THE STATUS AND DETERMINANTS OF SOLAR PHOTOVOLTAIC TECHNOLOGY UTILIZATION BY RURAL HOUSEHOLDS IN GOZAMIN WOREDA, AMHARA NATIONAL REGIONAL STATE, ETHIOPIA

MSc THESIS

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A THESIS SUBMITTED TO THE DEPARTMENT OF RENEWABLE ENERGY UTILIZATION AND MANAGEMENT, HAWASSA WONDOGENET COLLEGE OF FORESTRY AND NATURAL RESOURCE, SCHOOL OF GRADUATE STUDIES

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ADVISOR’S APPROVAL SHEET

This is to certify that the thesis entitled “The Status and Determinants of Solar Photovoltaic Technology Utilization by Rural Households in Gozamin Woreda, Amhara National Regional State, Ethiopia” submitted in partial fulfillment of the requirements for the degree of Master's with specialization in Renewable Energy Utilization and Management, the Graduate Program of the School of Natural Resource and Environmental Studies, and has been carried out by Yared Alazar Id. No MSc/REUM/R0014/2009, under my/our supervision. Therefore I/we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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DEDICATION

This thesis shall be for my beloved wife and son Wubsira Bitew and Kidus Yared respectively.

DECLARATION

I hereby declare that this MSc thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name: Yared Alazar

Signature: ___________

ABBEREVATIONS

AC- Alternate Current

CFL-Compact Florescent Lamp

DC- Direct Current

GHG-Green House Gases

GW- Giga Watt

IPCC- International Panel on Climate Change

IRENA- International Renewable Energy Agency

ISEI-International Solar Energy Institute

Kwh- kilo watt hour

MoWIE-Ministry of Water, Irrigation and Energy

MRV- Measurement Report and Verification

MW- Mega Watt

PV- Photovoltaics

SHS- Solar Home System

SPV- Solar Photovoltaics

TERI-The Energy Resource Institute

TABLE OF CONTENTS

ACKNOWLEDGEMENT iii
DECLARATION iv
ABBEREVATIONS vi
TABLE OF CONTENTS vii
LIST OF TABLES x
LIST OF FIGURES xi
LIST OF APPENDICES xii
ABSTRACT xiii
1. INTRODUCTION 1
  1.1 Background of the Study 1
  1.2 Statement of the Problem 4
  1.3 Objective of the Study 6
  1.4 Research Questions 6
  1.5 Significance of the Study 7
  1.6 Scope and Limitation of the Study 7
2. LITERATURE REVIEW 9
  2.1 History of Solar PV 9
    2.1.1 World's SPV History 9
    2.1.2 Ethiopia's PV History 9
  2.2 The Energy Sector in Ethiopia 10
    2.2.1 The Current Electrification Status of Ethiopia 10
    2.2.2 Off Grid Potentials for Rural Electrification in Ethiopia 11
  2.3 Solar PV system 11
    2.3.1 Types of Solar PV 12
    2.3.2 Components of Solar PV 12
    2.3.3 Pros and cons of SPV 14
    2.3.4 How Does a SPV Works? 15
  2.4 Description of solar home system and solar lantern technologies 17
    2.4.1 Solar Home System 17
    2.4.2 Solar Lantern 18
  2.5 Market Challenges of SPV in Ethiopia 18

2.6 Solar PV as an Energy Source to Rural Households 19
2.6.1 Rural Household Energy Sources for Lighting 20
2.6.2 Factors Related to Adoption of SPV by Rural Households 21
2.7 Challenges and Opportunities of Solar PV Technology in Rural Households 22
2.8 Theoretical Framework 24
2.8.1 Technology Acceptance Model (TAM). 24
2.8.2 Diffusion of Innovations Theory DOI) 25
3. MATERIALS AND METHODS 26
3.1 Description of the Study Area 26
3.2 Methodology 27
3.2.1 Sampling Design 27
3.2.2 Data collection methods 31
3.3 Data Analysis 33
3.4 Definition of Variables and Working Hypothesis 34
3.4.1 The Dependent Variable of the Model 34
3.4.2 The Independent Variable of the Model 35
3.5 Model Specification 41
3.6 Estimation of Multicollinearity 43
4. RESULTS AND DISCUSSION 45
4.1 Household Characteristics 45
4.2 Frequency of Users and Functionality of SPV Technologies 49
4.3 Patterns of SPV Technology Use 51
4.4 Determinant Factors Affecting Utilization of SPV Technologies 56
4.5 Constraints and Opportunities of SPV Technologies for Sustainable Adoption 60
4.5.1 Constraints of SPV Technologies 60
4.5.2 Opportunities of SPV Technologies 64
4.6 Other Technological Related Variables 65
5. CONCLUSION AND RECOMMENDATIONS 69
5.1 Conclusion 69
5.2 Recommendations 71
REFERENCES 72
APPENDICES 80

BIOGRAPHICAL SKETCH..92

LIST OF TABLES

Table 3.1 Household Size of Sample kebeles 28

Table 3.2 Stratification of Population 29

Table 3.3 Randomly Selected Sample households..30

Table 3.4 Definition and Scale of Measurement of Variables Included in the Model 40

Table 4.1 Characteristics of Households for Continuous Variables..45

Table 4.2 Characteristics of Households for Dummy Variables...46

Table 4.3 Monthly Failure of SPV Technologies..51

Table 4.4 Patterns of SPV Use 52

Table 4.5 Lighting Energy Sources before SPV Utilization 54

Table 4.6 Amount of Light Energy Sources Used before SPV Utilization..54

Table 4.7 The Maximum Likelihood Estimates of Binary Logit Model...55

Table 4.8 Number of technicians to install SPV. 65

Table 4.9 Installation cost 66

Table 4.10 Evaluation of technician's service..66

Table 4.11 Module cleaning per week 67

LIST OF FIGURES

Figure 2.1 Components of SPV Technology 13

Figure 2.2 Diagram that shows how a SPV works 16

Figure 3.1 Map of the Study Area 27

Figure 4.1 Constraints of Adoption of SPV Technologies 60

Figure 4.2 Affordability Challenge of SPV Technologies 61

Figure 4.3 Durability of SPV Technologies 63

LIST OF APPENDICES

Appendix 1. Variable Inflation Factor for Continuous Variables 80

Appendix 2. Contingency Coefficient for Dummy Variables..80

Appendix 3. Criteria for Wealth Category 81

Appendix 4. Criteria for Type of House...81

Appendix 5. Omnibus Tests of Model Coefficients..81

Appendix 6. Model Summary 82

Appendix 7. Hosmer and Lemeshow Test 82

Appendix 8. Structured Questionnaire for Household Survey..82

ABSTRACT

Solar Photovoltaic technology has been advanced in the world as a renewable energy source many years ago. The progress of the technology is due to its social, economic and environmental benefits. However, utilization of solar photovoltaic technology by rural households in Ethiopia is a recent phenomenon with low rates of use. To utilize these technologies consistently and sustainably, conducting researches is very crucial. Hence, this study was conducted to meet the aim of exploring the status and determinants of solar photovoltaic technology utilization by rural households in Gozamin woreda. Three kebeles called Wonka, Libanos and Yetijan were purposively selected to conduct the study. Simple random and stratified sampling methods were used as they give elements equal chance of being selected and be good representative of samples. Primary data were collected from sample households using structured questionnaire, field observation, and focus group discussion. In addition, secondary information was also collected from published and unpublished reports, magazines, journals, etc. to strengthen the primary data. From the three kebeles a total of 190 representative household samples were selected. Users were 31.5 percent and the rest 68.5 percent were non-users of solar photovoltaic technology. Binary logit model was used to analyze the correlation between utilization of solar photovoltaic technology and different explanatory variables. Descriptive statistics was also conducted to analyze the functionality, patterns and constraints of SPV technologies. The result of descriptive statistics showed that all the diffused technologies were functional. Despite this, 23.4 percent SPV technology adopters fail to function once or twice per month. Concerning the patterns of SPV utilization, all the adopters used the technology mainly for lighting. Additionally, 78.3 and 18.3 percent of the adopters use the technology for mobile charging and making petty trades respectively. The major constraints of SPV utilization were awareness gap, *price increment and SPV providers shortage comprising of 70, 26.7 and 3.3 percent respectively. Moreover, the result of the binary logit model showed that age and income affected utilization of solar photovoltaic technology significantly with (P< 0.01 and P< 0.1) respectively. Similarly, wealth status, awareness creations made, providers of the technology, house quality and price of the technology were also affected utilization significantly (P<0.05). Conversely, family size, agricultural land size, education level, market access, human capital and quality of technology were explanatory variables that were assumed to affect utilization, but they do not affected utilization of the technology. Suggesting distribution, financial and government institution to make awareness, encourage more individuals to be provider of SPV technologies and avail long term credit access to buy the technologies.*

Key words: Adoption, Ethiopia, Gozamin, Solar Photovoltaics, Utilization

1. INTRODUCTION

1.1 Background of the Study

Energy is arguably vital component in the development agenda. It has been contended that with the absence of energy, it is almost inconceivable to attain sustainable development and human welfare of a country (Sumathi *et al.*,2015; Matungwa,2014). Access to affordable, reliable and sustainable energy is crucial to achieving many of the Sustainable Development Goals ranging from poverty eradication through advancements in health, education, water supply and industrialization to mitigating climate change (UN,2016). Renewable energy in this regard plays an indispensable role in achieving these targets.

Renewable energy potential is estimated to account 14% of the total of primary energy supply and annual average primary energy demand has increased globally by 2.7% since 2014 (IEA, 2016). Though these demand increment, renewables totally contributed 19.3% of the total energy consumption in 2015 depicting much to be done to promote renewables. On the other hand, this sector has created 9.8 million jobs showing an increment of 1.1% compared to 2015 (REN21,2017). Generally, these renewables have significant importance in alleviating so many social, economic and environmental problems across the globe.

Ethiopia is endowed with renewable resources such as hydropower of 45000MW, solar 4-6Kwh/m^2, wind 1350GW, geothermal 7000MW, wood 1120 million tons and others located in different regions of the country (Derbew, 2013). Though all these potentials, wood is the only exceptional resource that is utilized to 50% and the rest have been utilized still not more than 5 % (ibid) which shows the potential is untapped. But, if utilized efficiently it will support the effort to take out the people from energy poverty.

Of those renewables, solar energy is one of them. This resource cannot be realized as it is but with the use of advanced technologies like solar Photovoltaics. It is a device that traps sunlight and convert it to electrical energy. Globally, the sun provides a solar energy of 105TW which is more than triple to that of the energy needs forecasted to 2050 which is 25-30TW (Kreith and Goswami,2007) and in Sub Saharan Africa the potential reaches from 371 to a maximum of 9528 EJ (Thomas *et al.,* 2004) indicating a huge potential if utilized wisely.

At the end of 2016 the total global Solar Photovoltaic (SPV) installation has increased to 303 GW (REN21, 2017). Of this, Africa is only home to 2.1GW of the world's total (IRENA, 2016). Solar energy can easily be brought to the rural community since it is decentralized, clean and free from greenhouse gas (GHG) emissions, reliable (Schützeichel, 2012; Solanki, 2015) and affordable as SPV module prices have fallen rapidly since the end of 2009, to between USD 0.52 and USD 0.72 /W in 2015 (IRENA, 2016). Hence, investment in SPV can bring social, economic and environmental benefits at local, national and global level.

Compared to other Sub Saharan African countries, utilization of SPV in Ethiopia (6.5MW) is low. For instance, South Africa accounts 65percent (1361MW) of the continent's cumulative installed SPV capacity, Algeria for 13 percent (274MW), Réunion for 9 percent (180MW) and Egypt for 1 percent (250MW). Uganda, Namibia and Kenya also account for around 1 percent each between 20MW and 24MW (IRENA, 2016). Most of the SPV in Ethiopia is used by ethiotelecom to run its landline mobile stations (MoWIE, 2013; Mekuria, 2016).

Electricity production and supply in Ethiopia is brought from hydropower, wind and diesel stand by generators. Of these, hydropower is the dominant, however, supply is characterized by an average monthly outage of 5.6 hours (Derbew, 2013; IRENA,2016). The electrification rate of the country is 25 percent, 10 percent in rural and 85 percent in urban areas and the rest 14.6 million households were lacking electricity (www.usaid.gov>powerafrica>et). But, according to www. lightingafrica.org>country, as of December,2017 the national electrification rate is 27.7, in rural 12.2 and urban 92 percent. Though some differences in numbers from one source to another, it clearly indicates that the country is bringing electricity access to the urban and rural ones. These households were getting an electric consumption of 77Kwh/year which is very low as compared to other African countries. The settlement pattern of rural population makes it challenging to connect to every rural village to the grid (Derbew,2013).

The key actors in solar PV utilization are the technology providing companies that deliver to the small shop owners at woreda level. Small shop owners that receive the technologies from provider companies and sells to the users are the second one. Thirdly, Amhara Credit and Saving Institution (ACSI) is the other actor in providing credit access to buy these technologies by respective users. The Woreda Water, Irrigation and Energy Office is also the other key actor that provides awareness raising to the rural communities to utilize these technologies. The other actors of solar PV in the woreda are the technicians that provide installation and maintenance service to the users. Last but not least, actors of solar PV are the end users themselves that found in different rural kebeles of the woreda.

According to the annual report of Gozamin woreda water, irrigation and energy office (2016), it had installed a total of 5768 SPV. Of these, 3864 are solar lantern with power range from 1Wp to 4Wp and 1904 are SHS with power greater than 6Wp. The major area of application of these SPV were for lighting, mobile charging, running electrical appliances like Television, Refrigerators, Barbering, Cooking and pumping water. Due to installation of these SPV technologies a total of 162 persons have got the opportunity of job. To mention some of the areas where job created are 12 persons in installation and maintenance, 134 people in mobile charging and 16 people in opening cafeterias and restaurants. During utilization of these technologies failures happen in the battery due to over and undercharging, in cables due to improper connection and modules due to the presence of shade and dust. Generally, the trend of SPV utilization is increasing from year to year but not at alarming rate. For instance, in 2005 E.C there was an installation of 488, in 2006 E.C - 344, in 2007E.C -596, in 2008 E.C - 7445 and in 2009 E.C -5768.

