations, SHS is modular and affordable for poor rural households, as increased capacity can be added to the system after initial installation.

Present analysis revealed on the frequency exploration that, non-significant ($P > 0.05$) 80.37% of adopters and 87.25% of non-adopter households were in cooperation disagreed that technical support for solar energy technology is easily available (Table 4.13). It revealed that adopters and non-adopter households were unconvinced on the maintenance of solar technology. It might be associated with there is not skilled technician provide service, the solar home systems, mostly free maintenance, and have lower income. This result was supported by studying (Moorthy *et al*., 2019). Harmoniously, significant ($P < 0.01$) the highest frequency 89.57% of adopter households and 81.21% of non-adopter households were equally agreed that solar energy technology is user-friendly (Table 4.13). It showed that of adopters and non-adopter households were thought, every member of the household can manage and free from fire hazard. It might be associated with SHS is easy to use, non-polluting to the environment and social health. This result was supported by a studying (Simpson and Clifton, 2017).

In the same way, significant ($P < 0.05$) more than half (55.83%) of adopters and 67.79% of non-adopter households were mutually agreed that solar energy technology is secure (Table 4.13). It revealed that adopters and non-adopter households were well aware of the solar energy is safe from anything else. It might be associated with the fact that SHS is secure from thieves, economic development, energy supply security, environmental benefits and secure street lighting in the dark. This result was supported by a studying Dehghani Madvar *et al.* (2018), improving energy security led to job creation indirectly and directly. Moreover, significant ($P < 0.001$) more than three-fifth (62.58%) of adopters and approximately more than seven-eighth (88.59%) of non-adopter households were equally agreed that use of solar technology is cost-effective (Table 4.13). It showed that of adopters and non-adopter households were aware that needs capital to use it. It might be associated with business benefits and the service provided. This result was similar to reported by Lo *et al*. (2018), various companies perceive PV primarily as a way to demonstrate their green credentials and, therefore, were as concerned about the cost-effectiveness of PV systems.

Table: 4.13. Characteristics of Technological Innovation

Variables	Likert Scale	SHS				Chi^2-value	p-Value
		Adopters (n=163)		Non-adopters (n=149)			
		Frequency	%	Frequency	%		
Solar energy technology is fully compatible with my household needs	D	13	7.98	1	0.67	9.972	0.007
	N	17	10.43	14	9.40		
	A	133	81.60	134	89.93		
Solar energy technology is easy to use	D	28	17.18	2	1.34	25.981	0.002
	N	17	10.43	9	6.04		
	A	118	72.39	138	92.62		
The positive results of using Solar energy technology are clearly visible	D	19	11.66	5	3.36	7.958	0.019
	N	26	15.95	22	14.77		
	A	118	72.39	122	81.88		
It is more advantageous to use Solar energy technology than Kerosene and firewood for lighting	D	4	2.45	1	0.67	7.954	0.019
	N	3	1.84	12	8.05		
	A	156	95.71	136	91.28		
Technical support for Solar energy technology is easily available	D	131	80.37	130	87.25	2.759	0.252
	N	23	14.11	13	8.72		
	A	9	5.52	6	4.03		
Solar energy technology is user-friendly	D	5	3.07	1	0.67	10.169	0.006
	N	12	7.36	27	18.12		
	A	146	89.57	121	81.21		
Solar energy technology is secure	D	30	18.40	13	8.72	7.265	0.026
	N	42	25.77	35	23.49		
	A	91	55.83	101	67.79		
Use of Solar technology is cost-effective	D	28	17.18	5	3.36	29.107	0.000
	N	33	20.25	12	8.05		
	A	102	62.58	132	88.59		

Sources: Own result, 2019

4.4.4.2. Interviewees Perceived Relative Advantage

Descriptive analysis revealed that, significant ($P < 0.001$) more than half (50.92%) of adopters and more than four-fifth (81.88%) of non-adopter households were equally agreed that they thought that solar technology was affordable (Table 4.14). It revealed that of adopters and non-adopter households thought that solar energy was accessible by poor household and medium in price. It might be associated with service and price, household income, accessibility by the poorest and standard quality product. This result was supported by a studying Kachapulula-Mudenda *et al*. (2018), solar energy technologies are capitals intensive, requiring a substantial upfront cost. With the majority of the rural poor not electrified and in far-flung and often inaccessible areas and must be cost effective. Likewise, more significant (P <0.01) more than two-fifth (42.33%) of adopters and more than two-fifth (46.31%) of non-adopter households were both agreed that they knew how they would get help with solar energy (Table 4.14). It revealed that of adopters and non-adopter households, access easily for technicians and finance. It might be associated with knowing how they would get finance to buy the technology, information especially in remote areas how to operate the technology, and how to get technical help. This result was supported by a studying Nygaard *et al*. (2017), support, technical service, financing supported, subsidies.

