THE ROLE OF SOLAR HOME SYSTEM TO SOCIOECONOMIC DEVELOPMENT AND REDUCTION OF GREENHOUSE GAS EMISSION IN RURAL AREA OF GESHA WEREDA, KAFFA ZONE, SNNPR, ETHIOPIA

MSc. THESIS

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JUNE,2019

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MSc THESIS

SUBMITTED TO HAWASSA UNIVERSITY WONDO GENET COLLEGE OF FORESTRY AND NATURAL RESOURCES, DEPARTMENT OF ENVIRONMENTAL SCIENCE, HAWASSA UNIVERSITY, WONDO GENET, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF RENAWABLE ENERGY UTILIZATION AND MANAGEMENT

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APPROVAL SHEET-I

This is to certify that the thesis entitled ''**The Role of Solar Home System to Socioeconomic development and Reduction of Greenhouse Gas Emission in Rural Area of Gesha Wereda, Kaffa Zone, SNNPR, Ethiopia''** is submitted in partial fulfillment of the requirements for the degree of Master of Science with specialization in Renewable Energy Utilization and Management, Wondo Genet College of Forestry and Natural Resource, and is a record of original research carried out by **Amanuel Assefa,** Id. No. **MSc/REUM/R002/10**, under my supervision, and no part of the thesis has been submitted for any other degree or diploma. The assistances and help received during the course of this investigation have been duly acknowledged. Therefore, we recommend that it be accepted as fulfilling the thesis requirements.

Approved by

Kamil Dino (PhD) ______ ______ Date

Name of Main Advisor | Signature

Yemiru Tesfaye ______ ______

Name of co-advisor | Signature | Date

APPROVAL SHEET II

We, the undersigned, members of the board of examiners of the final open defense by Amanuel Assefa have read and evaluated his thesis entitled ‘‘**The Role of Solar Home System to Socioeconomic development and Reduction of Greenhouse Gas Emission in Rural Area of Gesha Wereda, Kaffa Zone, SNNPR, Ethiopia’’**. This is therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of masters of Science in Renewable Energy Utilization and Management.

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STATEMENT OF AUTHOR

I hereby declare that this thesis is my original work and has not been presented for a degree in any other University.

Amanuel Assefa:_________________

Date: __________________________

List of Acronyms and Abbreviations

AC	Alternative Current
CFL	Compact Fluorescent Lamp
CO_2-eq	Carbon Dioxide Equivalent
DC	Direct Current
EEPCO	Ethiopian Electric Power Corporation
ETB	Ethiopian Birr
FGDs	Focus Group Discussions
GoE	Government of Ethiopia
GHG	Green House Gases
GTP	Growth Transformation Plan
GWh	Giga watt hour
HH	Households
HAP	House Air Pollution
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
JICA	Japan International Cooperation Agency

KII	Key Informant Interview
KW	Kilo watt
$Kwh/m^2/day$	Kilo Wat Hour Per Meter Square Per Day
KWP	Kilo Watt Power
LED	Light Emitted Diode
NABU	Nature and Biodiversity Conservation Union
NFPA	National Forest Priority Area
NGOs	Non-Governmental Organizations
PV	Photovoltaic
REF	Rural Electrification Fund
RENI21	Renewable energy policy for twenty ones' century
RFRA	Regional Forest Priority Area
RETs	Renewable Energy Technologies
SHS	Solar Home System
SNNPRS	South Nations Nationalities Peoples Regional State
SPSS	Statistical Package for Social Sciences
SRS	Systematic Random Sampling
SSA	Sub-Saharan Africa

TV	Television
UNESCO	united nation educational, scientific and cultural organization
UNICEF	United Nation International Children's Emergency Fund
UNICEF	United Nation International Children's Emergency Fund
USD	United States Dollar
Wh/ m^2	Watt-Hour Per Meter Square
WHO	World Health Organization

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ABSTRACT

Globally, around 1.06 billion people still do not have access to electricity, and most are live in sub-Saharan Africa and developing Asia. Off-grid renewable energy solutions have arisen as a mainstream solution to expand access to modern energy services. The purpose of this study was to assess the role of solar home system to socioeconomic development and reduction of greenhouse gas emission in rural kebele of Gesha wereda, southern, Ethiopia. From the total population, survey was conducted with a structured questionnaire for 229 households that were systematically selected from three rural kebeles which were selected purposively. The total of 18 the semi structured interview and 6 focus group discussion was conducted. Due to technology based social research a mixture of qualitative and quantitative methodological approaches is applied. All collected data was analysis by Statistical Package for Social Sciences and Microsoft excel *and, the qualitative data were analyzed through intensive textual analysis. The descriptive statistics results shown households was agreeing solar home system in social aspect benefit to health, education, access to information, socialization, safety and security, consuming women and children time. In economical point of view; better to consuming day to day traditional energy source expenditure and create new income to beneficiary. Solar home system has able to substitute the total traditional energy source expenditure from one to two years by reducing greenhouse gas emissions effectively at the same time, households are able to get more than one better illuminate light. An average enterprise monthly generate 944.45Ethiopian birr by watching TV and hair barberries. Also from exaction on mobile charging monthly they get an average of 550 Ethiopian birr. Environmental aspect; it reduced traditional energy source relate greenhouse gas emission. An average the annual rate of total Emissions reduction by firewood light source was 4.83 t* CO_2 *equivalent per households and to kerosene was of 0.046t* CO_2 *equivalent per households. As soon as, households installing SHS, can able to offset significant amount of greenhouse gas emission from traditional source of light. To increase the role of solar home system on rural area households it is better to share the best practice trends of SHS user to other non -user to improve their awareness on the technology, provides appropriate credit access of SHS to address the rural and remote area poor households, strength the potential of local solar technicians through finance and skill improvements to minimize the maintenance cost of SHS, controls illegal solar supplier and seller and support the legal supplier and seller of SHS to sustain the technology adoption.*

***Keywords**: Benefit, renewable energy, off grid, traditional energy source, solar home system, greenhouse gas.*

1. INTRODUCTION

1.1 Background of The Study

Around 1.06 billion people (14% of the global population) live without electricity, and about 2.8 billion people are without clean cooking facilities (REN21, 2018). From this, most of people live without access both electricity and clean cooking are in sub-Saharan Africa and developing Asia of rural regions (Hoque & Das, 2013). To eliminate this energy poverty, renewable energy has more affordable and solution to expand modern energy services in a timely and environmentally sustainable means (IRENA,2018). From off-grid renewable energy technology, solar home systems serve a dominant share solutions and it accounts for a small fraction (4%) of the total installed capacity (IEA, 2016a). The solar energy is attractive and recognized as the best choice for local power generation to rural and remote area due to its good illumination advantage for social, economic and environmental benefit to rural households (Morrissey, 2017). This good illumination of SHS used to minimized kerosene and firewood effect of limits productivity and opportunities for studying or income-generating work (Tedsen, 2013).

Sub-Saharan Africa is challenged by the world's lowest level of electricity access of 35% overall, and only 19% in rural areas (World energy council, 2018). In Sub-Saharan Africa, from the total population 62.5 percent which means 609 million people (6 out of 10) do not have access to electricity (world Bank, 2017).

Ethiopia is located between latitude 3° and 15° North and longitude 33° and 48° East in the north eastern Africa, land-locked, 1.1 million km^2 size (Gerlach & Peter, 2009; Fikremariam,2014). The geographical location of Ethiopia, close to the equator and with large high altitude landscapes, plays an important role for generate solar energy (Fikremariam, 2014). In line with this, the GoE showed its commitment to the promotion and widespread adoption of renewable energy technologies through the establishment of institutions and financing mechanism (REF) for off-grid rural electrification (Energy and resource institution, 2014).

Ethiopia has great potential to implement renewable technologies to decrease reliance on traditional fuel sources and increase rural electrification (Howell, 2012). It generates almost all its electricity from renewable resources, with massive potential for hydro, solar, wind, and geothermal power (world Bank, 2018). Whereas, the energy has a potential to generate over 60,000MW of electric power (USAID, 2016). The total net installed capacity of electric power plants increased by five times from 467,000 KW in 1994 to 2,311,000 KW in 2014 (Bahadur et al, 2017). However, EEPCO has electrification achieved up to 2014 about 24% and, from total about 85% of the urban population and 10% of the rural population is electrified (Evidence on demand, 2016). The rest people conventional rural energy usage is based on kerosene lamps for light and dry cell batteries for radios and tape recorders (Breyer et al., 2009). In Ethiopia fuelwood is also an important source of energy, the total energy supply from fuelwood increased from 78,550,000 m^3 in 1994 to 106,745,000m^3 in 2014, and households consume 76% of it (Bahadur et al., 2017).