Though some increments have been registered, still many rural people in the study area is in deficit of modern electricity. Not analyzing the determinants related to the use of SPV technologies is hence a gap that make more people not to be user of these technologies.

Therefore, this study may fill the gap in analyzing the determinants related to the use of SPV technologies in the study area.

1.2 Statement of the Problem

The proportion of the global population with access to electricity increased steadily from 77.7 in 2014 to 85.5 percent in 2014. Despite these improvements, 1.06 billion people were still without this essential service in 2014 (WB,2017).

The total annual expenditure on lighting sources in Ethiopia is estimated to be approximately 6300 ETB (US$ 331 million), of which 75 % is spent on kerosene and the rest on dry cell batteries. Based on the current price of kerosene over 200 million liters are used each year for lighting by rural households. Most households expressed a high degree of dissatisfaction over the adequacy, cost, convenience, and quality of lighting received from kerosene lamps (Ethiopian Market Intelligence, 2013). These sources of light are unsuitable as they cause indoor pollution, unhealthy and great contribution to GHG emissions.

To resolve the above problem nationally MoWIE (2016) distributed some 45365 solar PV throughout the country and total installed capacity is only 6.5MW. This clearly depicts that utilization of these technologies is low. Some of the barriers that prevent the country from progress are inadequate technical skills, lack of financing mechanism to draw-down the high upfront cost, inadequate awareness among policy makers and consumers, and poor linkage between the national level dealer/supplier and local level retailers and technicians (www.energypedia.info>wiki>challen...).

Gozamin woreda lacks to deliver for all of its inhabitants' modern form of lighting energy like electricity because out of the 25 kebeles only 5 kebeles are connected to grid according to the Woreda Water, Irrigation and Energy Office (2016) report. Grid connection is infeasible as the people are sparsely populated, less energy demand during peak times (Taina et al., 2016). For this reason, modern lighting sources may not be both unavailable and unaffordable for many in the near future; the use of kerosene, dry cell and fire wood are likely to continue. Off grid SPV technologies could be best alternative for such kinds of places to deliver modern energy source for lighting (Mohanty et al., 2016).

Limited or no adequate studies have been conducted concerning socioeconomic aspects of SPV in the country although Admasu (2010), Mazengia (2010) and Mekuria (2016) can be mentioned as a few. Accordingly, no study has been done regarding the status and determinants of SPV technology utilization by rural households in the specified study area as well as the country.

Particularly, there is knowledge gap in the study area related to issues of SPV awareness, price, availability, suppliers, etc. There is also scarcity of studies on the topic and studies need to be done to solve the energy poverty of the study area in particular. So, this study can contribute in analyzing determinants for stable distribution, installation and utilization of SPV in the off-grid parts of the study area.

1.3 Objective of the Study

The general objective of the study is to explore the status and determinants of SPV technology utilization by rural households in Gozamin woreda of Amhara Nationa Regional State, Ethiopia and the specific objectives are:

i. To assess the status of functionality and pattern of installed SPV technologies among rural households.

ii. To analyze determinants of SPV technology utilization in the study area.

iii. To determine constraints and opportunities for sustainable adoption of SPV technologies.

1.4 Research Questions

i. How is the status and use of installed SPV technologies?

ii. What are the determinant factors that affect utilization of SPV technologies by rural households?

iii. What are the constraints and opportunities for sustainability of SPV technologies?

1.5 Significance of the Study

This study has significance in identifying those factors to the proper utilization of SPV in the study area and findings from the study can be used by stakeholders like the study kebele administration offices, local providers of SPV and Gozamin Woreda Water and Energy Office. Since the determinant factors related to use of SPV were identified, the above stated bodies can sort intervention areas for better utilization of the technologies.

If the above-mentioned bodies take the determinants related to the use of SPV technologies in to consideration and work on, households' utilization of SPV would likely to enhance better. An increased utilization of SPV for light in the study areas could lead to a reduced use of unhealthy energy sources like kerosene.

Eventually, it lays foundation for other academicians to further study in the subject matter in the specified place or at country level.

1.6 Scope and Limitation of the Study

1.6.1 Scope of the Study

As solar PV technologies are not distributed to all kebeles and there is restriction in money to cover all kebeles, this study is limited in collecting information to three rural kebeles in the woreda. Time of investigation is limited to one shot data collection point as there is only one contact to the study population. Hence, it cannot show or measure changes about utilization trend of solar PV technologies in the study area. This study will not also size the PV system by calculating the energy consumption of households, rather it is limited in observing whether the installed solar PV technologies are functional or not. If they are not functioning, assessing the reasons for the malfunction are also the other aspects in which the study will focus. For the aim of this study, the author tries to limit his findings from interviews, questionnaire, printed material and another internet web sources related to the subject.

1.6.2 Limitation of the Study

This study does not include the 5 urban kebeles found in Gozamin woreda. This study does not include other large scale solar systems and only limited to analyzing determinants that are related to the use of SPV at household level.

2. LITERATURE REVIEW

2.1 History of Solar PV

2.1.1 World's SPV History

The use of solar technology around the globe had begun since the 7th Century B.C. and continued till today. People started out concentrating sun's heat with glass and mirrors to light fires and today we have everything from solar powered house to vehicles (Lotsch *et al.,* 2009*;* White, 2014; www1.eere.energy.gov/solar/pdfs). Since then by making a long journey of progress and innovation, photovoltaic cell invention was born in USA when Daryl Chapin, Calvin Fuller, and Gerald Pearson developed the silicon PV cell at Bell Labs in 1954. The PV's then extended their service being as a source of power for launching satellites up to the period of 1966. During 1970's the price of PV has drastically fall down from US $ 4 /watt in 2007 to US $20/ watt in 2015 (World Energy Resources,2016) and started to power resident areas. Today, a total of 303GW power is installed worldwide after passing many ups and downs (www1.eere.energy.gov/solar/pdfs).

2.1.2 Ethiopia's PV History

The first solar PV was established in central Ethiopia around 'Mitto' village of Ziway area in Oromia region (Foley,1995; Ethiopia Market Intelligence, 2013) for home and school lighting. A capacity of 10.5 KWp SPV was installed in 1985 to give service for 300 households. Later, the capacity had grown to 30KWp to give additional services like water pumping and grain mill (ISEI, 2012; Ethiopia Market Intelligence, 2013). Today, Ethiopia has installed 6.5 MWp capacity of SPV. Of this, more than 70 percent is used by ethiotelecom to run its landline mobile network stations and the rest percent is used by private sectors and government organizations like health centers and schools. Totally it is estimated that forty thousand rural households are using SPV mainly for lighting (MoWIE, 2013) and since 2005 45365 SPV technologies are disseminated to provide lighting (MoWIE,2016). Today a 100 MW SPV project auction process has been finished to start its development in Methehara (www.pv.megazine.com>enel-win...). This has significant contribution in addressing the electricity access problem of the country.

2.2 The Energy Sector in Ethiopia

Ethiopia's current installed generation capacity has reached to 4290MW and the current electricity supply has also risen to 3112 GWh/year (www.export.gov; www.mowie.gov.et/energysector). Though it is encouraging, still it needs more exertion of efforts to solve the electricity access problems of the people.

2.2.1 The Current Electrification Status of Ethiopia

Ethiopia like other African countries is suffering from sufficient energy access for its people especially the rural ones. Its energy supply is mainly derived from biomass constituting 92.4 percent causing environmental degradation as forests are cleared out, oil 5 to 7 percent, hydropower 1.6 percent and 6.5 MW solar installations (www.energypedia.info). Conversely, energy demand is increasing from 10 to 14 percent as the economy is getting faster. The main consumers of energy are residential, transport, industry sectors respectively (MoWIE, 2013). With the execution of the first growth and transformation plan (GTP), the country has realized in bringing electricity access to 60 percent of the total population (National Planning Commission, 2016). On the contrary, Taina *et al.*, (2016) showed that Ethiopia's electric consumption is 51 kwh/annum, 17 percent electrification rate and 68.7 million people are without electric access. Though differences in numbers from one source to another, one can look at there is a significant number of people who is requiring electric access. Hence, a lot of efforts need to be exerted to connect the population that is sitting without electricity access. According to MoWIE (2013), of these the majority are those living in the rural settings. Installing and utilizing SPV technologies can have wider merit to such kind of places.

2.2.2 Off Grid Potentials for Rural Electrification in Ethiopia

Due to remoteness of settlements from the existing grid, low electricity demand with prominent evening peaks, low population density and difficult terrain, grid extension is financially unviable and practically infeasible (Tania *et al.,*2016). Off grid extension can be best option for such kinds of cases to address the energy security of remote and sparsely populated people (Mohanty *et al.*,2016). It is suitable for providing the electric needs of individual households living in remote areas that are estimated to be 70 million people in Ethiopia (Tania *et al.,* 2016). This could be achieved using different energy sources, but, SPV like solar lanterns and solar home systems that deliver basic applications like lighting, mobile charging, running audio-visual equipment, refrigeration could be best options (Mohanty *et al.*,2016).

2.3 Solar PV system

The term photovoltaic has two parts: photo, derived from Greek word meaning light, and volt, relating to the electricity pioneer Alessandro Volta. So, photovoltaics could literally be translated as light- electricity. That is what photovoltaic materials and devices do – they convert light energy to electrical energy (photoelectric effect). Since the last 50 years, SPV has shown more advancements and improvements (www.nrel.gov; www.renewableenergy.com). Efficiency and application are some of the major milestone accomplishments, achievements and betterments done so far. While at the early infant stage, the PV's was delivering an efficiency of only 4 percent, that is the capability to convert solar energy in to electricity. But, nowadays, the efficiency has shown great betterments that reached to 14-25 percent as compared to other renewables (www. en.wikipedia.org/wiki/solar_cell_efficiency). Its application area has been diversified from powering wrist watch to lighting, cooling, heating, being fuel for vehicles and other many applications.

2.3.1 Types of Solar PV

The principal classifications are grid connected or utility interactive systems, stand alone or off grid systems and hybrid systems (EPIA, 2006). Of these systems, the off-grid type can address the energy access problems of remote rural areas (Mohanty *et al.,* 2016). Photovoltaic systems can be designed to provide DC and/ or AC power service, can operate interconnected with or independent of the utility grid, and can be connected with other energy sources and energy storage systems.

2.3.2 Components of Solar PV

A complete PV system delivers electricity to end users when it constitutes PV cell/module/array and balance of system(BOS) in combination. BOS components may also include storage battery, charge controller, inverter, a variety of cables, switches, junction boxes and other small items. They are very important for full functioning of the system. If part of it is not fulfilled, the whole system ceases to deliver electricity to the ultimate user. Furthermore, above 40 to 50 percent of the total cost is also incurred in this component to get electricity. Failures of installation occur most likely in this component than the PV modules (Foley, 1995).

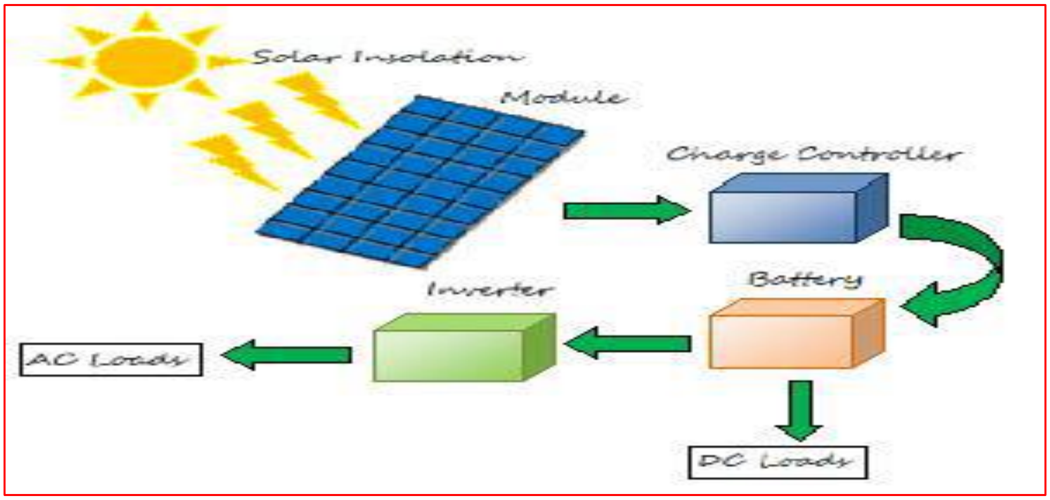


Figure 2.1 Components of SPV Technology

PV modules are one of the main constituent of a SPV system and it is considered as the heart of photovoltaic system. Solar cells are wired together to from modules (Roos, 2009). Modules in turn wired together to from an array. This extension of cell to modules and again to array is done to get more power produced from an array than a single cell. A variety of materials can be used to produce cells. Silicon is the most abundant material which is used to produce the three kinds of cells crystalline, polycrystalline and amorphous. The PV cell coverts sunlight instantly to DC electric power and when supplemented with inverters it also produces AC electric power (Foley,1995).

Inverters are the other component of BOS of a PV system. As there are no conversion efficiency losses, photovoltaic systems work more efficiently on DC loads. However, for certain applications or AC loads can be operated with solar electricity using inverter. It is an electronic component that converts DC power generated by solar PV in to AC. In a typical PV system, it is placed before loads and after batteries (Deambi, 2015). Battery is another BOS component of a PV system that stores energy when there is an excess coming in and distribute it back out when there is demand. Solar PV panels continues to recharge batteries each day to maintain battery charge.

Another basic component is charge controller, as its name indicates, it is a device that controls the amount of charging flowing in and out of battery (Mayfield, 2010). It is placed between the PV module and the battery. Thus, it prevents battery from overcharging and it prolongs the battery life of PV system. On the contrary, absence of this device may shorten battery life and decrease load availability (Deambi, 2015; www.solardirect.com/pv/systems/systems/htm).

2.3.3 Pros and cons of SPV

2.3.3.1 Pros of SPV

Photovoltaic systems can be an ideal solution for covering basic energy needs of contemporary and next generation societies. PV systems can facilitate a sustainable energy mix which is friendly to the environment by utilization of their significant advantages. SPV has tremendous merits if properly utilized by consumers. Firstly, it provides clean and green energy – as there is no GHG emissions. Secondly, supplied by nature – it is free and abundant, available where there is sunlight – promising energy source. Thirdly, cost of SPV is declining at a very alarming rate - currently reached to 0.7US$/watt. Fourthly, PV's produce electricity directly, operation and maintenance costs are assumed to be low (Luque and Hegedus, 2011). Fifthly, PV's have no moving parts – less breakages. Lastly, PV's are also silent – no noise pollution at all easy to install on rooftops or ground without any interference to residential life style (EPIA, 2006; www.renewableenergyworld.com).