Table 4.14 depicts the existing investigation revealed that significantly (P < 0.001) less than three-quarters (74.23%) of adopters and more than a half (51.68%) of non-adopter households were both agreed that they were willing to invest money and obtain some solar energy for their household. It revealed that adopters and non-adopter households were having a positive vision of solar energy adoption. It might be associated with interest in the new technology, educational level, and household income. This result was supported by Vasseur and Kemp (2015), the people with the highest income who have a positive attitude for PV. Even as, significant (P < 0.001) 72.39% of adopters and 53.69% of non-adopter households were equally agreed that they think by adopting the use of solar technology, they will be saving a lot of money in the long run in (Table 4.14). It revealed that of adopters were more than non-adopter households. It might be associated with job creation, free sources of energy use, minimize buying kerosene, and carbon financing. This result was supported by studies Batchelor *et al*. (2018), including acute respiratory, illness, heart disease, and even cancer may be shown and they could expense to treatment.

The result revealed that non-significant (P > 0.05) more than two-fifth (44.17%) of adopters and approximately a half (49.66%) of non-adopter households were mutually agreed that they were fully aware of the advantages of adopting the use of solar technology for their household use (Table 4.14). It revealed that adopters and non-adopter households were understood the benefits of the technology. It might be associated with free energy, renewable and no pollution to the environment. This result was supported by a study Kabir *et al*. (2017), solar energy hugely important not only for individuals, but also for the socioeconomic prosperity of companies, societies, states and nations. Moreover, non-significant (P > 0.05) 81.60% of adopters and 77.18% of non-adopter households were together agreed that solar energy technology was safe to use (Table 4.14). It revealed that of adopters were more non-adopter households. It might be associated with free and abundant used almost anywhere, no noise pollution for most applications, no air pollution during operation, and independent. This result was supported by a studying Woerter *et al*. (2017), most importantly, we see taxes voluntary agreements, public subsidies, and demand significantly induces the adoption of environmentally friendliness energy-related process innovation (green energy technologies).

Furthermore, significant (P < 0.01) 78.53% of adopters and 62.42% of non-adopter households were in cooperation agreed that the adoption of solar energy technology could quickly improve the general security of their area (Table 4.14). It revealed that of adopters were more than non-adopter households. It might be associated with safe street light lighting at night, quickly improve the area security, smoke-free, and indoor air pollution, forest degradation using for lighting, and sequestration of carbon. This result was supported by study Turney and Fthenakis (2011), CO_2 emission poses risks to human health and well-being.

Table: 4.14. Interviewees Perceived Related Advantage

Variables	Likert Scale	SHS				Chi^2-value	P-value
		Adopters (n=163)		Non-adopters (n=149)			
		Frequency	%	Frequency	%		
I think Solar technology is affordable	D	35	21.47	3	2.01	40.211	0.000
	N	45	27.61	24	16.11		
	A	83	50.92	122	81.88		
I know how I can get help/guidance on Solar energy technology	D	68	41.72	36	24.16	13.874	0.001
	N	26	15.95	44	29.53		
	A	69	42.33	69	46.31		
I am willing to invest money and obtain some Solar energy for my household	D	10	6.13	48	32.21	35.260	0.000
	N	32	19.63	24	16.11		
	A	121	74.23	77	51.68		
I think by adopting the use of Solar technology, I will be saving a lot of money in the long run	D	16	9.82	32	21.48	12.993	0.000
	N	29	17.79	37	24.83		
	A	118	72.39	80	53.69		
I am fully aware of the advantages of adopting the use of Solar technology for my household use	D	68	41.72	51	34.23	1.853	0.396
	N	23	14.11	24	16.11		
	A	72	44.17	74	49.66		
Solar energy technology is safe to use Adopter	D	20	12.27	16	10.74	3.415	0.181
	N	10	6.13	18	12.08		
	A	133	81.60	115	77.18		
Adoption of Solar energy technology can quickly improve the general security of my area	D	7	4.29	17	11.41	10.909	0.004
	N	28	17.18	39	26.17		
	A	128	78.53	93	62.42		