GTP-I (2010–2015), grid covering nearly 60 percent of towns and villages, representing about 80 percent of the population (Tsegaye, 2016). Grid Connected power 300MW, off-grid 40,000 SHS, Geographic access to electricity grid 55%, Connectivity approximately 30%, approximately 6,000 towns electrified (ibid). The target of increasing energy access for up to 4 million households by 2020 (Barnes, 2016).

The rural area of Gesha wereda was one of beneficiary to solar home system from REF program (kaffa zone energy GTP-I report,2015). Kafa zone energy office in GTP-II plan to distribute 17,000 SHS only it achieved 8905 (52%) and, relative to five years plan only achieved 28% of the target (Kaffa zone energy department GTP-II three years' report,2018). From the total number of SHS Gesha wereda disseminate 923 SHS and it achieves 62% of the target (kaffa zone energy GTP-II three years' evaluation report,2018).

The study may contribute to fill the gap by assessing the contribution and the best experience beneficiary of solar home system to rural area of Gesha wereda.

1.2 Statement of the Problem

Ethiopia has the second largest population in Africa with an estimated 102 million people and from the total 80.5% live in rural areas (Evidence on demand, 2016). According to document of USAID 2018, the household electrification rate remains about 40 percent and the access rate in rural 29%, in urban 85%access (USAID,2018).

According to the FDRE, Ministry of Water and Energy in 2012 data showed that about 71.1% of the total households use kerosene for lighting followed by firewood (15.9%) and electricity (12.9%). This contributes to greenhouse gas emissions, indoor air pollution, and local environmental degradation (Energy pidia,2017).

Gesha wereda like other Ethiopia rural area most of households use kerosene, dry-cell batteries torch and fire wood for lighting due to lack of grid access (GM clean Energy Fuel Effiecient Technolgy, 2015). According to Bonga town EEPCO district 2018 desk file, from 25 kebele only wereda main town had get access to grid and no rural area has got electric connections (Bonga town EEPCO district,2018). In the places where national grid is not available or installation of grid system has not been feasible so far, like this problem economically alternative solution is SHS (Pode, 2013).

kaffa Biosphere is estimate to cover 352,255 hectare and energy dependence upon wood (GM clean Energy FuelEffiecient Technolgy, 2015). NABU organization assess the current energy pattern of households in rural place especially the register place of UNESCO. Energy Similar to other parts of the country people of Kafa mainly use wood products for fire. This situation has been mentioned as one of the driving forces for deforestation (Renforus, 2010). To minimized the risk of social, economic and environmental effect disseminate of solar home system is positive significant. But, awareness is the main challenge to disseminate large number of SHS (Xu et al., 2016).

So, sharing the best experience on beneficiary of solar home system of rural people to other non-adopter household have positive significant to upgrade the awareness of rural people and necessarily to meet the current and following plans target effectively.

As far as, the researcher knowledge is concerned, there was no study conducted on the role of solar home system to socioeconomic and reduction of greenhouse gas emission in rural area of Gesha wereda, SNNPR region of Ethiopia.

1.3. Objectives of the study

1.3.1. General objective of the study

The main objective of this study is to assess the role of solar home system (SHS) on socioeconomic and greenhouse gas emission reduction in rural kebele of Gesha wereda.

1.3.2. Specific objectives of the study

- To assess the social benefit of solar home system to rural kebele of Gesha wereda.
- To examine some best practice of economic activity for improving the role of solar home system (SHS) to rural community.
- To investigate the role of solar home system (SHS) to reduce GHG emission to the environment.

1.4. Research questions

The research conducted the following questions

1. what are the social benefit of solar home system for rural kebele of Gesha wereda?

2. What are the best practice of economic activity by solar home system for rural kebele?

3. How using solar home system role for reduced GHG emission to the environment?

1.5. Significance of The Study

This study may support project implementers, region, zone and wereda water, mines and energy office and stakeholder, solar supplier and seller easily they aware and expand best experience to other off grid rural area. As the result, all sector and stakeholder better understand the benefit of the technology and they transit from traditional energy to solar energy. Also Government, development partners, research institutions, NGOs and private organizations which are working on Gesha wereda and can also use this study as baseline to work on untapped potential of solar energy.

According to NABU,2012 report, Kafa zone contains more than 50% of the remaining mountain forests in Ethiopia. It is the center of origin and genetic diversity of wild Coffee

Arabica. Gesha wereda NFPA's which constitutes highly endangered and conservation-worthy habitats. In 1980 the vast majority of the forest in the Kafa region was classified as National Forest Priority Area (NFPA). The Gesha NFPA's which constitutes highly endangered and conservation-worthy habitats. by the government to handle with the rapid forest decline. Most document indicate that, after the fall of the socialist regime all NFPAs were handed over to the regional states and became Regional Forest Priority Areas (RFPAs). To keep this forest, substitute consumption of wood for lighting by solar energy may support and protect natural and other forest. The rural households benefit from solar power directly conserve the habitat and forest by substitute firewood for lighting purpose and indirectly increase the carbon offset income from institution fund.

SHS that are commercially disseminated and used cost efficiently to substitute kerosene and dry cell batteries, reduce GHG emissions effectively. In that reason, dissemination of large numbers of SHS will make a significant contribution to climate protection.

Beyond to that, the goal of energy life cycle analysis is to understand whether technology transitions from fuel based to modern lighting. Substitute traditional light (kerosene and wood fire) by solar home system is much needed to address off grid rural and remote area. Because, solar energy generates free energy from the sun, requiring minimal maintenance, reduces GHG emissions, can be installed and operated anywhere, PV cells has no noise, alternative for use in remote areas expensive or impossible to run power lines.

In general, the study would help governmental institution and NGO implementers effective planning and undertaking programs rural areas.

1.6. Scope of the study

Geographically, the study place is limited to rural kebeles of Gesha wereda, kaffa zone, SNNPR region, Ethiopia. Conceptually, the research is limited to assess the contribution of solar home system on socioeconomic and greenhouse gas emission reduction in household level. Theoretically, the research is based on the idea of energy ladder, energy pattern, technology innovation theories to access the contribution of SHS to the socioeconomic and environment of household other than experimental analysis the study estimate expenditure of source of energy and reduction of carbon dioxide emission from kerosene and fire wood. In this study mixed research method were used in terms of time and data was gathered to identify the socio economy and environmental role of solar home system of rural households.

1.7. Limitation of the Study

This study not include the urban areas that are found in Gesha wereda. This study also limited to only solar home system and not including other large s;2olar PV. The research limited to access the contribution of solar home system in house hold level. The study faced limitation of time. Due to this, the study not realized the challenge and negative impact of solar home system.

1.8. Operational definition of Terms and Concepts

The questionnaire is characterized by the mixture of closed and open questions, allowing the collection of quantitative as well as information on before and after using SHS in the household. The questionnaire is structured as follows:

Demographic information: This part is designed to collected data on household head and wife age, sex, marital status, education level.

Socio-economic information: Major information is collected in this part. It is designed to collect data on social situation on health, education, social frame work, consuming women and children time, safety and security economic situation on traditional sources of energy for lighting and expenditures, enterprise, appliance expenditure of SHS technology (Harun, 2015).

Greenhouse gases information: Refers to many chemical compounds that are found in the Earth's atmosphere. These gases allow sunlight to enter the atmosphere freely. It designed to collect data on household air pollution, global warming, deforestation.

Access to electricity: access to electricity has been measured on the basis of household connections to the national electric grid of their respective country (Lighting global, 2018)

Rural electrification fund: Refers small scale solar home systems covering basic needs in a single household, or larger mini-grids, which provide enough power for home use implement by government program (Onsomu, 2013).

Off-grid: an electrical grid main electricity is not available used for stations with mobile phones, electrification for remote areas or rural electrification in remote areas.