2.3.3.2 Cons of SPV

Though all those potential merits, SPV have the following demerits: intermittency problem – at night, cloudy days or rainy days which reduces the power to be obtained, it requires additional equipment like battery, charge controller, inverter – increasing investment costs, requiring more land area for installation of PV's when done on the ground and relatively low efficiency reaching from14-25 percent as compared to other renewables.

In general, photovoltaic system can offer an arrangement of benefits and constitute an important area of technological application for the exploitation and use of renewable energy sources (Solar Power). Consequently, further technological progress and continuous financial support will play a crucial role for accelerating the adoption of SPV systems (www.renewableenergyworld.com).

2.3.4 How Does a SPV Works?

The operation of a basic photovoltaic cell, also called a solar cell – are made of the same kind of semiconductor materials- a, material that acts as electric insulator, such as silicon. For solar cells, a thin semiconductor wafer is especially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current – that is electricity. This electricity can then be used to power a load, such as light or a tool (www.science.nasa.gov/science-news/science-at-nasa/2002/solarcells).

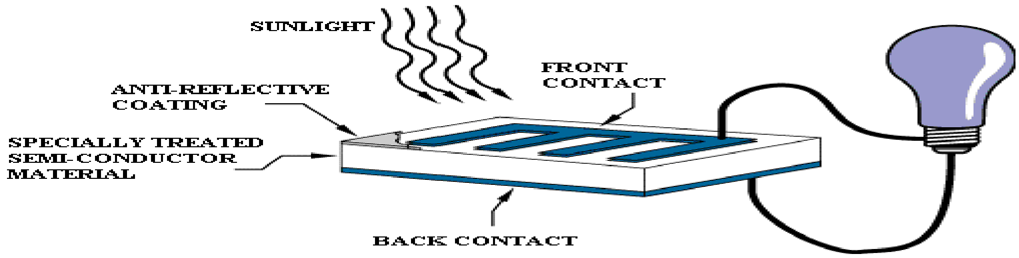


Figure 2.2 Diagram that shows how a SPV works

The components that make up the PV system can be assembled in to a variety of ways depending on the intended use or application. Lighting is one of the areas of application. Lighting systems are generally classified in to two as indoor and outdoor. Indoor lighting is further classified in to two as portable and fixed. Portable lighting system mainly include solar lantern whereas fixed system constitutes solar home systems. To get light, the PV's are assembled either in to solar lanterns or solar home systems. Solar lantern is a portable lighting device, that consists of solar module, battery, lamp, and electronics. The battery, lamp and other electronics are in a suitable housing made of metal, plastic, or fiber glass. The solar lantern is suitable for indoor or outdoor lighting and covers 360^0. The solar module converts incident sunlight to useful electricity. A solar home system offers convenient level of illumination in one or two rooms of a house in addition the system can run a small DC fan or DC television along with a CFL. The other component, solar home system includes electronics, module mounting hardware, battery box, interconnected wires, cable sand (Deambi, 2015).

2.4 Description of solar home system and solar lantern technologies

2.4.1 Solar Home System

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

A SHS typically includes one or more PV modules consisting of solar cells, a charge controller which distributes power and protects the batteries and appliances from damage and at least one battery to store energy for use when the sun is not shining.

During daylight the battery is charged. The stored energy can be used for generating light and running a television or radio during the evening. When the battery is fully charged, the regulator disconnects the module to prevent the battery from becoming damaged. This moment is called High Voltage Disconnect (HVD). Below a certain level of discharge the battery can also be damaged. Therefore, the regulator disconnects the load before the battery is completely drained. This moment is called Low Voltage Disconnect (LVD).

SHS contribute to the improvement of standard of living by reducing and improving the health as they replace kerosene, provide lighting for home study, giving the possibility of working at the night and facilitating access to information and communication (such as radio, television,etc.) (Kabir *et al*.,2017).

SHS can also play an important role in reducing GHG emissions as there is reduced carbon foot print and no direct emission of CO_2 unlike that of fossil fuels such as kerosene (Kabir *et al.*,2017).

2.4.2 Solar Lantern

A solar lamp also known as solar light or solar lantern, is a lighting system composed of an LED lamp, solar panels, battery, charge controller and there may also be an inverter. The lamp operates on electricity from batteries, charged through the use of solar photovoltaic panel. (www. en.wikipedia.org/wiki/Solar_lamp).

Solar-powered household lighting can replace other light sources like candles or kerosene lamps. Solar lamps have a lower operating cost than kerosene lamps because renewable energy from the sun is free, unlike fuel. In addition, solar lamps produce no indoor air pollution unlike kerosene lamps. However, solar lamps generally have a higher initial cost, and are weather dependent.

Solar lamps for use in rural situations often have the capability of providing a supply of electricity for other devices, such as for charging cell phones.

Therefore, in this study data related to these two technologies were considered for analysis to reach on the results.

2.5 Market Challenges of SPV in Ethiopia

Ethiopia had a promising off grid SPV market potential of about 52.3 MW and an estimated financial value of 500 million € in 2009 (Tolessa,2011) and on the other source it is indicated that there was a market of 244 MW with financial value of 3043 million € (Breyer *et al.,* 2009).

Though all these good opportunities, the market was full of problems. Some of the challenges of SPV that are preventing the off-grid people from getting the benefits of these technologies are: the technologies have no standard. Customers simply buy those technologies that were available in the market. This after a while, built no trust for consumers to buy products again and again. Another one is related to cost of the technology. Cost was not fixed based on logical economic principles. Rather sellers set out prices as per their desire to get exaggerated profit. Since the products are imported, there are no too much spare parts available as needed as possible by the customers. Hence, this made customers to discourage on buying and using the technology as fast as possible. As a result, these challenges made great contribution to the least performance and utilization of SPV in the country at large (www.energypedia.info).

2.6 Solar PV as an Energy Source to Rural Households

Solar PV has tremendous merits being energy source to rural people by providing lighting, mobile charging, running audio visual equipment, refrigeration and water pumping, street lighting (ISEI, 2012). In the rural areas where electricity is absent, people use kerosene wick lamps, hurricane wick lamps, dry cell batteries and candles to get light in the nightfall. All these sources are expensive, environmentally unfriendly and pollute the environment by emitting GHG. In Ethiopia it is estimated that over 235 million liters (or 180,000 tons) of kerosene are used for lighting purpose and when the cost is calculated, the retail price of this energy is over US$ 245 million. On the other hand, the amount of dry cell batteries used and discarded annually by the rural households is estimated at 278 million units (or 25,000 tons). This shows that much amount money is eroded from households to get light from these fossil fuel sources. The amount of carbon dioxide emitted from the use of kerosene for light purpose is 580,000 tons. Significant amount of hazardous heavy metals and chemicals escape in to the environment from unsafely disposed dry cell batteries by rural households (Ethiopia Market Intelligence, 2013). Reliable source to substitute these fossil fuels is solar PV which provides higher standard brightest light coming from renewable source- sun (Foley,1995).

SPV are very useful in charging growing number of cell phones in rural communities which ultimately enhances the communication patterns. According to Ethiopia Market Intelligence (2013), US$ 70 million is expended annually by rural households for mobile charging.

Water in rural areas is needed for either drinking and keeping sanitation or irrigating agricultural fields to enhance productivity. In this regard, SPV provides an inexpensive and reliable solution to ensure the supply of indispensable water (Foley,1995; Schützeichel, 2012).

Moreover, going out of the house at night is also very dangerous as it may lead to either theft or conflict with wild animals. Due to such reasons, only some people are moving on roads and the paths are only sparsely illuminated by battery operated torches. SPV offer safety street lights and enable a more varied communal life in the evening too (Schützeichel, 2012).

2.6.1 Rural Household Energy Sources for Lighting

In rural area that accounted to only 4.9 percent of the country's household is connected to electricity from the grid (MoWIE,2013). The rest rural household depend on different energy sources for getting light. The first source being imported dry cells from abroad. This source exceeds the grid connected households by much more accounting to 16 percent (MoWIE, 2013). Though this source of energy is solving the light problem of the rural people, it has economic and environmental costs. Foreign currency expenditure increment to the former and environmental pollution costs to the latter respectively are the major disadvantages.

According to MoWIE (2016), since 2005 a total of 45,365 SPV technologies are disseminated to provide lighting energy service mainly for off grid rural people. This is another second main source of energy being under use in the rural settings of the country. This is a clean and health protective technology that should be expanded to a wider extent.

Stand-alone generator sets are also the other means of lighting in the rural setting though their numbers are not clearly known.

Imported kerosene is the other source of lighting in rural areas. According to Douglas *et al.*, (2016), 9 out of 10 people uses kerosene as their primary source of light and the total amount of kerosene used per month is 2 liters. Kerosene is also a polluting means of lighting as well as it gives insufficient light.

2.6.2 Factors Related to Adoption of SPV by Rural Households

There are many factors that have direct and indirect effect to the adoption of SPV by rural households. Income, educational level, land holding size, price of PV could be mentioned as a few (Khnadker *et al.,* 2014). As one's income is going up from certain level to another, the probability of adopting SPV increases. Similarly, as one's educational level goes up from lower level to a higher, the probability of adopting SPV also increases. The same is also true for land holding size (ibid). Conversely, as the price of SPV increases that is investment of high up-front cost to purchase the PV decreases the probability of adopting SPV. This is of practical in most developing countries, Asia and Sub Sahara African Countries including Ethiopia (Karakaya and

Sriwannawit, 2015). Quality of the solar PV product is another crucial factor that affects the adoption of the technology. Delivering low performance of the products below the standard and expectation of customers is explained regarding the quality of the product. It may be extended that good quality can be seen with having ability to give more bright light, cone of light (large radiation) and long life of the product (Müggenburg *et al.*, 2012). In Ethiopia, for instance, there is a growing skepticism for products manufactured in Asia, especially those from China by customers. Customers developed mistrust for those SPV products for the products are damaged, and they are giving bad quality services. Hence, customers prefer purchasing quality products incurring higher prices to buying those China products with low prices (Müggenburg *et al.*, 2012; Karakaya and Sriwannawit, 2015).

2.7 Challenges and Opportunities of Solar PV Technology in Rural Households

Economic, technical and institutional factors are some of the challenges that are attributed to SPV technology. High upfront cost to purchase the PV module with its balance of systems (BOS) such as batteries, inverters, cables, junction boxes etc., easy and consistent form of financing to enable users buy and use with no difficulty are some of the issues that explain the economic factors. Similarly, according to Schäfer (2010), the most challenging factors that contribute to low utilization of SPV technology in the rural settings are high investment cost and low performance. High initial investment cost lumpsum payments for SPV made the rural community to refuse and not to use the technology although the rural community's awareness on the pros of the technologies is increasing from time to time. According to Solar Plaza (2017), to overcome this the Development Bank of Ethiopia (DBE) in partnership with International Development Association (IDA), is providing working capital loans to private sector household solar providers, as well as micro-financing to households for the purchase of solar lanterns and solar home systems(SHS).

Low efficiency performance of PV modules reaching from 14-22 percent, poor installation of the PV components by technicians are also some of the points that goes to the technical factors. Performance reduction of the already installed PV technologies bring bad outlook to those prospective clients leading to a small and reduced utilization of the technology. This poor performance arises due to inadequate installation of the PV components by technicians as per the desired quality level that is the use of wrong size of cables and wrong wire run length which they altogether contribute to undesired system voltage drop and energy loss.

Failure to provide training and capacity building to the technicians is directly attached to institutional factor (Foley,1995). Provision of insufficient technical awareness by government or other institutions to the end users on how to maintain and sustainably use of technologies is the other vital aspect that could be seen in link to institutions.

Regarding SPV distribution, there are only small distributors mainly concentrating on large cities and towns (TERI, 2014) which are not reachable to the rural communities. Besides this, there are no sufficient financial institutions that provide loan for the purchase of SPV for those financially incapable rural communities.

Installation of SPV technologies throughout the rural settings of the country has tremendous opportunities in bringing new jobs to youths who can install and maintain SPV technologies. For instance, with the help of Solar Energy Foundation, 64 youths have successfully completed and graduated from Rema school to install and maintain SPV technologies (Schützeichel, 2012).

Such kinds of initiatives stimulate SPV industry to boost at an alarming rate (Johansson *et al.*, 2012). In addition, it can create opportunities to many suppliers, retailers of SPV.

Although the electrification rate in Ethiopia is not greater than 26 percent showing an ample amount of the rural population without electricity connection, this is a great opportunity to the development of off grid solar solutions (Solar Plaza, 2017).

The technologies that are available like solar lanterns and solar home systems are user friendly, easier to operate if necessary awareness on how to operate and use is built.

2.8 Theoretical Framework

In general, acceptance is defined as “an antagonism to the term refusal and means the positive decision to use an innovation. Besides, acceptance has been viewed as a function of user involvement in systems development.

A number of models and frameworks have been developed to explain the user adoption of new technologies and these models introduce factors that can affect the user acceptance such as Technology Acceptance Model (TAM) and Diffusion of Innovation Theory (DOI).

2.8.1 Technology Acceptance Model (TAM).

TAM explains the motivation of users by three factors; perceived usefulness, perceived ease of use, and attitude toward use. Therefore, two chief beliefs like perceived usefulness and ease of use have considerable impact on attitude of the user. These can be determined as an unfavorableness and favorableness toward the system. Sometimes, other factors known as external variables (user training, system characteristics, user participation in design and the implementation process nature) are considered in TAM model (Lin *et al*.,2011).

2.8.2 Diffusion of Innovations Theory DOI)

DOI model examines a diversity of innovations by introducing four factors (which are the time, channels' communication, innovation or social system) which influence the spread of a new idea. DOI not only has been used at both organizational and individual levels but also, offers a theoretical foundation to discuss adoption at a global level. DOI model integrates three major components: adopter characteristics, characteristics of an innovation, and innovation decision process. In innovation decision step, five steps namely confirmation, knowledge, implementation, decision, and persuasion have taken place through a series of communication channels among the members of a similar social system over a period of time. In characteristics of an innovation step, five main constructs; relative advantage, compatibility, complexity, trialability, and observability have been proposed as effective factors on any innovation acceptance.