Source: Own result, 2019

4.4.4.3.Social Influence in Adoption of Solar Energy

As household survey analysis indicates that significantly ($P < 0.001$) 57.06% of adopters agreed that their peers think that they should use solar energy in their household. However, 63.76% of non-adopter households have disagreed (Table 4.15). It revealed that of adopters and non-adopter households were different understanding on the advice of experts and dominant person. It might be associated with influence leadership and influential people have an impact on the adoption of new technology. This result was supported by a study (Karakaya and Sriwannawit, 2015). By the same token, significant ($P < 0.05$) 90.80% of adopters and 81.21% of non-adopter households were mutually agreed that their family was very much interested in using solar energy technology (Table 4.15). It revealed that of adopters were more than non-adopter households. It might be associated with family interest, family size, household income, power of decision, and democratic. This result was supported by a study Selvakkumaran and Ahlgren (2019), peer effects work as they showed in Swedish Societies, the active engagement of current adopters with avoiding Trialability problem and low Observability.

Survey results analysis showed that significantly ($P < 0.05$) 61.96% of adopters agreed that their friends thought that they should adopt the use of solar technology. On the other hand, 38.93% of non-adopter households have disagreed (Table 4.15). It revealed that of adopters were more than non-adopter households. It might be associated with a friend's concern, the attitude of the technology, influential person, encourage and believe. In the same way, significantly ($P < 0.001$) 53.99% of adopter households and 75.17% of non-adopter households were together agreed that they knew where they could source for financial support to enable them to access solar energy technology (Table 4.15). It revealed that adopters and non-adopter households were understood how to access a loan. It might be associated with the cost of the technology, loan provider, and type of technology. This result was supported by a study Abdullah *et al*. (2017), the financial source during financial limitation during is the predominant source.

As current descriptive result presented that, significant ($P < 0.001$) 60.74% of adopters and 79.87% of non-adopter households were together agreed that they knew they could easily finance the purchasing of solar technology for their household use (Table 4.15). It revealed that of adopters were less than non-adopter households on how to access finance from the loan providers. It might be associated with loan providers, and banks. This result was supported by studying (Nygaard *et al*., 2017), financing schemes with a combination of guarantees and low-interest rates addressing both costs and finance. Furthermore, significantly ($P < 0.001$) 52.76% of adopter households and 69.13% of non-adopter households were together agreed that the local government was willing to provide support to people who were willing to adopt the use of solar energy technology in (Table 4.15). It revealed that adopters were less than non-adopter households the government needs to avoid fossil fuel sources. It might be associated with technology dissemination, willing to improve social well-being, and willing to reduce emissions to the environment. This result was supported by a study Abdullah *et al*. (2017), the government can enhance the development of solar energy by providing various incentives.

Table: 4.15. Social Influence in Adoption

Variables	Likert Scale	SHS				Chi^2-value	P-value
		Adopter (n=163)		Non-adopter (n=149)			
		Frequency	%	Frequency	%		
My peers think that I should use Solar energy in my household	D	29	17.79	95	63.76	69.279	0.000
	N	41	25.15	20	13.42		
	A	93	57.06	34	22.82		
My family is very much interested in using Solar energy technology	D	8	4.91	12	8.05	4.416	0.040
	N	7	4.29	16	10.74		
	A	148	90.80	121	81.21		
My friends think that I should adopt the use of Solar technology	D	11	6.75	58	38.93	65.403	0.040
	N	51	31.29	57	38.26		
	A	101	61.96	34	22.82		
I know where I can source for financial support to enable me to access Solar energy technology	D	60	36.81	16	10.74	28.783	0.000
	N	15	9.20	21	14.09		
	A	88	53.99	112	75.17		
I know I can easily finance the purchase of Solar technology for my household use	D	48	29.45	9	6.04	28.624	0.000
	N	16	9.82	21	14.09		
	A	99	60.74	119	79.87		
The local government is willing to provide support to people who are willing to adopt the use of solar energy technology	D	66	40.49	13	8.72	47.554	0.000
	N	11	6.75	33	22.15		
	A	86	52.76	103	69.13		

Sources: Own result, 2019

4.4.5. Econometric Regression

Model Specification and Test Results, goodness-of-fit tests showed in (Table 4.16). The VIF (Variance Inflation Factor) values were less than 10 and it shows that all the continuous independent variables have no multicollinearity problem. In the pairwise correlation test, there is no problem with a high degree of association among independent dummy variables. Out of 10 explanatory variables included in the model, six of them were found to be significant in influencing the household’s decision to adopt or not to adopt solar energy technologies. The remaining four variables; marital status of households, education level of households, roof suitable for installing SHS and land size of the households were not significantly affected solar energy adoption in the study area (Table 4.17). This implies that they do not determine the household’s continued adoption decision behavior of solar energy technology.