2.LITERATURE REVIEW

2.1. General Description of Solar Home System (SHS)

Solar photovoltaic (PV) is a semiconductor material that convert solar energy (sunlight) into electricity (Onsomu, 2013). The incoming sun light is composed of photon consists of various amount of energy having different wavelength of spectrum (Energy kids, 2017). This incoming photon strike the PV cell reflected, pass light or absorbed (ibid). From this, only the absorbed photon provide energy to generate electricity (Rahman & Ahmad, 2013).

A solar home system (SHS) is a small-scale cost effective mode of supplying power for lighting and appliance for remote off-grid and rural households(ibid). It generates electricity from sunshine and stores the electricity in a battery for consumption during the night or cloudy days (GmbH, 2014). In other word that does not connected to the grid used to meet their basic electric needs (Onsomu, 2013). SHS capacity consists of 10w to 130w supply and may contain two or more lights with phone charging capacity (Feron, 2016), and, higher capacity systems may provide sufficient power to operate several light bulbs, TVs and refrigerate medicines at rural clinics (world bank,2013).

The immediate impacts of using SHS is enables the household to have light after nightfall, makes study easier in the evenings, allows people to watch TV and be informed of many useful and socially desirable things happening around them (world Bank, 2017). Furthermore, it can lower levels of household air pollution (HAP) through reduced use of kerosene, and may even generate extra income by renting charger services for mobile phones (Hoque & Das, 2013;World bank, 2013). Solar electricity also has the potential positive externality of substituting for fossil fuels in electricity generation and thus contributing to lowering carbon dioxide emissions and the harmful effects of climate change (Barnes, 2016).

2.2. The Application of Solar Home System (SHS)

A solar home system (SHS) offers households in such developing countries. Convenient supply of electricity for lighting and running small appliances (like small television Set, radio, mobile phone charger) (Khandker et al., 2014). An SHS includes a solar panel, one or more batteries, a charge regulator or controller, an inverter to convert direct current (DC) to alternating current (AC) for grid-compatible AC appliances, cables, and switches for safety (Ahmed & Mourshed, 2016) . An SHS usually operates at a rated voltage of 12 V direct current (DC) to provide power for low power DC appliances such as lights, radios, and small TVs for about three to five hours a day compact fluorescent lamp (CFL) or light-emitting diode (LED) lights, and a universal outlet for charging cell phones and small appliances (Kabir et al., 2017).

Photovoltaic modules consist of a number of cells connected together to provide voltages and currents high enough for practical use (Harun, 2015). An estimate of Ethiopian PV experts led to PV system demand in power units of 2 W for light for one house 4 h/day, 10 W for light, charging and music,20 W, 50 W and 100 W which is sufficient for a little cinema or a health station with refrigerators (Breyer et al,2009). The array slope angle is set to 15 degrees and the array azimuth is 0 degrees which are referring to the South direction. The lifetime of this PV array system is 25 years with de-rating factor of 90% (Giday, 2015).

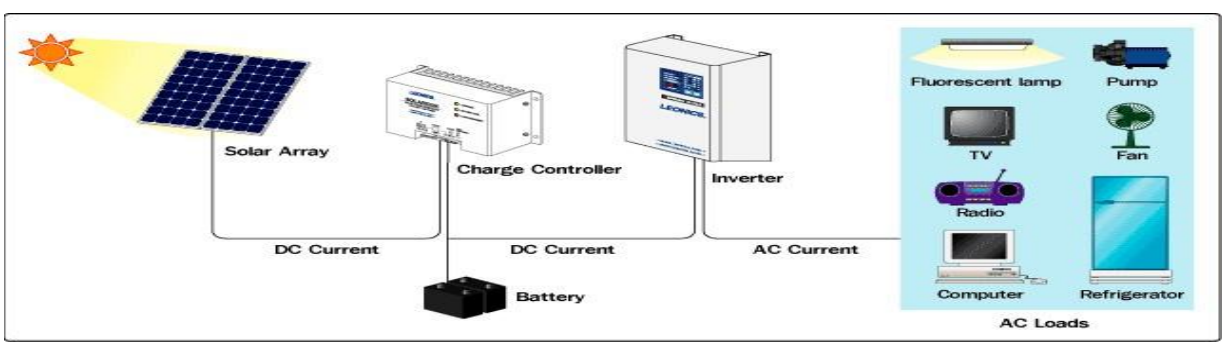

Figure 1:The application of solar home system, source: (Kabir et al., 2017)

2.3. Solar Home System in Ethiopia

Like everywhere in the world, consumers in Ethiopia have a need for such as light, communication or mechanical energy, but not electricity as an end in itself (Breyer,2009). In Ethiopia conventional rural energy usage is based on kerosene lamps for light and dry cell batteries for radios and tape recorders (Tsegaye, 2016).Transit to modern energy the Ethiopian government green economic policy promotes emission reduction and green energy development system (Mbogo,2018). The government formulated feasible policy that can help the country join renewable energy source (ibid). Some highlight from the policy, mainly ensure a reliable supply of energy at the right time and at affordable prices, particularly to support the country 's agricultural and industrial development, neutral development, Renewable energy based increase energy access and efficiency Public and Private Sectors Participation (Berlin Energy Transition Dialogue, 2017).

According to International Energy Agency Special Report (2016), In Ethiopia the priority technologies for the energy sector is power generation(IEA, 2016b). From the technology, solar photovoltaic is one option for access the electricity (ibid). In the country there is a very high potential of solar power generation in extensive areas of throughout the year (Fikremariam, 2014). The solar radiation averages 5.2 $kWh/m^2/day$ which values vary with the seasons, ranging from 4.55 to $5.55kWh/m^2/day$ and over space, ranging from 4.25 $kWh/m^{2/}day$ (REEEP,2014).

The first PV system was installed in the mid-1980s-these systems were installed for rural home lighting and for school lighting (ibid). The largest of these was a 10.5kWp system installed in 1985 in Central Ethiopia, which served 300 rural households through a micro grid in the village (ibid). This system was later upgraded to 30 kWp in 1989 to provide power for the village water pump and grain mill (Ethio Research Group, 2012). The solar system even in study zone, the Kaffa Development Association guest house, Bonga town, was installed long time ago (in 1997/1998 G.C) (Skałowski, 2012). The country is fast becoming one of the largest markets for solar lighting products in Africa (Evidence on demand, 2016). This might have been the one which opened a way to introduce more about a solar system for the locality (ibid). In country level the Solar Energy Foundation estimates that in addition to the 40,000 SHS installed by REF, some 60,000 were distributed by NGOs and close to one million solar lanterns sold (Africa development Bank,2017).

2.4. Social Benefits of Solar Home System

2.4.1. Improving Health

Importance of electricity for health care provision, over 30% of all health facilities in sub-Saharan African, serving approximately 255 million people, lack access (Practical Action, 2017). SHS benefit for avoid air pollution due to reduced flame-based lighting, reducing the risk of burns, accidents and fires (Harrison et al , 2016),electrified hospitals and health facilities can provide better health care services, which can be lifesaving, medical equipment is better sterilized, hygienic facilitating laboratory work, blood, drugs and vaccines can be kept safely (UNICEF, 2015). Lack of, or unreliable, access to electricity contributes to the immense healthcare challenge that developing countries face (SNV, 2012). Developing regions accounted for approximately 99% of the global maternal deaths in 2015, with sub-Saharan Africa alone accounting for roughly 66% (201 000) due largely to limited access to emergency obstetric care and insufficient maternal care during pregnancy and delivery (REN21, 2018).

Kerosene lamps are one of the major sources of household air pollution in developing countries, emitting black carbon, which can cause chronic pulmonary diseases and harmful emissions that can lead to respiratory diseases (Khandker et al., 2014;WHO, 2016) . The combustion of kerosene is associated with household air pollution causes over 4.3million premature deaths annually, predominantly due to stroke, is chimeric heart disease, chronic respiratory disease, and childhood pneumonia health care activities account for between 3-8% of greenhouse gas (CO_2 eq) emissions (ibid). Low-carbon energy solutions (like solar energy) and the development of combined heat and power generation capacity in larger facilities offer significant potential to lower the health sector's carbon footprint (WHO, 2015).