Relative Advantage: the degree to which an innovation is better than the idea, program or product it replaces.

Compatibility: how consistent the innovation is with the values, experiences and needs of the potential users.

Complexity: how the innovation is difficult to use.

Tribality: the extent to which the innovation is tested before a commitment to use.

Observability: the extent to which the innovation provides tangible results.

In adopter characteristics step, five categories; early adopters, innovators, laggards, late majority, and early majority are defined (Sila,2015). In conclusion, DOI more focus on the system characteristics, organizational attributes and environmental aspects.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

Due to high SPV adoption rate, more access to get enumerators and proximity to the town Debre Markos, this study was conducted in Gozamin Woreda of East Gojjam Zone of Amhara National Regional State, Ethiopia. According to the Woreda Water,Irrigation and Energy Office Annual Report (2016), Gozamin is located at a geographical location of 10^0 1´ 46 ´´and 10^0 35´ 12´´ N latitudes and 37^0 23´ 45´´ and 37^0 55´ 52´´ E longitudes and 300 kilometers far from the capital Addis Ababa. It is bordered by Sinan in the North, Abay River in the South, Debre Elias in the West, Aneded in the East, Machakel in the North-West and Basoliben in the South-East direction. According to Amhara National Regional State Bureau of Finance and Economic Development (2013), the total population of Gozamin Woreda is 145,023. Of these, males comprise 71,339 while the rest 73,685 are females. It takes fifth place in terms of being populous from East Gojjam Zone. The woreda consists of 20 rural and 5 urban with a total of 25 kebeles and a total area of 1218.06 square kilometer having a population density of 119.06. The urban 5 kebeles are connected to grid while the rest 20 rural are not. It has an altitudinal difference of 1200 – 3510 meters above sea level. Based on these altitudinal differences, Gozamin has Dega, Weyna-dega and Kolla agro climatic zones. Annual average rainfall is 1628 mm and 25^{O}C and 11^{O}C are the average maximum and minimum temperatures respectively.According to RETScreen software climate database of National Aeronautics and Space Administration, the woreda has an average daily solar radiation of 5.99kwh/m^2. This is of a great potential to adopt SPV in the rural parts of the woreda.

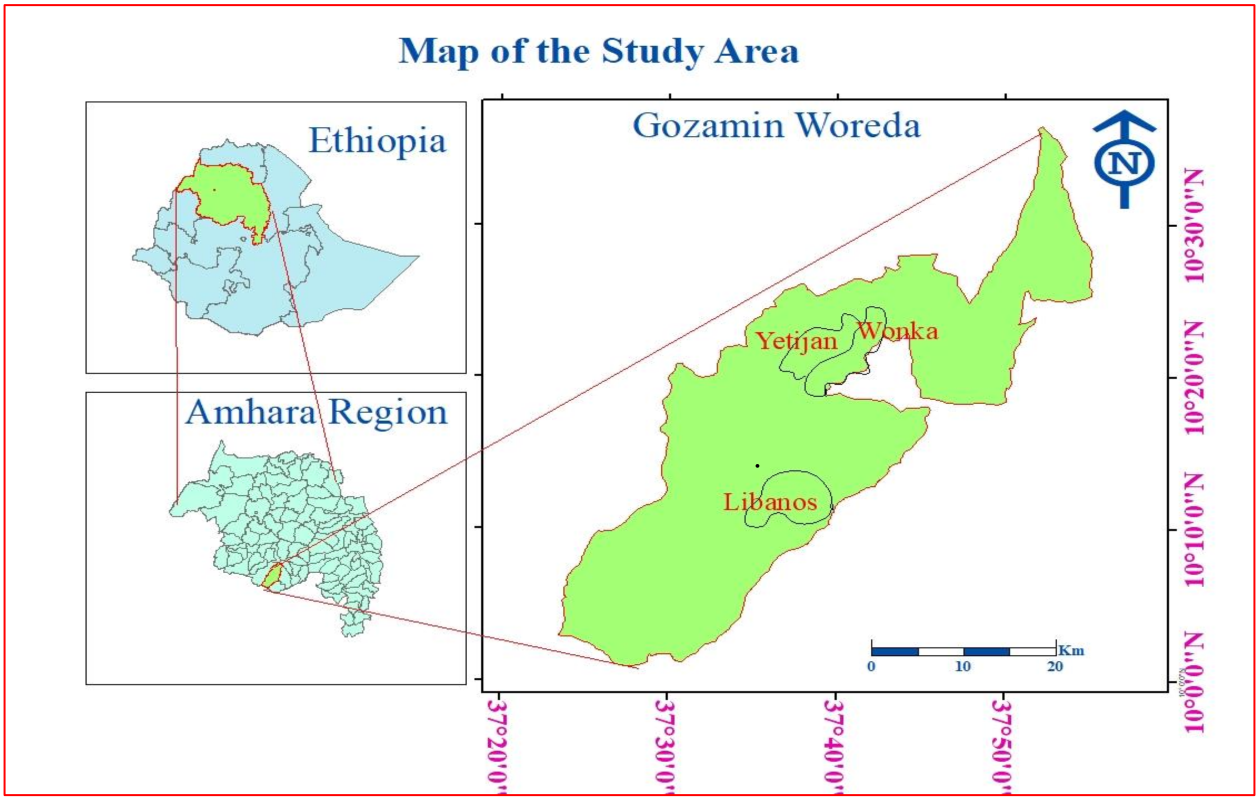


Figure 3.1 Map of the Study Area

3.2 Methodology

3.2.1 Sampling Design

Both probability and non-probability sampling designs were used in this study. Probability sampling or chance sampling give elements equal probability of being included in the sample size (Wilson, 2014). Of the probability sampling designs, simple random sampling and stratified sampling techniques were used in this study since these methods give elements equal chance of being selected in the sample and result in good representation of samples.

In building up of the sampling design the universe, sampling unit, source list, and sample size must be given due attention as well as should be known (Kothari, 2004). According to this direction, all the stated parameters were identified properly. Hence, the universe or population of the study area were residents of three rural kebeles (Wonka, Libanos, and Yetijan) of Gozamin woreda which were finite. Decision has been made that the sampling units were the geographic place, Gozamin Woreda and households living in the rural kebeles. Hence, three rural kebeles (Wonka, Libanos and Yetijan) from the 20 rural kebeles were selected purposively based on higher number of SPV adopter households, cooperativeness of the study population and proximity to the town Debre Markos. The households of the three rural kebeles comprise the sampling frame/ source list. The list was taken from each kebele administration office.

Table 3.1 Household Size of Sample kebeles

Kebele	Male	Female	Total
Wonka	505	114	619
Libanos	1175	197	1372
Yetijan	891	81	972
Total	2571	392	2963

Source: Kebeles' administration offices, 2016 annual report

Next, from the source list sample size was determined usingYemane's formula:

$$n = \frac{N}{1+N(e)2} \quad \text{..} \quad (3.1)$$

because the population is definite,

Where: n = the sample size,

N = the population and

e = the level of precision as cited in (Wilson, 2014). Based on this formula having a precision level of 7 percent, it can be computed as:

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

$$n = \frac{2963}{1 + 2963(0.07)2}$$

$$\underline{\underline{n = 190.93}}$$

was found but for simplicity a total of 190 samples were taken. After having the total sample size, the following step was to make stratification of users/adopters and non-users/non-adopters of SPV technology based on their utilization or otherwise.

Table 3.2 Stratification of Population

Kebele	User			Non- user			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Wonka	125	29	154	380	85	465	505	114	619
Libanos	420	65	485	755	132	887	1175	197	1372
Yetijan	241	43	284	650	38	688	891	81	972
Total	786	137	923	1785	255	2040	2571	392	2963

Source: Own survey, 2018

Selection of items from the two strata was the next step. This was done through proportional allocation method. That is, if Pi represents the proportion of population included in stratum i and n represents the total sample size, the number of elements selected from stratum i according to Kothari (2004) is:

i= n. Pi ……………………………………………………………………………………(3.2)

Hence, adopters of SPV were 923 and their counter parts were 2040. The calculated total sample size was 190, then using the proportional allocation method the sample size from each stratum was:

For adopter strata with N_1= 923, we have P_1 = 923/2963 and

Hence, n_1 = n. P_1

n_1= 190. 923/2963 = 59.18 ≅ 60.

Similarly, for non-adopter strata N_2= 2040, we have P_2 = 2040/2963 and

Hence, n_2 = n. P_2= 190. 2040/2963 = 130.81 ≅130. Thus, using proportional allocation, the sample sizes for the two strata were 60 and 130 respectively which is in proportion to the sizes of the strata viz., 923:2040. This method was considered the most efficient and an optimal design because the cost of selecting an item was equal for each stratum. Each element of the sample from the two strata were selected using Excel's rand function.

Table 3.3 Randomly Selected Sample households

Kebele	User			Non- user			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Wonka	9	2	11	24	3	27	33	5	38
Libanos	26	5	31	56	8	64	82	13	95
Yetijan	15	3	18	34	5	39	49	8	57
Total	50	10	60	114	16	130	164	26	190

Source: Own survey, 2018

3.2.2 Data collection methods

Both quantitative and qualitative approaches were used to collect data from the sample households. Primary data from household survey, field observation, key informant interview and focus group discussion were collected to achieve the desired goals of the study.

Household survey with structured questionnaire consisting of multiple choice, yes or no, close end, rank type questions were asked starting from 07 to 21/06/2010 E.C. Data related to demographic and socio-economic characters of households like sex, age, income level, education level, etc. were collected. Data was collected with 12 enumerators after they have been recruited based on educational level and past exposure to interview. These enumerators were given two days of training on the objectives, content of the questionnaire and method of data collection. Preliminary survey was also conducted with 15 randomly taken households from the three kebeles and based on this survey the necessary corrections were made on the questionnaire for the actual survey. Household survey was chosen as it is suitable to collect information from individual households and requires less cost, relatively less time and it can cover wide geographical location (Kothari, 2004).

Field observation was another method employed to collect data concerning the functionality of SPV technologies and it was important as it allows to eliminate subjective bias of respondents as the researcher directly observes physically what was going on the ground and it was independent of the respondent’s willingness. Using this method, the already installed SPV technologies were observed if they were free from shade, dust, whether they were installed at the appropriate angle or not, and whether they were functioning or not by switching the SPV bulb.

Key informant is a person who is knowledgeable about SPV technology. Key informant interview involves interviewing people who have particularly informed perspectives on an aspect of SPV technology. During village or farm walk on the kebeles, five farmers were randomly selected to give the name of fifteen key informant as per the definition mentioned. In this way 15 key informant from each kebele was identified and ranked based on their appearance. Ten to Thirteen people from each kebele with a total of 34 respondents, 29 males and 5 females constituting kebele leaders, women, kebele experts and youths were selected for their first-hand knowledge about SPV technology. In addition, two SPV providers from Debre Markos town and three experts from woreda office of water and energy were interviewed on SPV technology challenges and opportunities. Information from key informant was used to develop questionnaire for formal survey.

Finally, focus group discussion was held from the three kebeles constituting a total of 29 members, 26 males and 3 female discussants. Duration of discussion is on average 1.2 hours. The members of group discussants were from elder, youth, women, political leaders of the kebele. The central point of discussion was on the challenges, constraints and opportunities of SPV in general and setting of criteria's that can be used to classify household heads as wealthier, medium and poor, and quality house from the poor, etc. According to Kumar (2011), such kinds of discussions raise diversified opinions and ideas as well as it requires less time and cost to complete the task. This was realized in our group discussions too. It is believed to be powerful in eliminating exaggerated opinions that some individuals might express, as participants were checked by each other.

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.

3.3 Data Analysis

The data after collection, was processed and analyzed to meet the objectives of the study. Processing implies editing, coding, classification and tabulation. In data edition, the collected data was detected for errors and omissions and the necessary corrections were made. For instance, if a sample household omits two questions without answering, the total respondents for these two specific questions was reduced by two. It was done to facilitate coding and tabulation. Coding on the other hand refers to the process of assigning numerals or other symbols to answers that are put in to a limited number of categories or classes. Large volume of data was reduced in to homogenous groups in a process called classification. Summarizing raw data in compact form in to columns and rows is tabulation (Kothari, 2004).

For the first and third objective of this study descriptive analysis such as frequencies, percentages crosstabs were used to analyze the different demographic and socioeconomic characteristics of households such as age, education level, income level, etc.

For objective number two binary logistic regression was employed as the study has binary dependent variable utilization of SPV (0/1, adopter/non-adopter) if the respondent uses/adopts

SPV technology it is 1 and 0 otherwise. The dependent variable was presumed to be a function of 13 predictor variables.

As already noted a structured questionnaire was administered to 190 sample households. It allowed collecting data on socio economic, demographic and institutional factors of the household's. Results about the effect of these factors on household's SPV adoption status was analyzed using Statistical Packages for Social Science, SPSS 16.0.

3.4 Definition of Variables and Working Hypothesis

3.4.1 The Dependent Variable of the Model

In this study, utilization was considered as the existence of installed SPV technologies in the house of household head. Utilization of SPV technologies for this study therefore refers to the decision made by individual household to install and maintain the common SPV technologies. The minimum SPV technology which assumed to be included in this utilization definition was 1 regardless of the kind and size of the technology. However, the extent of utilization of SPV technologies could vary among users. Some may use it for longer and others for shorter period of time. Therefore, the variable takes 1 if the household head installed and maintained at least one technology.

3.4.2 The Independent Variable of the Model

Based on literature reviewed and authors experience the following independent variables were included.

Outlook of Price of SPV Technologies by Respondents

Price may refer to the initial cost (in ETB) to purchase SPV technologies. The price of SPV is assumed to affect SPV utilization negatively. That is, as the price is increasing from certain level to a higher, households resist to adopt these technologies since they cannot afford the cost of the technologies (Admasu, 2010). Moreover, as the level of price of SPV goes from a certain level to a higher, it is likely that utilization of SPV dwindles down. This can be explained by the fact that as price increases demand of households to purchase SPV declines and become reluctant to adopt SPV technology. Likewise, high cost and inability to finance SPV hampers households from utilizing SPV (Hemmen, 2011; Eronini, 2014). A value of 1 is given for those households who have negative perception of price on SPV and 2 for whom who have positive perception.