Table: 4.16. Test of the Model

<table>
<tr><td colspan="9">Block: 1 Method= Enter</td></tr>
<tr><td colspan="5">Hosmer and Lemeshow Test</td><td colspan="4">Model Summary</td></tr>
<tr><td rowspan="2">Step 1</td><td>Ch^2-Vaue</td><td>Df</td><td colspan="2">Sig</td><td>Step</td><td>-2 Log likelihood</td><td>Cox & Snell R Square</td><td>Nagelkerke R Square</td></tr>
<tr><td>10.147</td><td>8</td><td colspan="2">0.255</td><td>1</td><td>273.081a</td><td>0.399</td><td>0.532</td></tr>
<tr><td colspan="5">Omnibus Tests of Model Coefficients</td><td colspan="4" rowspan="4">a, Estimation terminated at iteration number 7 because parameter estimates a changed by less than 0.001</td></tr>
<tr><td rowspan="3">Step 1</td><td>Step</td><td>Chi^2-Value</td><td>df</td><td>Sig.</td></tr>
<tr><td>Block</td><td>158.846</td><td>10</td><td>.000</td></tr>
<tr><td>Model</td><td>158.846</td><td>10</td><td>.000</td></tr>
<tr><td colspan="9">Classification Table[a]</td></tr>
<tr><td colspan="4" rowspan="2">Observed</td><td colspan="5">Predicted</td></tr>
<tr><td colspan="3">SHS</td><td colspan="2">Percentage Correct</td></tr>
<tr><td rowspan="4">Step 1</td><td rowspan="3">SHS</td><td colspan="2"></td><td colspan="2">non-Adopter</td><td>Adopter</td><td colspan="2"></td></tr>
<tr><td colspan="2">non-adopter</td><td colspan="2">112</td><td>37</td><td colspan="2">75.2</td></tr>
<tr><td colspan="2">adopter</td><td colspan="2">35</td><td>128</td><td colspan="2">78.5</td></tr>
<tr><td colspan="6">Overall Percentage</td><td colspan="2">76.9</td></tr>
<tr><td colspan="9">a, the cut value is 0.05</td></tr>
</table>

Table: 4.17. Economic Regression, Logistic Model

Variables	B values	S.E.	Wald	P-values	Odds ratio
Constant	-9.823	2.552	14.815	0.000	0.000
Age (number of years)	0.037	0.018	4.225	0.040	1.038
Marital status (single=1)	0.684	0.474	2.082	0.150	1.981
Education (Illiterate=1)	0.435	0.349	1.553	0.212	1.545
Family size (number of people)	0.164	0.082	4	0.046	1.178
Yearly income (log) (ETH Birr)	0.783	0.578	1.874	0.002	2.188
Land size (ha)	-0.454	0.632	0.516	0.473	0.635
Roof suitable to install SHS (No=1)	-0.459	0.667	0.527	0.492	0.632
Technology Price (expensive=1)	-2.257	0.412	30.010	0.004	0.105
Kerosene (liters)	-3.877	1.130	11.772	0.001	0.021
Livestock own (number of livestock)	0.087	0.017	26.190	0.000	1.091

Sources: Own result, 2019

$\boldsymbol{Y_{SHS}} = \boldsymbol{\beta_0} + \sum \boldsymbol{\beta_i}\ \boldsymbol{x_i} + \boldsymbol{\epsilon_i}$

$\boldsymbol{Y_{SHS}} = \mathbf{-9.823} + \ \mathbf{0.037}_{\boldsymbol{Age}} + \ \mathbf{0.684}_{\boldsymbol{Mar.st}} + \mathbf{0.435}_{\boldsymbol{Edu}}\ \ldots + \cdots + \boldsymbol{\varepsilon_i}$

Where: Y_{SHS} =solar home system adopter, Mar.st=Marital status, Edu=Education and ε_i=Errors terms

Age of Households

As shown in Table 4.17 age of households was found to statistically significant (P < 0.05) affect solar energy technology and have positively influenced. The probability of older household heads to adopt solar energy technology is higher than those of their younger counterparts. As age increases by one year, the household heads are more likely to adopt solar energy technology and increases by 1.038 (odds ratio). This would probably be due to the chance that those of older were more likely to have experienced, or more aware of the climate variability, climate change, global warming affect their livelihood through their life and may have knowledge and wealth collected, therefore, can afford the upfront initial cost of solar energy technology and operational maintenance. This result was supported by studies (Getamesay Bekele *et al*., 2015; Haftu Etsay *et al*., 2017).