Decrease in kerosene and candles consumption reduces household air pollution with potential effects on health (WHO, 2016). Studies on kerosene used for cooking or lighting provide some evidence that their emissions may impair lung function and increase infectious illness including tuberculosis, asthma, and the risk of cancer (Kat Harrison, 2017). This effect especially in Africa and Asia significantly happen. Study shows, in case of Nigeria 30% of admission to hospital for burns are attributed to Kerosene lamp (Orlandi et al, 2016),in Bangladesh 80.5 % users stating that SHS would have an effect on their health explained it by an improved indoor air quality (Brossmann, 2013). No fewer than 3.8 million children and adults died prematurely from illnesses caused by house hold air pollution (WHO,2018). Acumen survey data,2017 shows, of 11 countries in Sub-Saharan Africa found that among health facilities that had an electricity supply, only 28% received it regularly (Kat Harrison, 2017).

The waste collection or disposal end-of-life recycling does not exist in rural Africa, neither for household waste nor for hazardous waste (Mudhoo et al., 2015). The dry cell battery used to radio and battery for light contain lead, cadmium and mercury, which the World Health Organization rates among the "ten chemicals of major public health concern (WHO, 2017).

2.4.2. Improving Education

Sub-Saharan Africa has the lowest rate of primary school electrification, only 35% of schools having access electricity (UNICEF, 2015). About 90 million pupils in the region attend a school with no access to electricity (Practical Action, 2017). For better access to lighting for children at home appears to increase study hours, a school's access to electricity may influence the motivation of its students, children can spend more time on education and homework, to increase study time or school attendance, to support preparation of teacher, to facilitate trainings for community members and to use educational aid electronic equipment solar energy is better supporting flow of rural learning teaching technique (UNICEF, 2015).

Kerosene and candles can limit students' study at home due to less brightness of light can make children inefficient and less focused on their work, serious air pollution emitted from kerosene candles harms children's visionary and air quality-related health and Fire risks posed by kerosene candles discourage children from continuing to study (Furukawa, 2014). Many SHS experts pointed out the possibility of school going children to study under electric lights in the evening to be a very important and inspires children to engage in more studying (Harun, 2015). Lighting also as an influence on school attendance, specifically in areas such as the rainforest where penetration of sunlight is poor and lighting required during the day (IEA, 2016a). SHS has provide opportunity of access to educational program in TV, Radio, mobile, Lighting helps to adult education at night school (Harrison et al., 2016).

Service sarl study data shows that, before solar light ownership, children were studying for 1.7 hours on average each night, and were often constrained by lack of access to light due to money for kerosene, or candles running out. After purchasing a solar light, children in the same households were studying for an average of 3.1 hours a night (SNV, 2012).

In Bangladesh Over 40 % of the SHS users stated that improved study conditions was one of their main reasons to purchase a solar system (Brossmann, 2013); In south Africa NuRa Energy concession areas of households survey data indicate 89% SHS has positive effects on their children's education (Azimoh, Klintenberg, Wallin, & Karlsson, 2015). Also Carbon less clear light like SHS motivate rural children to engage more time in reading and studying (Harun, 2015).

As general, energy access provides a series of benefits to the education sector and facilitates the utilization of potential that otherwise would be lost: the application of ICTs such as laptops, internet, and music players facilitate higher quality education for children and may even improvement their intellectual reasoning (UNICEF, 2015).

2.4.3. Information Facilities

Lighting was the most popular application, access to various entertainment and Communication facilities (Energy pedia,2018). SHS provides facilities to get information and entertainment through using TV, Radio and mobile phone. SHS are assumed to enable users to access information more easily through a TV or radio at home as well as improved lighting conditions to read the newspaper more frequently (Brossmann, 2013;Furukawa, 2014).

The study indicates, in Bangladesh 95% of SHS users reported that their access to information through mobile phone, TV or radio had been improved by their SHS (Urmee & Harries, 2011). As maximum SHS power is between 50 to 90Wp, use of black and white television sets is very much common in SHS-household (Harun, 2015). As a source of education and entertainment, TV offers useful information that can enhance knowledge and awareness of events and activities that are economic and social situation (Khandker et al., 2014).

The Internet has now made it possible to obtain and share information like education and health issues with local and international organizations such as NGOs, farmers' organizations, and women's organizations, increase in decision-making power (Grimm, 2014). Also, open opportunity to international development agencies and national development partners are already experimenting with new information technologies and electronic communication networks for rural development (Kabir et al., 2017). SHS power also provides other benefits by facilitating information flows for both consumption and production day to day economic data (Khandker et al., 2014).

2.4.4. Strength Social Framework

SHS increasing social gathering for watching T.V, radio & other electrical devices, spend time together as a family, eat together and share experiences of the day (Harun,2015). It benefit for socio-economic development framework and increase leisure time (Khandker et al., 2014). The presence of electricity also increases their social status among their peers, since, in many cases, relatives from neighboring communities visit them more often to enjoy these benefits friends entertain by important program watched by all household members and in almost every household (Dimitriou et al, 2014). Mobile phone helps in close contact between relatives, friends and neighbors (Harun,2015). Watching TV and using internet service perceived as an entertaining activity by the SHS users (Brossmann, 2013).

2.4.5. Benefit on women's and children use of time

There is a clear and important intersection between access to energy and gender equality (IEA, 2017). Women benefit more than men from some of the determined outcomes including the improved indoor air quality and the overall working conditions in the house (Brossmann, 2013). In developing countries, women tend to accept responsibility for collecting and preparing fuel for cooking (Practical Action, 2016). SHS benefit for use children and women to spend time for buying kerosene and collecting wood (Practical Action, 2017*;* Rao et al., 2016).

Households dedicate an average of 1.4 hours a day collecting fuel, a burden born mainly by women and children (IEA, 2017). According to acumen's data study in Africa shows, an average of 3.5 hours saved per month from avoiding going to market to purchase kerosene or candles, and visiting kiosks to charge phones (Kat Harrison, 2017). Solar PV technology program in remote, rural and off grid villages have a great impact especially on women and children provide energy access to the vulnerable population like women and indigenous people (Feron, 2016). Further than to this, women and children in particular will have more time for education, leisure and economic activity (Harun, 2015).

2.4.6. Safety and Security

SHS provide an increase sense of security to households from socially desirable things happening around them (Harrison, 2017) . SHS illuminate indoor house as well as some area of surrounding households, which increase safety for the household member, especially for the women and children decrease stealing in household (Harun, 2015;Orlandi et al., 2016). Related to this good illumination at night provides protection against reptiles and reduces the rate of theft in the villages (Azimoh et al., 2015). It has also reduced the use of candles and fire wood there by decreasing the risk of fire accidents (Harrison et al., 2016).

In East Africa, over 60% of customers surveyed by solar companies had an improved sense of security (ibid). In Uganda, solar kits have been used by some households to provide security lighting at night (Orlandi et al, 2016), in Kenya they have been used to deter wildlife damage to crops and livestock (Kat Harrison, 2017). In this way, solar lamps contribute to defensive capacity, and mitigate the risk of losses. In other way, SHS is free source of energy means the sun provide more energy than we could ever use, so no one can monopolize or restrict the sun light (green match,2018). Accessibility aims at equal opportunities to receive clean energy for all population lead to good governance and security of community by determines the equity between different groups of people like gender and race (Harun, 2015).

The other related problem on firewood collection presents large physical and time burdens which disaster settings, however, firewood collection can also put girls and women at great risk of physical or sexual assault and injury due to the distances they must travel in a context of immunity, armed violence and/ or increased community tensions (UNICEF, 2015).

2.5. Economic Benefit of Solar Home System

2.5.1. Avoided Buying Traditional Light Source

The Africa development bank data shows that in Ethiopia source of light from 2011 to 2014 decrease due to dissemination of modern energy. Kerosene light lamp (local kuraz) decrease from 41.23% to 33.54%, firewood in 2011 decrease from 12.99% to 9.68%, candle from 0.24% to 0.08%, and from renewable energy, Solar energy increase 0.13% to 3.05% (Africa development Bank,2017). However rural people until using traditional light source. According to Tilahun study in Benchmaji rural area 23% use dry cell batteries, 17% use kerosene, 16% use firewood and 3(1%) use diesel Generator and the rest use SHS to be the household's main source of energy for lighting (Tilahun,A. 2018).