Awareness Creations Made on SPV Technologies to Respondents

Awareness may refer to the activity made by government agencies to make households conscious about the benefits of SPV. It is expected that several awareness creations made to households on SPV concerning where it is available, type of technology, the prices, the significant advantages, etc. is likely to affect or influence utilization positively because awareness could make human beings more informed and conscious on the advantages and benefits of utilizing SPV. As there is an enhanced awareness on SPV, household's utilization remarkedly increases (Keriri, 2013). Likewise, lack of awareness is identified as a key barrier for utilization in developing countries (Qureshi *et al.*, 2017). A value of 1 is given for those who responded yes and 2 for no.

Income Level of Respondents

Income could be defined as the amount of money (in ETB) that a household obtains from different activities on average per year from 2016 to 2017.It is likely and expected that as the household's income level rises, households decide to utilize SPV due to the fact that, households are willing to pay and afford the price asked to buy SPV (Hemmen, 2011; Keriri, 2013; Jayaweera *et al.*, 2018) and household's desire a shift from traditional to modern energy sources (Leach, 1992).

Availability of SPV Technologies

As there is more access to SPV technologies, it is expected that households become courageous to utilize SPV. It also facilitates households to go to SPV and has positive influence in the diffusion of the technology (Qureshi *et al.*, 2017). This can be explained by the fact that as there is more availability of different kinds of SPV, provision of SPV to be bought by potential households based on their earning capacity enhances. A value of 1 is given for those who replied yes and 2 for no.

Educational Background of Respondents

It refers to the educational status of the household head. This is a proxy for the capacity of the head of a household to access and understand the technologies. Educated households can understand, analyze and interpret the privileges of new technologies than uneducated households. Some studies found a positive relationship between education and decision to install

SPV technologies (Jayaweera *et al.*, 2018). This is because education gotten from professionals is influential in reducing skepticism and encouraging households to proceed from intention to action as such it plays a vital role in utilizing SPV. Therefore, literate households were expected to be more likely to utilize SPV technologies. A value of 1 is given for those who have skill of above reading and writing and 2 for those who cannot.

Age of Respondents

The number of years of household since birth at the time of survey can be referred to age. Age of respondents is assumed to have a negative relationship with utilization of SPV. As the age of households increases, adoption decision of SPV decreases. This may be due to consideration of the assumption that older people have more experience that helps them to adopt new technologies. However, because of risk averting nature older age households are more conservative than young ones to adopt SPV technologies (Mukami, 2016).

Perception of Quality of SPV Technologies

Quality of SPV may refer to the ability of SPV to give the desired and standardized services (that is light) a bit for a longer period up to 25 to 40 years (Hemmen,2011). Perception is measured when the household has positive attitude given 1 and 2 for negative perception. When there is a higher quality of SPV, it is likely that utilization of SPV increases (Ugulu, 2016). This may be due to the fact that as the quality of SPV enhances, the technology functions properly and reduces maintenance cost on one hand and spare part (system component) requirement on the other hand.

House Type of Respondents

House type may refer to a house made of metal or thatch rooftop with a size of more or less than fifty square meters. It is expected that a metal rooftop with wider area house type owner is expected to utilize SPV than thatched rooftop and narrower size house type. A value of 1 is allocated for metal rooftop and 2 for thatched rooftop house type. In various studies, it is considered as a sign for utilization of SPV technology. That is, as the house of households was getting metal rooftop and a size of greater than 50 square meters, use of SPV is expected to increase (Ugulu, 2016; Jayaweera *et al.*, 2018).

Sufficiency of Providers of SPV

Providers of SPV is defined as those individuals who sells only SPV products in their shop, but not delivering installation and maintenance service. The presence of sufficient SPV providers is assumed to affect utilization of SPV positively. That is, as there are more number of SPV providers, utilization of SPV increases. This may be due to the fact that presence of providers in many places offers options in price and quality of SPV for households. Consequently, as the options in quality and price is diversified, more households could be attracted to utilize SPV.

Agricultural Land Size

Area of land used for agricultural practices refers to the agricultural land size. It is measured in hectare possessed by households. Land holding is another indicator for the positive utilization of SPV. That is, as the land holding size increases, utilization of SPV also enhances (Khandker *et al*, 2014). This may be due to the fact that as the land holding increases, production of different crops also increases leading to an enhanced revenue. Eventually, when the revenue of households increases, they develop interest to utilize SPV.

Wealth Status of Respondents

Being owner of many animals (oxen, cow, sheep, goat, etc.), and technologies (mobile phone and water pump, etc.) represents better off household given a value of 1 and a value of 2 for the contrary of better off. As the household was wealthier enough, it was likely that uptake of SPV enhances (Khandker *et al*, 2014). This can be explained by the fact that, becoming wealthier is to have higher level of overall assets including financial resources. As a result, households could pass strong decision to utilize SPV technologies.

Family size of Respondents

Family size may refer to the number of individuals that are living in the house of the household's head. It is expected that, as the number of individuals increases in a house, utilization of SPV also increases. This could be due to higher demand for light at the night fall especially by students for studying their education. This demand in turn affect the utilization of SPV positively.

Active Labor of Respondents

Active labor may refer to the number of household member who is at least enrolled at secondary school or hired at different levels. It is likely that as this member increases, utilization of SPV is also positive. This is because, as the human capital increases, information, knowledge and revenue are expected to increase. Consequently, pushing the household to adopt SPV technologies. A value of 1 is given for those who have at least one active labor and 2 that do not have at all.

Table 3.4 Definition and Scale of Measurement of Variables Included in the Model

Variable	Variable Code	Type of Variable	Definition and Scale of Measurement	Expected Sign
Utilization of SPV	Utilization	Dummy	1= if the household utilizes SPV and 0= otherwise	
Perception of Quality of SPV	Quality	Dummy	1= if household has negative perception and 2= Positive perception	Positive
Educational Background	Education	Dummy	1= if household is literate (above reading and writing) and 2 = if illiterate	Positive
Outlook of Price of SPV	Price	Dummy	1= if household expectation is cheap and 2= if expensive	Negative
Availability of SPV Technologies	Availability	Dummy	1= if the household responds yes and 2= if no	Positive
Awareness Creations Made	Awareness	Dummy	1= Yes and 2= No	Positive
Sufficiency of SPV Providers	Providers	Dummy	1= if households respond sufficient and 2= if not	Positive

House Type of Respondents	Housequa	Dummy	1= Quality and 2=Poor	Positive
Active Labor of Respondents	Actlab	Dummy	1=Yes and 2=No	Positive
Wealth Status of Respondents	Wealth	Dummy	1= Better-off and 2=Poor	Positive
Income Level of Respondents	Income	Continuous	Amount of ETB earned monthly	Positive
Age of Respondents	Age	Continuous	Number of years HH's lived	Negative
Family Size of Respondents	Famsize	Continuous	Number of individuals that live in the house of HH head	Positive
Agricultural Land Size	Landsize	Continuous	Area of land used for agricultural practices measured in 'timad' 1hectare = 4 'timad'	Positive

3.5 Model Specification

There are several methods to analyze data involving binary outcomes. However, logit and probit models are popular statistical techniques in relation to explanatory variables that are expected to influence the outcome. Hosmer and Lemeshow (2000) has pointed out that the logit model has advantages over the other model to analyze dichotomous dependent variable. Because it is an extremely flexible and easily used function and it lends itself to a meaningful interpretation. Hence, according to Hosmer and Lemeshow (2000), the logistic distribution function is econometrically specified as:

$$Pi= [\frac{1}{1+e^{-z(i)}}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

Where Pi is the probability of deciding to use SPV technologies for the i^{th} household and $Z_{(i)}$ is a function of m explanatory variables $X_{(i)}$ and is expressed as:

$$Zi = \beta 0 + \beta 1 + X1 + \beta 2X2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots . \beta mXm \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . \ldots\ldots . (3.4)$$

Where, β_0 is the intercept and β_i are the slope parameter in the model. The slopes tell how the log odds favor of deciding to use SPV technologies changes by unit. The stimulus index, $Z_{(i)}$, refers to as the logs of the odds ratio in favor of deciding the use of SPV. The odds is defined as, the ratio of probability that a household uses SPV Pi to the probability that he will not (1-Pi).

$$(1- Pi) = [\frac{1}{1+e^{-z(i)}}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

$$\frac{Pi}{1-Pi} = [\frac{1+e^{z(i)}}{1+e^{-z(i)}}] = e^{z(i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

$$\frac{Pi}{1-Pi} = [\frac{1+e^{z(i)}}{1+e^{-z(i)}}] = e^{\beta o} + \sum_{i=1}^{M} \beta i\, Yi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.7)$$

Taking the natural logarithms of the odds ratio of equation (3.7) will result in what is called the logit model as indicated below:

$$ln \frac{Pi}{1-Pi} = \ln [e^{\beta o} + \sum_{i=1}^{M} \beta i\, Yi] + Zi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.8)$$

If the disturbance term U_i is taken in to account, the logit model is specified as:

$Z_i = \beta_0 + \Sigma\, \beta_i X_i + U_i$ ……………………………………………………………(3.9)

Where Z_i = the log odds ratio in favor of use of SPV

β_0 = intercept term

$\beta i =$ parameters to be estimated

$Xi =$ hypothesized determinants

$Ui =$ disturbance term

3.6 Estimation of Multicollinearity

Before running the model, it was necessary to check the existence of multicollinearity problem among continuous and discrete independent variables. Multicollinearity problem arises when at least one of independent variables is in linear combination with the other.

According to Gujarati (1995), there are various indicators of multicollinearity, for this study multicollinearity was checked by using variance inflation factor (VIF) (used to measure the degree of linear relationship) among continuous independent variables and contingency coefficient for discrete independent variables and the formula to compute variance inflation factor (VIF) is: $VIF(Xi) = \frac{1}{1-\mathrm{Ri}^2}$, Where Ri^2 = is the squared multiple correlation coefficient between Xi and other independent variables. SPSS was used to get the value of VIF. The larger the value of VIF, the more will be collinear with the variable Xi. As a rule of thumb, if the VIF of a variable exceeds 10, it is considered that there is high multicollinearity. The value of VIF displayed in appendix 1 and it showed that there is no serious multicollinearity problem in the continuous variables.

Similarly, multicollinearity for discrete explanatory variables were checked using contingency coefficient computed as: $C = \sqrt{\frac{X^2}{N+X^2}}$, Where C = Coefficient of Contingency, X^2= Chi-square random variable and N= Total Sample Size Multicollinearity arises when its value approaches 1 and the table displayed in appendix 2 showed there was no multicollinearity problem among dummy variables. After checkup of these two types of multicollinearity test, the independent variables were inserted in SPSS software to bring out the binary logit output.

4. RESULTS AND DISCUSSION

4.1 Household Characteristics

This section describes and discusses the profile of sampled households in terms of their socioeconomic demographic characteristics including other related institutional factors.

Table 4.1 Characteristics of Households for Continuous Variables

Characteristics	Users (N=60)			Non- users (N=130)			Total (N=190)			t - test
	Mean	Min	Max.	Mean	Min	Max.	Mean	Min	Max.	
Age	37	30	49	51	28	68	46	28	68	0.000***
Income	1174	250	5000	732	200	2800	872	200	5000	0.000***
Family Size	4.93	1	8	4.57	1	8	4.77	1	8	0.089ns
Land Size	1	0.25	1.75	0.75	0	1.75	0.75	0	1.75	0.002***

Source: Own survey, 2018

ns, *** indicates non-significant and *** significant at 1%.

Users appear to be younger than non-users and in comparison, with the mean age for the total sample holding the middle age 30 to 49; The result indicates that users have a higher income on average than non-users which is one and a half larger than the average income of non-users; the results didn’t show a difference between users and non-users in terms of family size. Slight differences in land size holding being users are higher than their counter parts (see table 4.1).

Table 4.2 Characteristics of Households for Dummy Variables

Characteristics	Users (60)		Non-users (130)		Total (190)		χ^2
	No	%	No	%	No	%	
Quality of SPV							
Negative	9	15	22	16.9	31	16.3	0.111(ns)
Positive	51	85	108	83.1	159	83.7	
Education							
Literate	49	81.7	73	56.2	122	64.2	0.001***
Illiterate	11	18.3	57	43.8	68	35.8	
Price							
Cheap	8	13.3	7	5.4	15	7.9	0.059*
Expensive	52	86.7	123	94.6	175	92.1	
Availability							
Yes	27	45	45	34.6	72	37.9	0.170 (ns)
No	33	55	85	65.4	118	62.1	
Awareness							
Yes	15	25	14	10.8	29	15.3	0.011**
No	45	75	146	89.2	161	84.7	
Providers							
Sufficient	31	51.7	26	20	57	30	0.000***
Not	29	48.3	104	80	133	70	

House Type							
Metal rooftop	56	93.3	93	71.5	149	78.4	0.001***
Thatch rooftop	4	6.7	37	28.5	41	21.6	
Active Labor							
Yes	44	73.3	97	74.6	141	74.2	0.851(ns)
No	16	26.7	33	25.4	49	25.8	
Wealth status							
Better off	31	51.7	32	24.6	63	33.2	0.000***
Poor	29	48.3	98	75.4	127	66.8	

Source: Own survey, 2018

ns, *, **, *** denotes non-significant, significant at 0.1%, 0.05% and 0.01 % respectively.

Those significant variables are discussed here under.

House Type of Respondents

Respondents were asked to give an answer whether they were living in a quality (metal roof and more than 50m^2 area) or poor house (thatch/metal roof and less than 50 m^2). 93.3 percent of the users answered that they lived in quality and 6.7 percent in poor house. Whereas, 71.5 percent of non-users group lived in quality and 28.5 percent of the same group lives in poor house (see Table 4.2). This is an indicator factor that boost household heads to utilize SPV technologies as user households in the quality category were larger than the non-users. The chi-square analysis also showed that there was systematic association between quality of house and SPV utilization. That is, as the household is getting quality, utilization of SPV technology enhances.