Level of Education of Household heads

Many studies have shown an education level of households was positively affected solar energy technology adoption, due to ease the transfer of promotion and note-taking than an illiterate one. This is justified by the fact that the level of education increases the sense of adopting innovation, skill, and ease of appraising new technologies Gebrehaweria Gebregziabher *et al*. (2014); Haftu Etsay et al. (2017); Miassi and Dossa (2018). However, the current study was statistically non-significant (P > 0.05) affecting solar energy technology in the study area (Table 4.17). This might be the probability of the households had only read and writing ability. In addition to this due to higher educated households, they did not take the risk of technology adoption, and the early adopters were having the ability to read and wrote. This is contradictory with the studies by Simpson and Clifton (2017), early adopters are also more educated and higher in socioeconomic status than the general population.

Number of Families of Households

A number of families of households were found to statistically significantly (P < 0.05) affect the solar energy technology adoption, and have positively influenced (Table 4.17). The probabilities of more the number of family households have a higher chance to adopt solar energy technology than those of less family size households. As the family size of households increases by one person, the household heads more likely to adopt solar energy technology and increased by 1.178 (odds ratio). This might be associated with probably due to expense sharing among them, have more chance to have jobs and earned money, and have different decision power to adopt the technology. This is supported by (Haftu Etsay *et al*., 2017).

Yearly income earned

The cash income of the households was statistically significant (P < 0.01) effect on the rate of adoption of solar energy technology adoption in the study area (Table 4.17). This probability of household income increase by one Ethiopian Birr, the household head is more likely to adopt solar energy technology increase by 2.188 (odds ratio). This might be associated with probably economic status, have resistance to the upfront cost, and the ability to resist the operational and maintenance cost after installation. This result is supported by studying (Haftu Etsay *et al*., 2017; Hirmer and Cruickshank, 2014; Kabir *et al*., 2018; Warkaw Legesse and Chawla, 2016).

Price of Technology

The prices of technology are statistically significant ($P < 0.01$) negative influence on the solar energy technology adoption (Table 4.17). The probability of technology price increases by one step (i.e. Medium to expensive) the households less likely to adopt solar energy technology and decrease by 0.047 (odds ratio). This might be associated with the probability of low economic status, the question on the product quality, which is vitally important for the adoption of solar energy technology. Due to low-quality influenced not only the adopter households' condition, but also the political and financial arrangements. This result was supported by a studying Hirmer and Cruickshank (2014); Kabir *et al*. (2017); Karakaya and Sriwannawit (2015); Khan and Khanam (2017); Lo *et al*. (2018), the lower the installation cost of PV systems, the more likely that people will adopt them. According to Tilahun Nigussie *et al*. (2017), PV capital cost (KW) = PV system + Soft costs or other costs. Besides, other costs such as labor, installation, structure, costs, and civil work also contribute a significant portion of the capital costs (Soft costs or other costs) accounts for 22% of total module costs.

Kerosene user households

The households use kerosene lanterns for lighting were statistically significant ($P < 0.01$) affect solar energy technology adoption and have negatively influenced in the study area (Table 4.17). The probability of households using kerosene increase by one household, the household is less likely to adopt solar energy technology and decreases by 0.021 (odds ratio). This might be associated with the probability of accessibility by the poorest household, low cost, and bought their needs. This result was supported by studies Kabir *et* *al*. (2018); Khan and Khanam (2017), due to solar energy technologies have high upfront costs, difficult to access, and afford by the poor, kerosene, used for lighting are potential for safety hazards, and significant numbers of burn injuries caused by kerosene lamps were reported around the world.

Livestock own households

The numbers of livestock own households were statistically significant ($P < 0.01$) affect and positively influence the solar energy technology (Table 4.17). The probability of households having an amount of livestock increase by one, the probability of adopting the technology is more likely to adopt solar energy technology increases by 1.091 (odds ratio). This probably could be due to several livestock are assets, and can offer the initial investment cost of solar energy technology, operation, and maintenance cost through the life of the panel. This results supported by studies Abdullah *et al.* (2017); Frederiks *et al*. (2015), the probability of a household adopting technology increases with the increasing household high number of livestock households were reported better in adopting.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusions

The study established that sex, age, number of families, educational level, yearly cash income earned, number of animals owned, house owned, house connected to the national grid, access to credit service, and technology price were statistically significant influence solar (PV) energy technology adoption in the studied area. The study concludes that there needed the county administration and concerned stakeholders to create awareness.