Because one of the main uses of the SHS is for lighting (world bank,2013). A kerosene lamp producing 37 lumens for 4 hours a day will consume about three liters of kerosene per month and 30 W SHS substitutes the use of 3 kerosene lamps with brighter LED lighting (GmbH, 2014). SHS householders who used solar-powered LED lights avoided buying kerosene every month for kerosene lamps (ibid).The LED bulb is perceived as a qualitatively better light beyond its capacity to replace kerosene lanterns (Grimm et al., 2015). Some rural households using of kerosene due to needs small amounts of money every week and every month compare to SHS invest a relatively high amount of money at once (Hoque & Das, 2013). But, kerosene prices are an estimated 46% higher in rural areas of Africa compared to urban areas and in East Africa kerosene is the main source of lighting prior to solar light purchase (Kat Harrison, 2017). Rising fuel prices SHS technologies may become more cost-efficient than off-grid alternatives based on fossil fuels (Harun, 2015). Estimates that $10 solar lights can help African families save an average of $60 annually, simply by not using kerosene for lighting purposes (world Bank, 2017). The other household source of light in Africa was torch and it was short life-span and require frequent battery changes (Lighting global, 2018). After SHS installation, monthly kerosene expenditure decrease saves users time, money, and energy for purchasing and transporting kerosene from markets and, maintenance costs are projected to be minimal over 25 years (Grimm, 2014;Kabir et al., 2017).

There is evidence that introducing an SHS reduces household expenditure on other items, such as kerosene (Khandker et al., 2014). Possibly it use leaving women with additional disposable income (Practical Action, 2017). Solar home system also contribute to absorptive capacities and households' ability to respond to disasters, strengthened through higher incomes and expenditure, livelihood diversification (Kat Harrison, 2017). The study shows, in Cameroon households including transport for lighting spend around 78 million USD per year (SNV, 2012);comparing the status daily costs for kerosene for households in Kenya, the ten weak cost for spending on kerosene equivalent to one year Pico home system (Alstone, Gershenson, Turman-bryant, Kammen, & Jacobson, 2015). In currently, the cost reduction of solar system may afford to the demand of the community relative to kerosene (Orlandi et al, 2016). Also, consumer finance, micro-finance and pay as you go solutions can help to the initial investment cost (Harrison et al.,2016). Indirectly financial savings on SHS made possible by reduced energy expenditure or higher incomes.

2.5.2. Expand Small and micro Enterprises

Electricity is considered a powerful instrument for raising productivity and improving living conditions (WHO,2013). Off-grid PV systems can promote local economic development since rural electrification has the potential to contribute to the user income (Feron, 2016). Solar systems can be used to start new or extend existing income-generating activities at home due to improved lighting in the evening hours (Brossmann, 2013).

The study shows in Bangladesh, 30 % of the surveyed house holds the electrification impacts on expenditure of households and by SHS their domestic goods can increase by 23-27 percent from previous goods (Khandker et al., 2014). Electrified regions enable to attract more consumer and generating higher profit due to local employment opportunity contributes to night trading and the consumer attract by appliance like television programs (Rao et al., 2016). Study found that, in Ghana an average income of solar electrified enterprises was 82% higher than non-electrified enterprises, In Uganda with solar home systems experienced higher profits due to their ability to attract new clients with 12% more businesses reporting growth in sales than those without home systems and 91% of business-use customers had seen increases in their income of nearly 60% on average (Kat Harrison, 2017).

The sum spent on a solar PV system would increase the economic well-being of households much more than lighting (Baurzhan & Jenkins, 2016). As people emerge from poverty, demand for energy will increase, and power system planning will have to account for spillover effects

(Dahlke, n.d.). Furthermore, poverty reducing impacts could also be achieved by promoting larger-capacity SHS that can be used for income-generating activities (Kabir et al., 2017).

2.5.3. Avoid Consumption of Appliance

In fact, many rural off grid area mobile phone and other electronic device are presence which charged that electronic appliance by extra expenditure. SHS avoiding the cost of recharging mobile, battery of recorder and radio (Brossmann, 2013). In Bangladesh, the consumption of dry-cell batteries is reduced by using SHS between 1.6 and 1.8 pieces of these batteries are use every month (Brossmann, 2013). The data shows, in Cameroon households including transport for recharging phones spend more than 52 million USD and for battery torches they spend 43.39 USD per year (SNV, 2012). Households which buy SHS increase their income by charging mobile, by watching TV and by giving service for appliance (Harrison et al., 2016).

2.6. Solar Home System Benefit for GHG Emission Reduction

Governments is to limit global warming to an average of no more than 2 °C, relative to pre-industrial levels (ECOHZ, 2017). United Nations and others global organizations are working to protect the natural environment reducing global warming for human well-being and development (Harun,2015). During the combustion of fossil fuels, the greenhouse gases CO_2, CH4, and N_2O are emitted to atmosphere (EPA,2016).

In developing countries, the populations without electricity use mostly kerosene based lighting, which poses serious health and safety hazards, along with contributing to global warming (Khandker et al., 2014). A recent study in Kenya found a 61% reduction in airborne particulate matter in the main living space of households that adopted a solar light (Lam et al., 2017). The United Nations Environment Program (UNEP) estimates that, replacing all fuel-based lamps with modern energy efficient lighting would save 90 million tons of CO_2 annually (UNEP, 2013). Kerosene lamps emit both carbon dioxide (CO_2) and black carbon which a result of incomplete combustion of fossil fuels, biofuels, biomass, carbonaceous material (Tedsen, 2013). These Particles absorb sunlight and heat the atmosphere, increasing radiative forcing, and are a major climate warmer, second only to CO_2 (Monarchsolar,2017). In developing countries, the populations without electricity use mostly kerosene based lighting, which poses serious health and safety hazards, along with contributing to global warming (Lighting global, 2018).

The annual greenhouse warming contribution of black carbon emissions from simple wick lamps and hurricane lanterns is equivalent to 240 million tons of CO_2 and reducing lighting-based black carbon emissions by 50% would be equivalent to a 2.5 GW ton reduction in CO2 over the next 20 years (lighting global, 2014). This must involve the transformation of the energy sector, as it accounts for roughly effective action in the energy sector by using renewable energy like solar energy (IEA, 2016). Switch to a low carbon economy is characterized by a vision, based on the long-term, socio-economic, and environmental benefits of greenhouse gas emissions reduction (Ministry for Europian, 2016). The impacts of climate change on societies around the world are evident and there are no global warming emissions associated with generating electricity from solar energy (Brossmann, 2013). Due to their relatively low environmental impact, PV technologies for rural electrification yield long-term benefits in terms of pollution abatement and climate change mitigation (Feron, 2016). Avoid GHG emission by replacing kerosene lanterns with cleaner, safer alternatives like solar products help reduce household air pollution, reduce carbon footprint which the amount GHG emission caused by individual or group during burning fossil fuel (Energy pedia,2018; Monarchsolar,2017). Generally, the dissemination of SHS is believed to contribute to a cleaner living environment have two different outcomes: a reduced contamination through toxic waste and decrease kerosene related significant amounts of CO_2 and black carbon emission.

3. RESEARCH METHODOLOGY

3.1. Description of study place

3.1.1. Location

The study was conducted in Gesha wereda, Gesha is located in geographical coordinates: a $6^{0}35'0''$ N latitude and $35^{0}28'0.00''$ E longitude (landpidia,2016). This wereda is one of among 13 wereda in Kaffa zone and, is located 538km west of the capital Addis Ababa and 126km from the capital city of the zone, Bonga (Wikipidia,2019). Gesha is bordered on the south by Bita wereda, on the west by the Sheka Zone, on the north by the Oromia Region and Sayilem wereda, and on the east by Gewata wereda. Gesha wereda contain 25 kebele including Deka Town.