Educational Background of Households

The educational status of the heads of sample households was compared. Based on the survey result, literates (may not necessarily be related to know how of the technology, rather general education) from the user group exceeds nearly by half than non-users (see table 4.1). This indicates that education was important to utilize SPV technologies. Those with better educational attainment were more likely to utilize SPV technologies than with lower educational attainment.

Outlook of Price of SPV Technologies

The result indicated that the outlook of price of SPV technologies by users (86.7%) and non-users (94.6%) who responded expensive were higher by more than six and seventeen times than who replied cheap respectively. This could be an important factor making household heads able to utilize SPV technologies. The chi-square analysis showed there is systematic association between price of SPV and utilization of SPV. That is, utilization enhances when there is cheap price outlook than expensive.

Awareness Creations Made to Respondents

As indicated in table 4.2, awareness creations made shows smaller to both groups. Because, 75 % of the users replied the absence of awareness than 25% and 89.2% replied the same (no awareness) than 10.8%. But, users who said awareness was made (yes) by government agencies were higher by more than two times from their counter parts, non-users. This indicates that if little effort is done on awareness creation, utilization of SPV increases.

Sufficiency of SPV Technology Providers

The result in table 4.2 indicates that more than two and half of the users (51.7%) agreed that there were sufficient providers of the technology than their counter parts (20%). Hence, this factor could also be taken as another important factor that help households to decide in utilizing SPV technologies. The chi-square analysis also showed that there was systematic association between sufficiency of suppliers and SPV utilization. That is, as the number of providers (SPV product sellers, not delivering installation and maintenance) increases, utilization is assumed to increase.

Wealth Status of Respondents

The result indicated that users (51.7%) appear to be better-off than non-users (24.6%). Because the better-off users are higher by more than two times than non-users. This reveals that larger portion of user group is in better-off category than non-user group. So, this factor could also be taken as an important factor in making decision on utilizing SPV technologies. The chi-square analysis showed that there was systematic relationship between wealth status and utilization of SPV technologies. That is as there are more wealthier households, utilization of the SPV technologies increases.

4.2 Frequency of Users and Functionality of SPV Technologies

Depending up on using of the technologies, 60 of the respondents were users and the rest 130 were non-users of the technologies. This implies that 31.5 and 68.5percent of the respondents were users and non-users of SPV technologies. This result was strongly agreed with keriri (2013) in that out of the total respondents' 33 percent of them were installing and using the SPV technologies. This implies that most of the respondents are not users. Being the presence of awareness problem, having low income level and having no belief in the technology are some of the reasons that justify this finding. Hence, showing the frequency of users.

The technologies distributed and used by users at the time of interview were all functional, that is, 60 of them were giving appropriate service though defects and failure to function was happening during the past five years. Rooftop proper handling is assumed to be the main reason for functionality of the technology. This does not mean that they are giving service without any interruptions and failures throughout the past five years, rather some amount of interruptions and failures due to technical, weather condition and other reasons has happened. This is elucidated by 23.4 percent of the users that SPV fail to function properly once or twice per month respectively. Similar finding was found from Murali *et al.,* (2015) in that due to monsoon reasons SPV fail to function up to three times per month because at the time of monsoon the sun cannot shine as there is heavy cloud and rain may be for prolonged time in a day or weeks. Hence, in the study area the case is strongly similar especially during the summer season. Around 21.7 and 1.7 percent of the adopters responded that the SPV technologies fail to function once and twice per month respectively.

Table 4.3 Monthly Failure of SPV Technologies

Frequency of Failure Per Month	Number	Percent
None	46	76.7
Once	13	21.7
Twice	1	1.7

Source: Own survey, 2018

About 23.3 percent of the households were able to fix problems with their family members. The failures were fixed by 21.7 percent through wiping the module and 1.7 percent with removal of shades from the modules. This clearly shows that most of the SPV technologies were functioning properly and if wisely used it may function up to 25 years and sometimes it goes to 40 years.

Regarding replacement of different parts of SPV, 98.3 percent of the adopters were not replacing any part of SPV and only 1.7 percent responded that they made replacement once to bring the improper functioning to proper use. In addition, none of the respondents was responding no whole new replacements was done when asked if they were making new whole replacements. This implies that if a SPV technology is wisely used, it needs no replacement of different parts of the technology and may last long to about 25 to 40 years.

4.3 Patterns of SPV Technology Use

Users were asked for what purpose do they use SPV technologies and all the users (60) responded that they were using SPV technologies mainly for lighting purpose. Mobile charging was used by 81.6 percent users of SPV technologies besides lighting and 18.4 percent of the respondents used SPV technologies for making petty trades like opening small cafeterias and restaurants in addition to lighting.

Table 4.4 Patterns of SPV Use

Patterns of SPV Use	Number	Percent
Lighting and Mobile charging	49	81.6
Lighting and Petty Trade	11	18.4

Source: Own survey, 2018

As indicated in table (4.4), the major pattern of SPV use is lighting responded by all (60) respondents. This result agreed with Hannah (2011), a study conducted 10 to 14 kilometers far from Nazreth, Ethiopia, in that 89 percent of the respondents were taking advantage to undertake education for their children; furthermore, health and hygiene improvements were gained by 89 percent of respondents because of the presence of light from SPV. About 95.7 percent of the respondents of this study showed that SPV supplements bright light and 82.6 percent of the respondents also strongly agreed with the betterment of their life style. Similar results from Kenya by Mukami (2016) showed that 38 percent of the respondents prefer SPV for lighting though its strength of similarity is less. Lighting as a major pattern could be explained by the fact that women use light in the night for cooking dinner, for strengthening social interactions with neighbors at the sunset using coffee ceremony, reducing or lessening the risk of fatal kerosene lamp accidents and the light is used to be secured from robbers in the nightfall.

Lighting being one of the major patterns of use of SPV technologies, it is obtained from different sources of energy such as kerosene, dry cell batteries and wood before inception of SPV. Kerosene is the main source of light by more than half of the respondents (55 percent). This result was supported with (Gebregiorgis, 2015) at Saharti Samre Woreda of Tigray region in that kerosene was used by 71.1 percent of the respondents for lighting purpose. The possible reason could be due to easily availability of kerosene in the market though its cost is expensive, and more than 66 percent of the respondents responded that their house is 2 to 3 kilometers far from the nearby forest. Thus, unable to collect wood for light purpose.

The amount of utilization of these energy sources are more than 0.5 liters per week by nearly half (48.2 percent) of the respondents, and more than 2 pairs of dry cell batteries per month by 76.9 percent of respondents. About half drop out or significant reduction of using these sources of energy are obtained after inception of SPV as noted during the group discussion time. This result complied with a study of Wijayatunga and Attalage (2005) in that 103 out of 112 households dropped their kerosene expenditure to zero. This finding is also supported with a study conducted in India by Murali *et al.*, (2015) in that SHS user households dropped their kerosene utilization from 4 to 3 litres per month. This can be explained by the fact that SPV technologies are renewable energy sources and keeps the health of respondents as they do not emit soot like kerosene wick lamps and, they provide bright light.

Before they utilize SPV technologies 55 percent of the users were using kerosene, 18.3 percent dry cell batteries, 11.6 wood and 15 percent both wood and kerosene.

Table 4.5 Lighting Energy Sources before SPV Utilization

Lighting Energy Source before SPV	Percent of utilizers
Kerosene	55
Dry cell	18.3
Wood	11.6
Wood and kerosene	15

Source: Own survey, 2018

Users of 48.9, 46.7 and 4.4 percent were used 0.5, 0.5-1 and 1-2 liters of kerosene per week. Again 46.7, 40 and 13.3 percent of users were using 1, 2 and 3 pairs of dry cell batteries. Similarly,66.7 and 33.3 percent of users used less than or equal to 0.5 and 0.5 to1 meter cube of wood. This amount of kerosene, wood and dry cell were utilized with the absence of using SPV technologies. This implies the contribution of SPV technologies in protecting the environment from pollution, keeping the health of people that suffer from the burning of fossil fuels and facilitating socio economic activities in the study area.

Table 4.6 Amount of Light Energy Sources Used before SPV Utilization

Kerosene (Lt/Wk)	Percent of utilizers	Dry cell (Pair/ Mth)	Percent of utilizers	Wood (m^3/Wk)	Percent of utilizers
<=0.5	48.9	1	46.7	≤ 0.5	66.7
0.5-1	46.7	2	40	0.5-1	33.3
1-2	4.4	3	13.3		

Source: Own survey, 2018

Table 4.7 The Maximum Likelihood Estimates of Binary Logit Model

Variables	Estimated Coefficient (B)	Standard Error (S.E).	Wald Statistics	Significance Level (Sig.)	Odds Ratio Exp(B)
Price	-1.058	.510	4.306	.038**	.347
Market	.073	.337	.046	.829	1.075
Quality	.607	.447	1.845	.174	1.835
Education	.316	.401	.623	.430	1.372
Income	.001	.001	3.828	.050*	1.001
Age	-.414	.072	32.759	.000***	.661
Family	.220	.274	.644	.422	1.246
Land	-.521	.481	1.172	.279	.594
Awareness	1.199	.476	6.352	.012**	3.318
Providers	1.044	.397	6.915	.009***	2.841
House	1.297	.569	5.191	.023**	3.657
Human	.034	.415	.007	.934	1.035
Wealth	1.151	.571	4.071	.044**	3.163
Constant	16.261	3.310	24.141	.000	1.154E7

Exp (B) shows the predicted changes in the odds for a unit increase in the predictor.

Omnibus Tests of model coefficients: chi-square 167.865 sig. 0.000

Percentage of correct prediction 92. 1 %; N= 190

*, **, and *** significant at 0.1, 0.05, and 0.01 level respectively

4.4 Determinant Factors Affecting Utilization of SPV Technologies

The binary logit model revealed that variables only seven variables were found significant to utilization of SPV technologies (Table 4.7). These were age and income level of respondents with significant level of ($p<0.01$) and ($p<0.1$) respectively. Outlook of price of SPV technologies by respondents, wealth status of respondents, awareness creations made to respondents, sufficiency of SPV providers locally, and house type of respondents were also significant at ($p<0.05$) level. That is, all these factors were identified as factors that significantly associated to the utilization of SPV technologies in the study area.

Wealth Status of Respondents

Wealth status of households is an important factor in adoption of SPV technologies. In this study wealth status is found to be positive and significant at ($P< 0.01$). Households with better-off wealth are 3.163 more likely to adopt SPV technologies. This result was consistent with the findings of Khandker *et al.*, (2014) in that wealthier households' do not hesitate to adopt the technology due to frustrating the high upfront cost and a 10 percent increase in non-land assets increases the probability of SPV adoption by 0.2 percent. This could be due to the fact that households' having higher overall assets, this in turn, may help them to pass a decision on adoption of SPV.

Outlook of SPV Price by Respondents

As expected, a significant negative relationship between price and adoption of SPV technologies at ($P<0.05$) is found. The result of this study also showed that price is found to decrease the probability of households' decision by a factor of 0.347. This result was in line with study of

Khandker *et al* (2014) in that for every 100 (basic unit of money in Indonesia) increase in price, there is a decrease in the probability of adoption by 2 percent. The result was also highlighted by Qureshi *et al* (2017) in that high initial cost and inability to finance SPV systems prevented all the respondents from using these technologies. This could be explained by the fact that as the price of SPV technology increases by a unit price, probability of decision on adoption of SPV technology decreases by respondents.

Awareness Creations Made to Respondents

Awareness in this study may refer to the provision of relevant information in person to the households about SPV where they can be purchased, the prices, the benefits, the drawbacks etc. Awareness creations specifically on the theoretical and technical aspects of SPV technologies adoption is one of the factors that influence household's decision whether to adopt or not to adopt SPV technologies. As the analytical result of binary model indicated, households who obtained awareness, has more probability to adopt SPV than who did not take awareness. That is, households who get awareness about SPV technologies are found to be positively related with adoption of SPV at ($P<0.05$) and the odds ratio in favor of decision on SPV by a factor of 3.318 for a unit increase of households who received awareness on SPV technologies. This finding is similar with the findings of Ng'eno (2014) and Keriri (2013) in that there is a positive correlation between awareness and SPV adoption and that finally contributed to an enhanced adoption of the technologies. This could be explained by the fact that awareness's that households gain from government or other bodies help them get the knowledge and initiation to take rational decision on adoption of SPV technologies.

Age of Respondents

The effect of age of household on decision to adopt SPV technologies is expected negative and its effect is found to be negative. This indicates that the likelihood of adoption of SPV technologies is more among younger than older households. This can be due to eagerness to accept and test innovations like SPV and get functions of the technologies is higher by younger than older. The binary model shows that age is negatively and significantly ($P < 0.01$) related to adoption of SPV. For one-year increment in age, adoption of SPV technologies decrease by a factor of 0.661. This result was supported by Gebregiorgis (2015) in that more than two third percent of the total respondents who adopted solar energy were youngest. Additionally, this result also complied with the study of Vasseur and Kemp (2015) in that adopters were younger than non-adopters though the trend is not strong. But, in contradiction with Ugulu (2016) in that as age increases, adoption of SPV increases. The possible reason may be as age increases, there is a higher probability of earning income by households, this in turn enables households to be economically strong to pass a decision in the adoption of SPV. Thus, the argument that younger households happen to adopt SPV technologies may not hold true every time.

Income Level of Respondents

The binary logit model result showed that income level of respondents was one of the factors that is positively related to the adoption of SPV technologies with ($P<0.1$). Hence, the result indicated that adoption of SPV technologies is higher by a factor of 1.001 for those who have one-unit income increment than their counterparts. This result agreed with the study of Khandker *et al* (2014). On the other hand, low income level of households prevents them from buying these technologies as stated by Feron (2016). This can be explained by the fact that as the income level is positive, the probability of adoption rate also increases.

House Type of Respondents

As it was expected, house quality of respondents was positively and significantly related to the adoption of SPV technologies. Based on the result of binary logit model, the relationship was significant ($P<0.05$) with adoption of SPV technologies. Hence, households living in quality house were able to pass decision to adopt SPV technologies by a factor of 3.657 than their counter parts, those who live in poor house. This result corresponds with study of Khandker et al (2014) in that housing structure (built in bricks) is one of the influencing factors for positive adoption of SPV. This may be explained by the fact that as the household gets wealthier and earn more income, there is an assumption that the household keeps the quality of house by building from quality raw materials. Thus, it can develop the capacity to afford the prices asked to buy SPV technologies since the price of SPV may be very smaller as compared to cost to keep the house quality.