The solar home system, solar lantern, firewood, kerosene, and dry cells were energy sources used to satisfy household energy demand for lighting. Household energy demanding for lighting and their per capita energy demand was a statistically significant effect on solar energy technology adoption. The researcher concluded that the solar home system must disseminate for the rural household to get lighter.

The energy demand and carbon dioxide emission of the households for baking, cooking and lighting were 1,356,788.88 kWh per year (518,666.3 kg CO_2eq per year), 1,155,239.19 kWh per year (459,986.48 kgCO_2eq per year), and 9,564.50 kWh per year (736.26 kgCO_2eq per year) respectively.

Furthermore, the researcher required to assess the determinants for the adoption of solar (PV) energy technology for domestic usage. In bright of the above findings, the study concludes that the people of Hawzen district have not adopted much of solar (PV) energy technology. Those who have been using solar for charging their Mobile phones and for lighting only. The factors like level of knowledge and awareness, level of income, availability of alternative sources, characteristics of technology innovation, perceived relative advantage, and social influence has a statistically significant effect on solar energy (PV) technology adoption in the study area. With the increased cost of living against incomes which are not rising respectively, this gives the government a chance to attract investors powerful to engage in the solar energy technology investment as a way inspiring the lives of the residents as the adoption of solar energy technology will result in saving money currently used to buy kerosene. The health and education standards will also improve as this will mean increased study time and reduced respiratory health challenges.

5.2.Recommendation

Based on the above findings the researcher recommends that the government, NGOs, and concerned stakeholders should plan training, workshops, and seminars with the purpose of dissemination, and information related to solar energy technology thus raising knowledge and awareness among the rural dwellers. The government should encourage investors to invest in solar power technology to investment, installation, and implementation.

- We need to find a way to reduce the cost of implementing solar energy technology and providing for the needs of the low-income earners (the poor household).
- The study further found that the high cost of the solar equipment and the fact that most of the people did not have regular income and therefore they were unable to afford solar equipment. The Government should consider a zero-rating tax on solar equipment to influence lower pricing thus making it more affordable for the purchase and installation of a solar system
- The household should be encouraged to harness solar technology since it is easily accessible compared to other sources of energy given that the household comes from a remote area where the sun is abundant.
- Focus on awareness creation to households on the benefits of improved baking and cooking stoves (ICS), on health impacts of baking and cooking with traditional source of energy could help accelerate the shift towards modern improved baking and cooking approaches. Empowering women on reducing their burden from traditional source of energy use and subject to the health impacts from of burning it.

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APPENDICES: 1.Questionnaires

Questionnaires

Dear Sir/Madam,

I am a student at Wondo Genet College of Forestry and Natural Resource, Hawassa University. Currently, I am doing a research on "factors affecting the adoption of solar power technology for domestic usage in the eastern zone of Tigrai, Ethiopia, in partial fulfillment of the requirement for a Master of Science in Renewable Energy Utilization and Management

I kindly request your assistance in completing the attached questionnaire which forms a major input of the research process. The information and data will be used for academic purposes only and the information received is assured to be confidential.

I would like to thank you in advance for your valuable time and consideration.

Berhane Hidaru

INSTRUCTIONS

ANSWER THE FOLLOWING QUESTIONS BY TICKING OR MARKING THE BOXES USING (X) OR (√) OR BY FILLING THE EMPTY BOXES.

PART I: General Demographics Characteristics

1. Gender of respondent? 1. Male 2. Female
   A. Age________________________
   B. Marital status: 1. Married, 2.Single,3.Divorced, .Widow,5.Widower,6.Separated
   C. Education level: 1. Illiterate, 2. Read and write, 3. Primary school, 4.Secondary school, 5. Some certificate, 6. Some degree and above
2. Is your house connected to the national electricity grid?
   1. Yes, 2. No, 3.Connection in progress, 4.Nor the hope of accessing electricity power soon
3. Family size including the parents
   A. Male _______ B. Female ________
4. The main occupation of the household head________________________________
5. Do you have your own house? 1. Yes2.No3.Rent
6. If yes, is the roof suitable for SHS installation?
   1. Yes, 2.No, 3.Needs some modification, 4.total roof will be replaced
7. If No, does the roof of the house build again to a suite for SHS installed? 1. Yes, 2.No
8. Do you already use solar energy (SHS) in your home? 1. Yes 2. No
9. If yes, what do you say about the Price of technology? 1. Expensive, 2.cheap, 3.Midium, 4. Not available
10. If yes, which type of system do you own?
    A. Solar lantern (1.S_2, 2.S_3, 3.Others (specify)…………………………)
    B. SHS (1.8Wp2.10Wp3.20Wp4.40Wp.5.60Wp6.75Wp7.80Wp8.100Wp9.130Wp 10, D20)