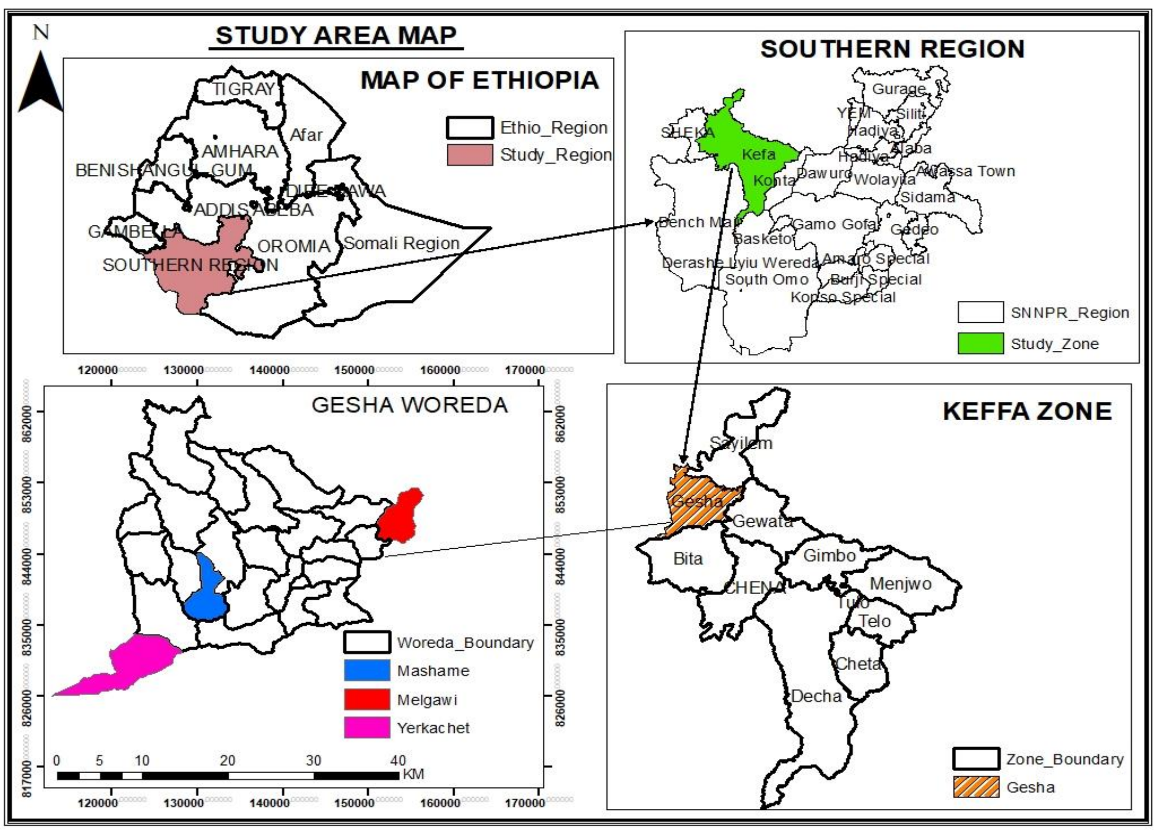

Figure 2: study area map

3.1.2. Topography

The area has a varying topography composed of steep 25%, mountains 50%, and plateau 25%area that covers. The area is characterized bimodal rain fall pattern having the mean minimum 1750 and mean maximum annual rain fall is 2200mm. The land is moderately/intensively cultivated and an area of around 10 km * 20 km with undisturbed montane broadleaf forest (Abraham, 2018). It has a humid climate having the mean maximum 24 °C and mean minimum temperature of 14 °C, the altitude ranges from 1500-3000m (landmapia, 2014).

3.1.3. Socio Economic Characteristics

Based on the 2007 Census conducted by the CSA, this wereda has a total population of 85,104, of whom 41,441 are men and 43,663 women; 3,433 its population are urban societies. The 1994 national census indicates Gesha had a population of 117,121, of whom 56,929 were men and 60,192 women; 2,579 or 2.2% of its population were urban dwellers (way back machine,2015). Concerning education, 15.73% of the population were considered literate; 10.98% of children aged 7-12 were in primary school; 2.44% of the children aged 13-14 were in junior secondary school; and 0.57% of the inhabitants aged 15–18 were in senior secondary school. Concerning sanitary conditions, about 7.72% of the urban houses and 9.6% of all houses had access to safe drinking water at the time of the census, while about 5.25% of the urban and 49.34% of the total had toilet facilities Gesha suffers by poor infrastructural facilities like road & electricity. The altitude of the district ranges from 1500-3000m (Debebe,2018).

3.1.4. Farming system

The crop production of the study area is traditional and rain-fed. The farming system is characterized as mixed crop-livestock production system and depending on the prevailing agroecological conditions, different crops are grown, and of these, maize, sorghum, barley, wheat and teff are the main cereal crops, Enset (Abraham, 2018). The soil type of the area is dominantly Nit sols with clay loams in texture and acidic in reaction which is agriculturally productive. Cattle rearing are one of the sources of livelihood in the studied woredas. The forest consists of forest Arabica coffee, evergreen mountain forest, traditional honey collector box survival widely in forest and western boundary constitutes the Gesha National Forest Priority Area (Debebe,2018).

3.2. Research design

This study was adopted a descriptive survey research design. The main target to select this design was researcher aim to collect, describe, analyses and concluded the characteristics or behavior of existing condition. Which was useful to obtain information concerning the status of the SHS benefit to population, "What exists" with respect to economic, social and environmental conditions in SHS. The exist things was the effect of traditional light source and the positive impact of solar home system. This study data was utilized rural kebele people who was homogeneous in the culture and norms.

3.2.1. Sampling Techniques

The study used both purposive and random sampling methods. Gesha wereda was selected purposively due to the population homogeneity in culture and norms, the presence of solar home system distributions and the shortage of grid power (kaffa zone energy office annual report, 2018). From 25 kebeles of Gesha wereda, three kebeles was sampled purposively by considering the number of solar home system dissemination and solar coverage. These sampled kebeles are maligawi, meshami, yerikichiti kebeles. According to annual Gesha wereda water, mines and energy office reports,2018 on those kebeles, the solar coverage was in maligawi (78%), meshami (82.5%), yerikichiti (74%) relatively higher than other kebeles (Gesha wereda energy office desk file, 2010-2018). Sample households was selected through Random Sampling (RS) method based on Probability Proportional to Size (PPS) method. HH list of each selected kebeles collected from a list of households obtained from the administrative records of each kebele.

3.2.2. Sample Size Determination

For this study, the sample size (n) was determined using the formula proposed by Yamane, 1967. The precision level assumed to be committed in this study was taken to be 6% (0.06), with confidence interval of 94%.

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

Where n is the sample size, N is the population size (total HHs in sampled kebeles) and e is level of precision.

$$n = \frac{2021}{1 + 2021\ (0.06)2}$$

$$n = \underline{\underline{244}}$$

The respective numbers of households were allocated for each sampled kebele based on PPS of each selected kebeles as indicated in the below table.

Table 1:Distribution of sampled households in each kebele

No.	Name of Kebele	Total Number of HHs	Number of sampled HHs
1	Melegawi	$N_1 = 612$	$N_1/N*n = 612/2021*244 = 74$
2	Meshami	$N_2 = 724$	$N_2/N*n = 724/2021*244 = 87$
3	Yerikicheti	$N_3 = 685$	$N_3/N*n = 685/2021*244 = 83$
Total		N = 2021	N = 244

From the total sample size (244), 10 HHs were not interviewed due to local security problem (in meshami kebele). This means that, 234 (96%) household respondents were included for data collection. But, out of the interviewed, 5 respondents' response were found to be incomplete. As a result, the valid data were collected from 229 (94%) HHs. Sample size was including adopters of SHS due to they have significantly shows the previous traditional light source effect and the role of SHS from their experience, the previous adopter energy pattern and current energy pattern of non-adopter almost similar. So, the survey data obtain from adopter households well to shows the role of SHS in rural area (Gesha wereda desk file data,2013-2018).

3.3. Data Types and Sources

In order to generate the necessary data for this research work, the study used both primary and secondary sources of data's. Primary data obtained through household surveys using structured questionnaires, Key Informant Interviews (KII), Focus Group Discussions (FGDs) and field observation. Whereas, secondary sources obtained from published materials (available in the form of journals, articles, thesis, and websites), and unpublished documents (zone, district and kebele office reports) as both soft and hard copies.

3.4. Method of Data Collection

The study involved a range of data collection methods from both primary and secondary sources.

3.4.1. Primary data

Primary data were collected from questionnaire, focus group discussion, key informants interview and direct field observations.