Sufficiency of Providers of SPV Technology.

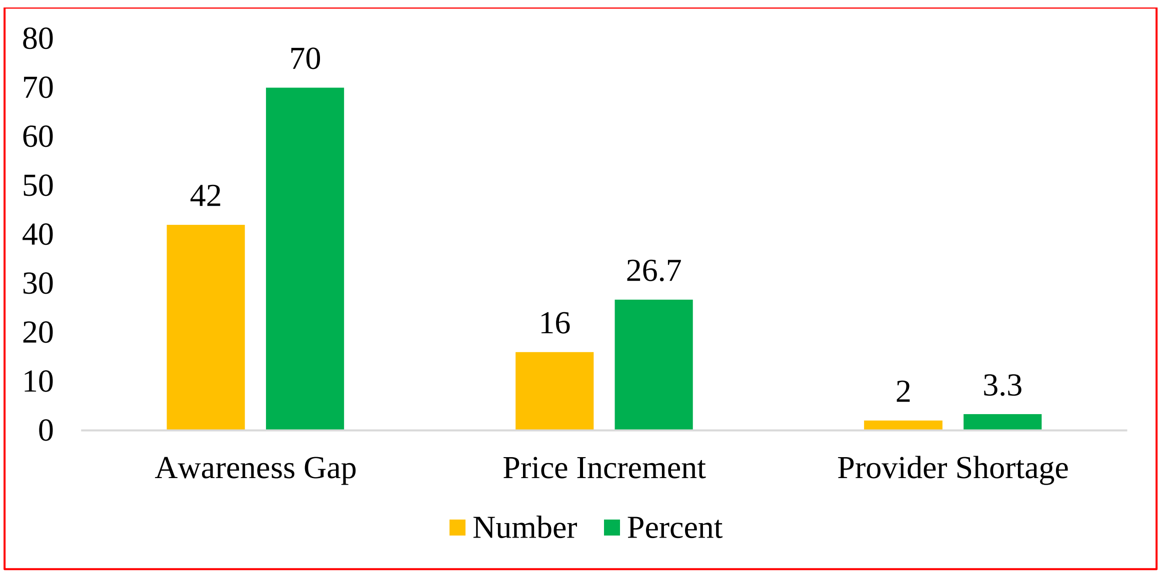
As there are more number of providers of SPV technology locally, respondents could get different options related to price, kind of the technology, amount, etc. to utilize the technology. Hence, the result of the model showed that households that said there were sufficient number of providers of SPV significantly ($P<0.05$) related with adoption of SPV. A factor of 2.841 in the odds ratio on the decision to adopt SPV for those that said there were sufficient number of providers of SPV higher than their counterparts.

While other remaining factors such as educational level of respondents, perception of households on quality of SPV, local market access of SPV, family size of respondents, agricultural land size and human capital of respondents were not affecting the adoption of SPV technologies significantly.

4.5 Constraints and Opportunities of SPV Technologies for Sustainable Adoption

4.5.1 Constraints of SPV Technologies

The basic challenges identified by the user respondents were awareness gap, price increment and provider shortage comprising of 70, 26.7 and 3.3 percent respectively. These problems were also validated during group discussion. In addition, the discussants also raised no availability of spare parts (system components), no access to long term credit, less quality of SPV and reduction of power during summer season were some of the big challenges to adopt SPV technologies in rural parts of the study area.

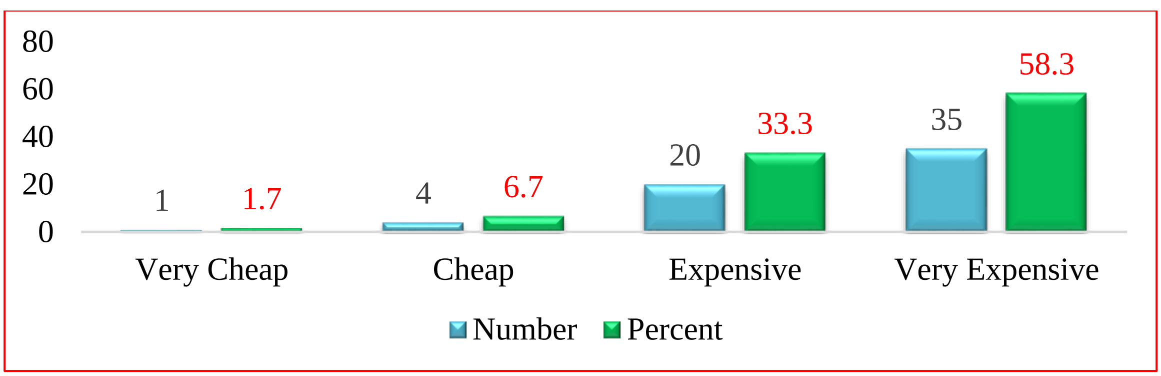


Source: Own survey, 2018

Figure 4.1 Constraints of Adoption of SPV Technologies

Concerning the challenges and constraints of adopting SPV technologies, various factors were analyzed. Awareness gap was one of the main factors that challenge the rural communities from adopting SPV technology. As households were with no information on the price, where the technologies are found, the way to manipulate for daily use, how to maintain when defects happen, etc., households' decision to adopt these technologies decreased. This result agreed with Chaurey and Kandpal (2010) in that when there is no or low awareness, decision to adopt SPV dwindles and as a result dissemination of SPV remains low. The possible reason behind this finding is assumed to be little or no awareness creations about SPV by extension agents was done. On the other hand, 81.2 percent of the respondents witnessed that support given by the government agencies is none in a year.

About 58.3, 33.3,6.7,1.7 percent of adopters were giving a response that a SPV technology was low, good, very good and excellently affordable respectively. This agrees with price increment raised by 26.7 percent of the adopter respondents (figure 4) making not to be affordable so that adoption of SPV technologies becomes difficult in rural communities.



Source: Own survey, 2018

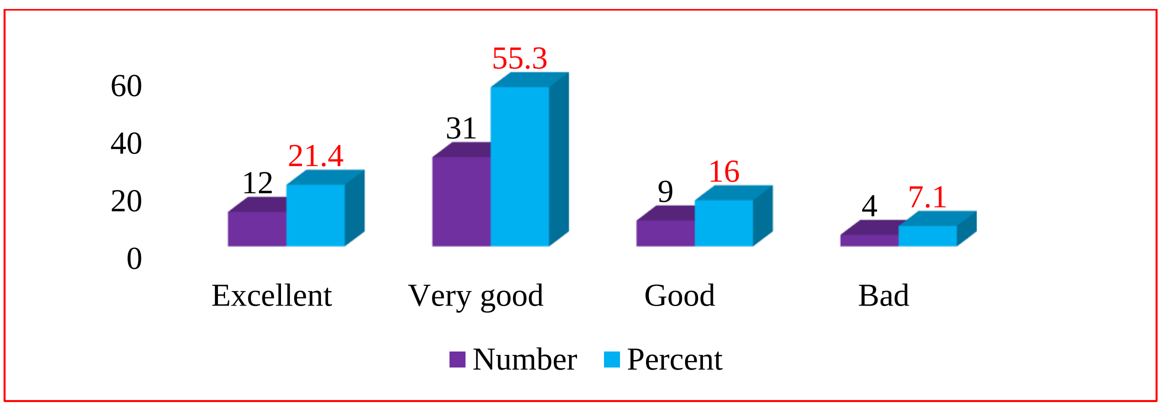
Figure 4.2 Affordability Challenge of SPV Technologies

Affordability of SPV as indicated in figure (6), is very expensive by most (58.3 percent) of the respondents. This result complied with Feron (2016) in that high initial investment costs made SPV unattainable by the rural communities. This finding could be explained by the fact that when households are economically deprived and not in a strong bargaining position to negotiate, the acquisition of SPV decreases, except for the rural elite. Of the adopters of SPV technologies 93.3 and 6.7 percent are users of solar lantern and SHS respectively. The prices paid to be owner are not more than 3000 and 4200 Ethiopian Birr (ETB) for the two types of technologies respectively. Opinions collected from group discussants showed that the price is very expensive. This is an indication to low level of adoption of these technologies. This result was supported by (ibid) in that high price of SPV makes adoption decision of households' to be low and hence dissemination of these technologies become smaller. This could be reasoned out with demand law from economics that states as the price of SPV increases, demand by households to buy technologies decreases and hence decision to utilize SPV dwindles.

Unavailability of long-term access to credit to buy these technologies and inaccessibility of spare parts (system components) to maintain when defects happen are the other big challenges raised by respondents during group discussion period. Being unable to give solution for the availability of spare parts, raised a question of ensuring the sustainability of SPV entailing the energy supply to be unreliable, thus it compromises their sustainability. This result was supported by Gebregiorgis (2015) in that spare parts like fuses are not easily available to the rural community and Feron (2016) in that the spare parts are found some kilometeres far from the actual users. The main reason why spare parts are not accessible may be due to they are imported from abroad and their price increases the overall cost so that it continues as a challenge in adoption of SPV technologies. On the other hand distribution networks concentrate on highly populated areas and forget the rural people where by the population is dipersely found. Lack of attention and focus by financial institutions hampered the rural community from getting long term credit to access SPV technologies is the other possible reason in connection with access to long term credit problem.

Though all these constraints to adopt SPV technologies, they have some opportunities as distinguished by focus group discussants in saving time, money and effort to have light; and keeping the health of especially women and children by avoiding the black soot of kerosene wick lamps during the night time.

Users of solar lantern were asked to evaluate the durability of the technology and most of the respondents about 55.3 percent responded that the SPV durability is very good followed by 21.4 percent who said excellent. Contrary to this, few about 16 percent and 7.1 percent responded that SPV durability is good and bad respectively.



Source: Own survey, 2018

Figure 4.3 Durability of SPV Technologies

As indicated in figure (5) of the result section, most (76.7 percent) of the respondents agreed that the SPV are durable. This result agrees with Hemmen (2011) in that SPV can be used for up to a period of 40 years. Moreover, similar results from Nigeria by Ugulu (2016) showed that 72 percent of the respondents were using up to 4 years without any problem. The possible reason for this finding could be proper roof top installation and handling of SPV. Consequently, SPV could not be easily destructed and damaged with animals or human beings in the ground. Eventually, durability implies the other opportunity of SPV the technologies.

4.5.2 Opportunities of SPV Technologies

On the contrary, SPV have got opportunities in some aspect as drawn from the group discussion.

Keeping Health

As the group discussants expressed their view on the issue of keeping health, more than 80% of the people were suffering from the use of kerosene wick lamps due to emission of black soot which enabled them to cough more. Women and children were the main victim of these source of lighting. But, after installation of different SPV technologies it was able to keep the health of women and children

Saving time, effort and money to have light

Before installation of SPV, about 80% of the people suffer by walking almost 3 to 5 kilometers which took 25 to 50 minutes to buy kerosene. These time and effort would have been used for other purposes. Additionally, light from kerosene was uneconomical since at least 50 ETB is expensed to have kerosene per month. But, after installation no time and extra money was expensed to have light in the nightfall. All were possible with SPV technologies.

Durability

Those who installed SPV were witnessing about the durability of SPV technologies. The technologies were durable for about five years without any defect if they were properly used. Since most of the technologies were installed at the rooftop, there was no direct contact with animals and humans. Besides this, the balance of system such as batteries and other cables should be properly installed and kept making the technologies durable as per the discussion of the group members.

Environmental benefits

The cumulative effect of kerosene lamp black soot released to the atmosphere from all the respondents before installation was assumed to be high though it was not measured by themselves. But, after installation the group members understood the decrement of the black soot implying the positive contribution of SPV technologies in environmental protection.

4.6 Other Technological Related Variables

In addition to the above determinants, technology related variables affect utilization of SPV technologies. Some of these were installation cost and service, availability of alternative technologies can be mentioned.

Table 4.8 Number of technicians to install SPV.

Sufficiency of technicians	Number	Percent
Yes	34	56.6
No	26	44.6
Total	60	100

Source: Own survey, (2018)

As indicated in table 56.6% of the respondents replied there were sufficient number of technicians to install the SPV technologies. Graduates from Debre Markos University and Debre Markos Poly Technique College are the major installers.

Installation Cost

Table 4.9 Installation cost

Installation cost	Number	Percent
Cheap	32	53.3
Expensive	28	46.7
Total	60	100

Source: Own Survey, (2018)

The installation cost asked by the technicians was expensive as replied by the 53.3 % users of the technologies. While the remaining 46.7% responded the cost of installation was cheap.

Technician's Service

Table 4.10 Evaluation of technician's service

Technician's service	Number	Percent
Excellent	18	30
Very good	29	48.3
Good	9	15
Bad	4	6.7
Total	60	100

Source: Own Survey, (2018)

Users of the technology were asked to evaluate the service delivered by the technicians. About 48.3% replied very good followed by 30%, 15% and 6.7 % for excellent, good and bad respectively (Table 4.10). So, it indicates the service provided by the technicians to the users is up to the desire of the users.

Module Cleaning

Table 4.11 Module cleaning per week

Module cleaning frequency	Number	Percent
Once	15	25
Twice	4	6.7
Every day	0	0
Not at all	41	68.3
Total	60	100

Source: Own Survey, (2018)

The result showed that 68.3% of users do not at all clean the module per week, but 25% and 6.7% responded that they clean their module once and twice per week respectively. This implies that the modules are not cleaned to increase the power output of the technology.

Availability of alternative technologies

Only 5 biogas plants were found as alternative technology from the respondents. Of the five, one respondent has got both SPV and biogas technologies. The biogas was used for cooking and for lighting when the SPV fail to function.

Availability of credit access

Amhara Credit and Saving Institution (ACSI) avails credit access to buy SPV technologies in which the loan should be returned in a year time. Of the total users 87 % bought their SPV with access from ACSI whereas, the rest 13 % bought from their own. In relation to credit access, credit given is short term as discussed by members of the group discussants. This result implies that the majority of the users bought with credit in which the access should be expanded.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In order to assess the current status of installed SPV technologies among rural households in terms of frequency of users, functionality and pattern of use as household energy source, a total of 190 sample households taken and 31.5 percent of them were users of SPV technologies.