C. If question #10 answer is solar home?							
Type of SHS	No.of light-bulb	Operation Hour	No.of TVS &Radio	Operation Hour	No.of refrigerator	Operation Hour	Others (specify)

11. When do you own the solar energy source? 1.6 months ago, 2.1 year ago, 3. 2 Years ago 4.3 years ago
12. If #8answer is No, Would you like to own a solar home system? 1. Yes , 2.No
13. If yes, when do you like to have it? 1. Now, 2.When available, 3.After one year
14. Are you credited access for solar technology? 1. Yes, 2. No
15. If you don't have electric source, what do you use for lighting and electric source for your electronic media? ___________________________________
16. What is your energy choice for lighting? 1. Solar, 2.Kerosene, 3.Firewood, 4.Cow dung,5. Agricultural residue, 6.Electricity, 7.candle

PART II: Determinants variables on solar energy technology adoption

1. Please indicate the degree to which you agree or disagree with the following statements.
2. Use a scale of 1-5 where; [1] is strongly disagreeing; [2] disagree; [3] neutral; [4] agree; and [5] Strongly agree.

A. Characteristics of Technological Innovation

S/n	Variables	Strongly disagree [1]	Disagree [2]	Neutral [3]	Agree [4]	Strongly agree [5]
1.	Solar energy technology is fully compatible with my household needs					
2	Solar energy technology is easy to use					
3	The positive results of using Solar energy technology are clearly visible					
4	It is more advantageous to use Solar energy technology than Kerosene and firewood for lighting					

5	Technical support for Solar energy technology is easily available					
6	Solar energy technology is user-friendly					
7	Solar energy technology is secure					
8	Use of Solar technology is cost-effective					

2. In your opinion, what other factors affect the adoption of innovation technologies in your area? ________________________________

PART III: Dependent Variables:-

1. Indicate the degree to which you agree or disagree with the following statements regarding the adoption of Solar Energy Technology in your Constituency. Use a scale of 1-5 where; [1] is strongly disagreeing; [2] disagree; [3] neutral; [4] agree; and [5] strongly agree

(a) Interviewee's perceived Relative Advantage in Solar energy technology adoption

S/n	Variables	Strongly disagree [1]	Disagree [2]	Neutral [3]	Agree [4]	Strongly agree [5]
1	I solar technology is affordable					
2	I know how I can get help/guidance on Solar energy technology					
3	I am willing to invest money and obtain some Solar energy for my household					
4	I think by adopting the use of Solar technology, I will be saving a lot of money in the long run					
5	I am fully aware of the advantages of adopting the use of Solar technology for my household use					
6	Solar energy technology is safe to use					
7	Adoption of Solar energy technology can quickly improve the general security of my area					

(c) Social influence on Solar energy technology adoption

S/n	Variables	Strongly disagree [1]	Disagree [2]	Neutral [3]	Agree [4]	Strongly agree [5]
1	My peers think that I should use Solar Energy in my household					
2	My family is very much interested in using Solar energy technology					
3	My friends think that I should adopt Use of Solar technology					
4	I know where I can source for financial support to enable me access Solar energy technology					
5	I know I can easily finance the purchase of Solar technology for my household use					
6	The local government is willing to provide support to people who are willing to adopt the use of solar energy technology					

2. Determinants of domestic solar power technology usage

1. Level of knowledge and awareness of solar technology

S/n	Variables	Strongly disagree [1]	Disagree [2]	Neutral [3]	Agree [4]	Strongly agree [5]
1	There is a high Level of solar power in use per installation? E.g. Charging a phone or in any other use					
2	Many households have Solar systems installed					
3	Households have been given formal and informal training on Solar systems					

4	There are Accessible Solar Technology Providers in the area					
5	Your household would consider acquiring a solar household system					
6	Households use other forms of energy for lighting to a large extent? I.e. Kerosene, Firewood or dry cells					

2. Level of income

No	Variables	Strongly disagree [1]	Disagree [2]	Neutral [3]	Agree [4]	Strongly agree [5]
1	There is a high level of investment in a solar system					
2	Employment of people, mainly on a monthly salary or savings					
3	There is a high level of people with regular income					
4	High Extent of involvement in "Ekkub[8]" that contribute money					
5	High Extent of borrowing loan for anything in the bank or with any microfinance institute					
6	High Degree of involvement in shares in any kind of Capital Authority shares					