3.4.1.1. Household Survey

The household survey was conducted with sample HHs. A detailed and well-designed structured questionnaire was developed in a way that enables to gather full information about the study's objectives. Households survey questionaries' was prepared related to contribution of solar home system in English language and translated to kafigna language. The data collected through direct interview of the sample HHs using the questionnaires. The questionnaire was pre-tested among seven randomly selected households from sampled kebeles to detect misunderstandings, ambiguities, or other difficulties of participants.

3.4.1.2. Key informant interview

Key informant interviews is a qualitative in-depth interviews with people who know what is going on in the community. The purpose of key informant interviews is to collect information from a wide range of peoples including zone and wereda energy expert, NABU expert, kebele leaders, heath center extension, school leadership, wereda women office expert with their particular knowledge and understanding, can provide insight on the contribution of solar home system to socioeconomic and environment. Interview was guide to set the general topics and create stimuli for the discussion. This allows clarity of ideas and information and, obtain information from many individuals, including minority or silent majority viewpoints. Generally, the interview was carried out with a total of 18 key informant interviewees which have included 3 from zone expert (zone energy expert, NABU experts and environment conservation office expert), 3 experts from wereda each office expert i.e. energy office expert, women office experts, heath office expert, 6 from kebele school directors and health experts (1from school director and 1 from heath expert from each kebele), 6 elder informants (two from each kebele). Due to general questionnaire, the average duration of interviews was about 35 minutes and it is found interviewed household members showed good interest in the survey activities.

3.4.1.3. Focus group discussion

This method aimed to obtain from purposely selected group of individuals the social, economic and environmental benefit of solar home system to study area. The relevant of this to allows the interaction with range the key informant and the researcher to focus group norm and dynamics related to the uses of solar home system. A total of six FGDs was conducted on (two FGDs in each kebele with seven participants in each FGDs) by researcher and woreda energy expert. The discussion was including women, small enterprise, solar seller, kebele leaders, omo agent, heath extension, kebele police and kebele model farmer. The qualitative information gathered their thoughts, opinions, and ideas related to the contribution of solar home system and the effect of kerosene and wood for lighting purpose. The average duration of FGDs was about two hours and 15 minutes with good initiative and freely talked the existing phenomena.

Figure 3: FGD participant in maligawi kebele

3.4.1.4. Field observation

In addition to key informant interview and focus group discussions, for this study field observation was conducted to understand the contribution of solar home system for lighting and other appliance purposes. This method particularly was used as a supportive or supplementary technique to collected data that can complements the information gained from documents and key informants. In addition, this observation was used to counter-check information provided by household respondents and focus group participants.

3.4.2. Secondary data

The relevant secondary data was collected from different sources such as published and unpublished books, journals and reports. Other data's available at kebele, district or zonal level was also used. Different websites were visited for the purposes of literature as well as for general analysis of the document.

3.5. Data Collection Procedures

The data collected in three rural kebeles of Gesha wereda through nine data collectors (three from each kebele) involved for data collections and they speak kafigna language. For follow this questioner the collector train two hours training related to the method and best data collect technique. The data collected within three weekends in the morning and afternoon. This is because the respondents are farmers it is in Sebastian days that the data collectors more probably get the respondents free of work at home. Each data collector spent the full weekend's days in their kebeles and the researcher supervised them. The semi-structured interviews and the FGDs with KIs were held by the researcher within three weeks' side to side the questionnaire.

3.8. Method of Data Analysis

The data obtained from both primary and secondary data sources was analyzed by using both qualitative and quantitative method of data analysis. The qualitative data's collected through KIIs, FGDs, and observational notes was transcribed, categorized, and interpreted qualitatively.

The quantitative data obtained from questionnaire data was analyzed by using descriptive statistics such as frequency and percentage to identify the economic, social and environmental benefit of solar home system compare to traditional light source.

The economic benefit analyzed based on the information obtained from survey, interview, focus group discussion and desk file which includes stakeholder discussions, sector knowledge of experts and sector desk file data. The data estimated expenditure of an average consumption of energy cost. The calculations are based on the study done by world energy congress,2011 and the results obtained would be used as a representative data for understand the benefits of the solar home system. The cost benefit analysis has been mainly taken from the local market of study area and the calculations have been carried out in Ethiopian birr (ETB).

The benefit of SHS to reduction of greenhouse gas emission based on IPCC default net calorific values emission factors and carbon storage in forests calculated by taking the amount of fossil fuel generation offset and multiplying by the average emissions rates for those fuels. Moreover, both Microsoft Excel and Statistical Package for Social Sciences (SPSS) version 20 used to analyse the data and present the findings.

4.RESULTS AND DISCUSSION

4.1. Household characteristics

4.1.1.Demographic analysis of households

A total of 229 respondents, 64.6 % male and 35.4 % female, from the three kebele were interviewed. In our country context the age categories 18-35 young, 36-49 youth and over 50 years was elders (Ethiopian young and youth policy,2015). This means that in the study area male household heads are more new technology adoption decision takers than the female counter parts. This may be because; rural female household heads are unable to access different sources of information about the new technologies since they spend most of their time at home to carry out in door tasks. This finding agrees with (Rebane et al., 2011), they analyze the determinants of SHSs awareness and adoption in Nicaragua. They use survey data from 158 households in rural Nicaragua, 40 of which had adopted SHSs. They found being male as a positive determinant of SHSs adoption decision.

The number of respondents between the age of 18-35 was 48.5%, 36-49 was 36.7% and over 50 was 14. 8%. This shows that the largest proportion of the respondents was aged between 18 up to 35 years. As a result, they were adopting the solar technology and beneficiary than other age group of households. But not mean that all young's directly adopting the solar technology and this may be because of older people are more conservative towards accepting new technologies and instead they prefer to continue using the technology they are used to practice and easily attracted by the new technology than the other age group of households. The marital status of respondents shows that 82% were married, 5.6% unmarried, 9.2% divorced and 7.4%

widows. Therefore, these findings indicate that the probability of a household's SHSs adoption preference is based on its cleaner and smokeless, convenient to use, replace kerosene and dry cell batteries, mobile phone charging and helping all types of marital status. However, most of widow and divorce households told they have satisfied by SHS as it made their life easy due to more responsibility of buying and collecting firewood in the study area was for women and children.

From the total respondents, 53.3% were literate (can read and write) and 46.7% cannot read and write. From the result literate level of households not significant difference on technology adoption. The averages family size of respondents was 5 and the range was 2 up to 13. The survey data indicate most households which have children have the probability to buy SHS than small family size this may be households have more reason to choice the technology like to improve their study time, to save their time, to save mobile exaction costs, to use many light service than small family.

4.2.2. Overview about rural household SHS system

Most of solar home system installation was done by wereda experts and the solar panel was placed in the roof of their house. Few households placed their solar panel at the top of constructed buffet. From the total SHS, 55.5% was purchased by credit (i.e. 77 % of maligawi and 84% of yerikichiti kebele households took from REF program) and 45.5% were purchased directly from solar suppliers.

Figure 4:The installation of SHS in study area

Of the total SHS, 34.5% were installed in 2013,7% in 2014,10.5% in 2015,36.2% in 2016, 5.7% in 2017 and 6.1% in 2018. From interview and FGD result, households use SHS for light purpose in night time after 1pm and in average they use for 4-5 hours per day and, SHS life time was vary seasonally in winter and summer. Some households to save battery they give priority to appliance and first they preferred to light. The survey data shows in figure 4 households use SHS in average 4.6 hour per day.