Regarding functionality of the technologies, the descriptive result indicated that all (60) of the installed SPV were operational during the survey time. Installing the SPV at the rooftop by most households kept the technologies from damage by animals as well as human beings contributing to be functional up to a period of 5 years though there were intermittency of SPV to supply the required power due to weather conditions and technical skill incapacities. So, proper installment and management enhances functionality of SPV technologies.

Lighting from SPV is the major pattern of use. It was evident from the group discussion time that, it keeps the health of especially women and children by replacing kerosene wick lamps, reducing fatal kerosene lamp accidents and a means to secure the house from robbers at the nightfall. Therefore, utilization of SPV brought significant reduction (almost by half) fossil fuel energy sources for light.

In order to identify determinant factors affecting utilization of SPV technologies in the study area, a total of 13 explanatory variables were included for the analysis in the binary logistic regression model. The result showed that among the hypothesized variables seven variables were found to be significantly related to the adoption of SPV technologies. The likelihood of utilization is higher with a decrease in age of the household head (household characteristics), an increase in awareness creations made, sufficiency of providers of SPV (institutional factors) and an increase in wealth status, house quality and income level (socioeconomic factors). However, it is likely to be lower with increase in price. Hence, findings of this study highlight the above likelihood adoption for sustainable utilization of SPV technologies.

As replied by 82.1 percent of the respondents that they do not have gotten any awareness from government agencies in a year time; hence, awareness gap was one of the major constraints identified. High upfront cost or initial investment cost to be owner of the technology was also the other big challenge put in the second place. Thirdly, unavailability of long term credit access and inaccessibility of spare parts (PV system components) was the other reason distinguished as a constraint for sustainable adoption of SPV. Therefore, due to these and other limitations, large portion (68.5 percent) of households in the study area were found to be discouraged from adopting SPV technologies.

Durability of SPV technologies, reduction of time, effort and money and keeping the health of women and children and environmental protection were some of the opportunities of SPV technologies that was summarized during the group discussion period.

5.2 Recommendations

Based on the findings of the study, the following recommendations can be suggested:

Every supportive effort for SPV utilization will be ineffective until the households are not fully aware of SPV technology benefits and drawbacks. The government agencies and providers along with other concerned organizations should strengthen and continue to aware the rural people and nominate the authentic shops from where people can buy quality SPV. Because awareness creation was found statistically significant in relation to use of SPV technologies.

Shortage of SPV providers was also found statistically significant in relation to the use of SPV technologies; hence, the woreda trade office should encourage more individuals to participate in the provision and delivery of the technologies.

No access to long term credit schemes and unavailability of spare parts of technologies were some of the constraints for fast adoption of SPV technologies. So, financial and distribution institutions should give due attention to resolve such kinds of problems.

Most households in the study area manage their SPV by installing at the rooftop to get power but subjected to shade and dust. Thus, reducing power output. So, attention and technical support should be given to reverse the problem.

The extent of adoption of SPV at zone, region and country level were not addressed with many more explanatory variables and larger sample size. Hence, further and detail study about the extent of SPV utilization in both urban and rural areas at the stated different levels is essential.

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APPENDICES

Appendix 1. Variable Inflation Factor for Continuous Variables

Variables	Collinearity statistics	
	Tolerance	VIF
Age	0.983	1.017
Family size	0.926	1.080
Agricultural land size	0.913	1.095

Income is dependent variable.

Source: model output

Appendix 2. Contingency Coefficient for Dummy Variables

	1	2	3	4	5	6	7	8	9
1.Price	1	0.028	0.082	0.136	0.039	0.228	0.059	0.050	0.040
2.Market		1	0.022	0.017	0.090	0.033	0.067	0.011	0.162
3.Quality			1	0.003	0.108	0.071	0.093	0.097	0.069
4.Education				1	0.042	0.175	0.115	0.113	0.105
5.Awareness					1	0.010	0.009	0.017	0.105
6.Providers						1	0.146	0.112	0.075
7.House quality							1	0.157	0.202
8.Hum. capital								1	0.121
9.Wealth									1

Source: model output

Appendix 3. Criteria for Wealth Category

Criteria	Better off	Medium and Poor
Agricultural land size	≥ 1 hectare	<1 hectare
Oxen	≥ 4 oxen	< 4 oxen
Cows	≥ 3 cows	< 3 cows
Sheep and goat	≥ 5 sheep and goat	< 5 sheep and goat
Mobile phone	≥ 1 phone	< 1 phone
Pump	≥ 1 pump	< 1 pump

Source: own survey, 2018

Appendix 4. Criteria for Type of House

Criteria	Quality	Poor
Roof	Metal	Thatch
Size	> 50 m^2	<50m^2

Source: own survey, 2018

Appendix 5. Omnibus Tests of Model Coefficients

	Chi-square	df	Sig.
Step	167.865	13	.000
Block	167.865	13	.000
Model	167.865	13	.000

Source: Model output

Appendix 6. Model Summary

-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
69.123[a]	.587	.823

Source: Model Output

Appendix 7. Hosmer and Lemeshow Test

Chi-square	df	Sig.
3.008	8	.934

Source: Model Output

Appendix 8. Structured Questionnaire for Household Survey

Dear Respondent, I am a graduate student from Hawassa University, Wondo Genet College of Forestry and Natural Resource. Currently, I am conducting my research on the status and determinants of solar photovoltaic utilization on rural households in Gozamin woreda.

For this reason, your active participation and responses are very important in meeting the objectives of the study. Thus, I kindly request your active cooperation in responding the questionnaires. The questionnaire is solely for academic research only and so that any information you provide will be kept confidential.

Thank You!!

I. GENERAL HOUSEHOLD CHARACTERISTICS

1. What is the sex of the household? 1. Male 2. Female
2. What is the educational background of the household head? 1. Illiterate 2. Reading and Writing and above
3. Income level per month

Income source	Wage/salary (Birr)	Petty trade (Birr)	Remittance /regular support (Birr)	Business (Birr)	Productive activities (crop/dairy/apiary/ poultry/fattening)	Total (Birr)
Amount per month						

4. How old is the age of the household head?
5. What is the sex of the household head? 1. Male 2. Female
6. Total agricultural land holding size for the household head is ------- ‘timad’

II. FREQUENCY, FUNCTIONALITY AND PATTERN OF USE OF SPV TECHNOLOGY

7. Have you been using any Solar PV technology in your house in the past five years? 1=yes; 0=No
8. If answered yes above, when was the time you have started using this technology?

1.This year 2. Before a year 3. Before two years 4. Before 3- 4 years 5. Before 5 years

9. If yes to question #6, can you please give me the top important reasons for using solar PV by making rank?

Reasons	Rank
1. To minimize cost of kerosene	
2. To keep health of the family	
3. To let the children, study their education better	
4. To run petty business/mobile charging, tea house, etc.	
5. To be able to use electric appliance at home	

10. If no to question #6, can you please give me the top important reasons for not using solar PV by making rank?

Reasons	Rank
1. Low income to afford price increment of the technology	
2. Awareness problem/ not knowing the technology/	
3. No belief in the technology	
4. No nearby supplier of the technology	
5. The technology is not given with credit	

11. How often your solar PV technology fails to function per month on average?

    0.0 1. 1 2.2 3.3 4.4 5.5 6. More than 5 times

12. Were you able to fix some of the causes of failure in your own/other family members?

    1.Yes 2. No

13. If yes to the above question, what kind of failures were fixed in your own? Rank them

14. Since starting to use the solar PV, have you ever replaced some parts of the solar PV to bring it back to operation? 1.Yes 2. No

15. If yes to the above question, how often since starting to use it? 1. 1 2.2 3.3 4.4 5.≥5

16. Since starting to use solar PV, have you replaced the whole parts of solar PV with the new one? 1. Yes 2. No

17. If yes to the above question, how often since starting to use it? 1. 1 2.2 3.3 4.4 5. ≥5

18. What are the major purposes you use solar PV in your house?

Major Purposes	Lighting	Mobile charging	Running electrical appliances	Petty business	Others
Rank					

19. Do you combine solar PV with other types of energy sources? 1.Yes 2. No

20. If yes to the above question, which purposes do require additional energy sources?

Major Purposes	Lighting	Mobile charging	Running electrical appliances	Petty business	Others
Rank					

21. For which purpose you use solar PV almost every day?

Major Purposes	Lighting	Mobile charging	Running electrical appliances	Petty business	Others
Rank					

22. Are there any purposes for which you are not able to use your solar PV regularly due to capacity or other reasons? 1.Yes 2. No

23. If yes to the above question, what are these purposes?

Purposes	Welding	Iron press	Stove for cooking	Refrigeration	Others
Rank					

24. Is the technology working today or not? 1. Yes 2. No

25. If your answer is no to question number 24, what was/were the reason/s for not working?

1. Installation 2. Shading 3. Soiling 4. Parts broken 5. Other

26. What type of energy source were you using before you started to use solar PV technology?

1. Kerosene 2. Fire wood 3. Dry cell 4. Others

27. If your answer is kerosene to question number 26, how many liters of kerosene were you using for light per week? 1. <0.50 2. 0.5-1 3. 1-2 4. 2-3 5. >3
28. If you were using fire wood for question number 26, how much meter cubic of fire wood were you consuming per week? 1.< 0.5 2. 0.5-1 3. >1
29. If you were using dry cell, how much pairs of dry cell were you using per month?

1. 1 2.2 3.3 4.4 5. ≥5

III. DETERMINANT FACTORS AFFECTING SPV UTILIZATION

30. Was there enough awareness being made about the importance and availability of PV technologies? 1. Yes 2. No
31. From where do you have installed the technology?1. From government 2. providers/distributors
32. By whom was the installation made?

1. Government technicians 2. Private technicians 3. By themselves

33. Was the installation cost cheap or expensive? 1. Cheap 2. Expensive 3. No payment

34. How many times a week do you clean the solar module?

1.Once 2. Twice 3. Three times 4. Daily 5. Not at all

35. Do you think are there enough providers of PV technology in the nearby (<10 kilometers)? 1.Yes 2. No

36. What is your perception towards the quality of PV technologies? 1. Negative 2. Positive

37. Could you please mention some of the assets possessed / wealth status?

Asset	Cart	Mobile	Motor	Bicycle	Car	TV	Sofa	Oxen	Cows	Sheep and	Irrigation
Quantity											

38. Could you please tell me the quality of your house? Encircle your choice.

Roof		Wall			Size		
Iron	Thatch	Brick	Wood	Stone	< $50m^2$	50-$100m^2$	>$100m^2$

39. Can you please give the number of your family members that are learning at high school?

1. 0 2.1 3.2 4. 3 5. 4 6>4

40. Can you please give the number of your family members that have graduated from university? 1. 0 2.1 3.2 4. 3 5. 4 6>4

41. Can you please give the number of your family members that are working in different levels? 1. 0 2.1 3.2 4. 3 5. 4 6>4

42. How many family members live in this household?

43. How many members of your households are dependents (below the age of 15 or do not contribute to any active labor to household income/production activity)?

44. How many times have you got technical assistance/support concerning maintenance from the government experts per year?

0. None 1. Once 2. Twice 3. Three times 4. Four times 5. >= Five times

45. Are the solar PV's enough to supply the appropriate brightness in the house?

1. Yes 2. No

46. Do you agree that using solar PV's can bring better lifestyle?

1. Strongly Agree 2. Agree 3. Dis agree 4. Strongly Disagree 5. Neutral

47. How much kilometer is the nearby forest from your house? 1. <1 2. 1-2 3. >3

48. What type of technology are you using for lighting? 1. Lantern 2. SHS 3. Others

49. How many lantern/s do you use? 1.1 2. 2 3. 3 4. 4 5. > =5

50. How many SHS do you use? 1.1 2. 2 3. 3 4. 4 5. > =5

51. How much Ethiopian Birr did you pay to buy one solar lantern?

1. ≤1000 2. 1001- 2000 3. 2001-3000 4. 3001-4000 5. ≥ 4000

52. How much Ethiopian Birr did you pay to buy one SHS?

1. ≤4200 2. 4201- 7600 3. 7601-11200 4.11201-17000

IV. CONSTRAINTS AND OPPRTUNITIES OF SPV TECHNOLOGIES

53. In your own view, could you please rank the major challenges of solar PV technology from top to least?

Challenges	Awareness gap	Price increment	Suppliers shortage	Installation problem	Shortage of technical support	Quality problem	Others
Rank							

54. In your own view, could you please rank the solutions to the challenges of solar PV technology from top to least?

Solutions	Awareness raising	Price decrement	Increasing Suppliers	Proper installation	Giving technical support	Ensuring Quality	Others
Rank							

55. Are there obstructions that prevent solar radiation to reach to the modules?

1.Yes, there are trees 2. Yes, there are neighbor buildings 3. No, there are no any obstructions

56. Are there relevant spare parts of solar PV that can be changed when failure happens?

1. Yes 2. No

57. Is the solar PV's capacity well enough to run electric appliances like for example TV set, Refrigerator, Funs, etc.? 1 Yes 2. No

58. How do you evaluate the durability of solar PV in comparison with availability, cost, and access to technical support and spare parts? 1. Excellent 2. Very good 3. Good 5. Low

59. How do you evaluate affordability of Solar PV compared with their utility to meet major household energy demands and household income? 1. Excellent 2. Very good 3. Good 5. Low

BIOGRAPHICAL SKETCH

Yared Alazar was born in Gojjam, Ethiopia on July 19, 1978 He attended his elementary and secondary school at Dembecha from 1983 to 1994. Then he joined Ambo College of Agriculture in 1995 and graduated with diploma in General Agriculture on July,1996. The author hired by Tigray Educational Bureau as a teacher and served from 1997 to 2001.

Coming back to Dembecha, he joined the Woreda Office of Agriculture to serve as an Agroforestry and Soil and Water Conservation expert in 2002. While he was working, he joined Haramaya University in 2006 for further study and graduated with B.Sc degree in Plant Science on September 2010.

The author later employed at East Gojjam Zone Environmental Protection, Land Administration and Use Department as Forestry expert in 2011. But, meanwhile there was a shift in position to EIA expert and served till 2016. He then joined Hawassa University, School of Graduate Studies at Wondo Genet College of Forestry and Natural Resource for Master of Science in Renewable Energy Utilization and Management.