3. Availability of alternative sources of power

No	Variables	Strongly disagree [1]	Disagree [2]	Neutral [3]	Agree [4]	Strongly agree [5]
1	There is an availability of electricity near you through schemes like REA? (Rural Electrification authority)					
2	There is a high level of usage of alternative energy sources that can Be available to you					
3	There is a high accessibility of vendors who sell wood, charcoal, Others wood-based fuels from your home high					
4	There is close proximity to Grid electricity near household					

PART IV. Wood-based energy consumption

1. Economic characteristics

(a) Type and number of livestock owned

Livestock	Cow	Ox	Heifer	Bull	Gulf	Goat	Sheep	Donkey	Mule	Hen	Chicken	Beehive
Number												
Income from sales												

(b) Average yearly income (Birr) from the sale of livestock products

Livestock products	Milk	Butter	Egg	Honey
Yearly income from sales				

(c) Income from sale of cereals, oilseeds, and pulses in 2010/2011

Crop type	Cereals					Oilseed			Pulses			Others
	Teff	Wheat	Barley	Maize	Sorghum	S. Flower	Linseed	Flax	Chickpeas	Lentils	Vetch	
Yearly income from the sale												

(d) Income from sale of other crop types and planted trees in 2010/2011

Crop type	Vegetables (Garlic, Onion, Cabbage, Potato etc.)	Spices (Basil, rue, ginger, fenugreek etc.)	'Gesho', fruits etc.	Planted tree	Others
Income from sale					

(e). Size of land holding? In hectare or in 'Tind'

[8] Ekkub means Informal saving money

(f) Do you have your own house? 1. Yes, 2. No

2. Household Energy consumption

1. What kind of stove did you use for baking 'Injera?' 1. Three stone fire (open fire) 2.Traditional enclosed Injera stove, 3.Meritstove, 4. other______________

2. What type of fuel do you use for Baking 'Injera?' 1. Fuel wood, 2. Dung, 3.Crop residues, 4.Sawdust, 5.Paper/carton

3. What is your preference? ____________________________________

4. How many baking sessions in a week? 1. One session 2. Two sessions, 3.Three sessions, 4 .Other_______________________

5. on average, how many kg of fuel per session you consume?

Unit	Fuel wood	Cow dung	Crop residues	Sawdust	Paper/carton	Others
Kg						

6. What kind of stove did you use for cooking stew/coffee/water heat? 1. Lakes, 2.Mirchaye, 3.Metal stove, 4. Traditional closed Mud stove, 5. Traditional three stove fire

7. What type of fuel do you use for cooking stew/coffee/water heat? 1. Charcoal, 2. Firewood, 3.Dung cake, 4.Biogas stove, 5.Solar cooker, 6. Kerosene

8. On average, how many kg for cooking stew / coffee /water heat per week?

Unit	Charcoal	Firewood	Dung cake	Biogas stove	Solar cooker	Kerosene
Kg						

9. What is your energy fuel for lighting? More than one answer is possible, 1.Firewood, 2. Dry cells 3.Solar 4.Kerosene lantern5.Candle

10. On average, how many kg/L/Numbers do you consume per week?

Unit	Firewood	Dry cells	Solar	Kerosene lantern	Candle
Kg/L/Numbers					

Checklist of key informant and Focus group discussion

A. Regional mines and energy Agency

1. How do you evaluate solar power technology availability (scarcity) as a region?
2. How do you evaluate the solar power technology dissemination?
3. What are the main challenges or opportunities to disseminate the solar power technology?
4. How do you evaluate the level of awareness of the rural households on solar power technology?
5. What is the rate of adoption as a region by type of technologies?
6. What is the future plan for solar power technology dissemination?

B. For district level experts

1. How do you evaluate the current solar power technology availability (scarcity) in the district?
2. What are the measures being taken against the problem of solar power technology scarcity in your locality?
3. What are the factors affecting solar power technology adoption?
4. Are there plans to further promote alternative sources of energy?

C. For development agent (Kebele level expert)

1. How do you evaluate the current solar power technology availability in your area?
2. What are the main reasons for households in adopting solar technology?
3. Are there extension services related to domestic energy?
4. What is the status of solar power technology adoption in your locality?
5. What are the factors affecting solar power technology adoption?
6. How do you understand the benefits of improved cook stoves

APPENDICES: 2. plate about the study area

Appendix: 2.1. Different types of SHS

Appendix: 2.2. Different types of solar lantern

Appendix: 2.3. Dung and firewood

Appendix: 2.5. Enclosed traditional Tigrai Type, Mirt “Injera” & cooking

Appendix: 2.7. Regional and kebele expert, Sluh and Debre-birhan & dweller discussion