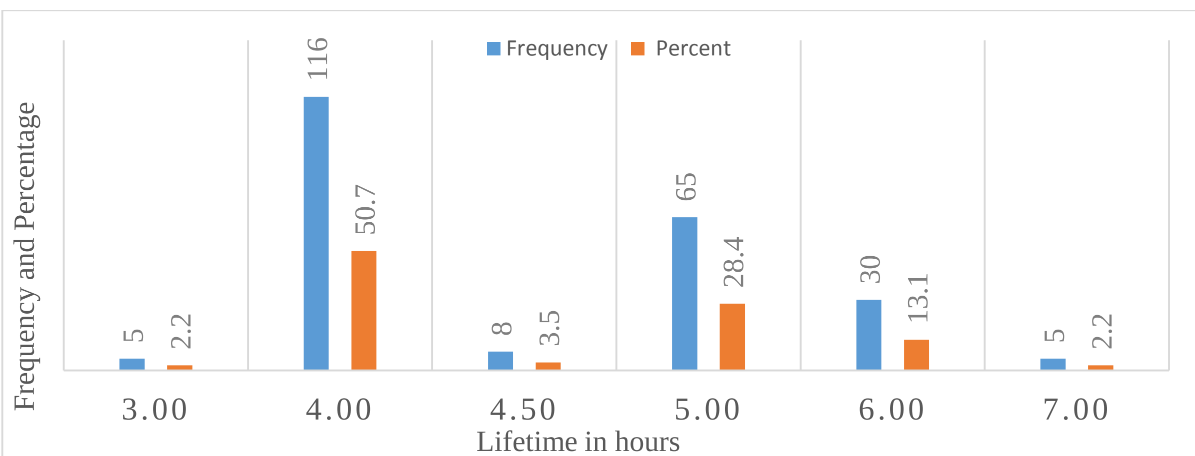

Figure 5 :The lifetime of SHS in frequency and percentage

The survey data shows dominantly most of beneficiary of SHS capacity was 10W and 20 W solar system as shown in figure 5. The system service includes lamps, Mp3 player, charging electrical appliance. This result similar with the study of Gerlach,2009 idea of nearly all Ethiopians in rural areas could have access to electricity and they could afford it. These estimates show that 70% of rural population would significantly improve their standards of living and effectively save money for energy needs if they had access to SHS in the power range of not more than 20 W.

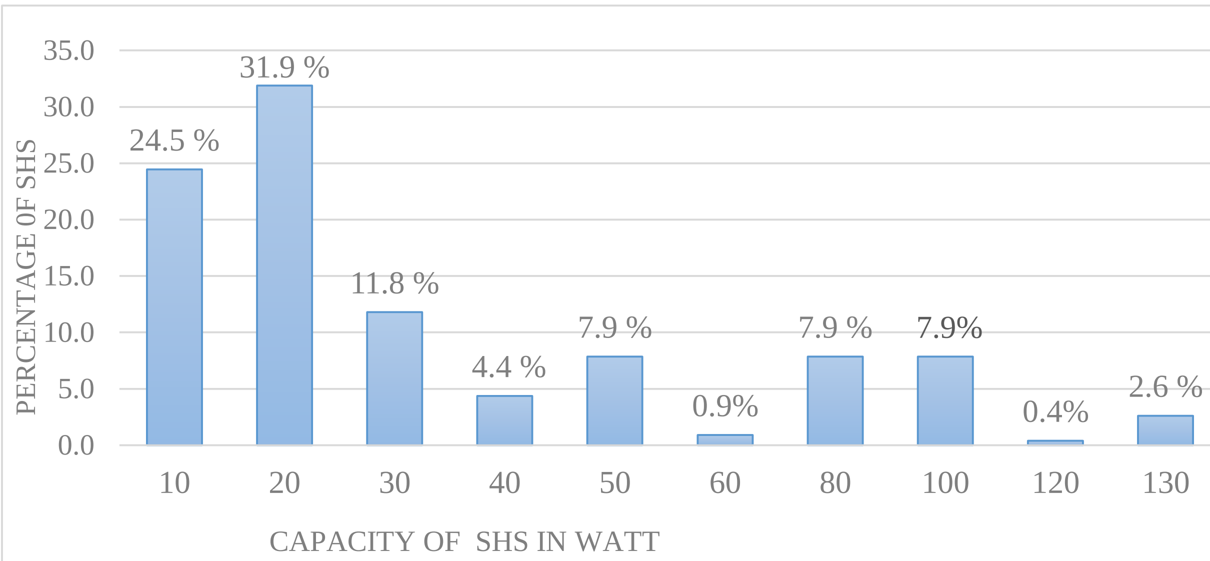

Figure 6: The capacity of SHS in percent

4.2.3. Main reason of households to buy SHS

As the survey data shows the main reason that all households choose solar home system is to run as a lighting device. This indicates that light is the primary benefit generated from these systems. About 92% of households buy SHS to improve educational quality of their children and to avoid traditional light expenditure,82.9% to decrease house hold air pollution,79% to get information by using TV, radio, mobile and the likes. From the interview and focus group discussion it is possible to understand that one of the reason which forced them to use SHS was the strength implementation of rule and regulation on deforestation. The conservation of forest gain attention due to the forest register by UNESCO and NGO like NABU have work strongly on the preservation of forest by their own experts. However, the Kafa Biosphere Reserve there is a high potential and numeral benefits of using solar energy in the area (GM clean Energy Fuel Effiecient Technology, 2015).

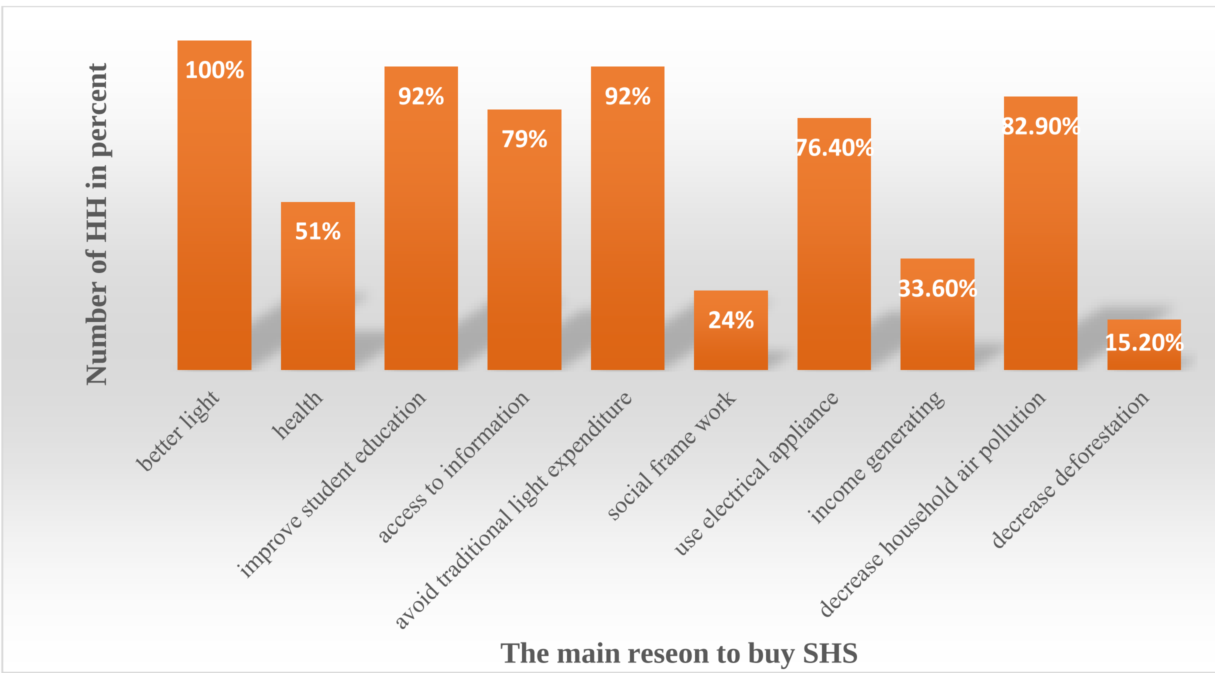

Figure 7: main reason of HH to buy SHS in percent

From this analysis, while disseminating SHS to households describing the benefit to health due to solar home system is free from air pollution and its give better illumine light than other traditional light source. This finding agrees with (kat Harrison,2016), it found solar home system creates opportunities through extra lighting hours and better lighting quality for income-generating activities and productive work-hours in the home. In addition, this study agrees with the World Health Organization's (WHO,2014) Guidelines for Indoor Air Quality state that existing evidence shows that household use of kerosene can lead to particulate matter which dangers to human health. Education is the other reason for households to buy SHS because of many households have children and they find to improve their student time and doing homework time by good illumine light. Access to information was the other reason to by SHS due to network were available in study area and user have more chance to use social media and broad cast information for communicate and share idea in simple way they charge their phone by using SHS. Energy access, and lighting particularly, can provide opportunities for social interaction. 24% households decide to buy SHS for opportunity to strength their social unity. Because one of the positive impact of SHS create socialization in community by watching TV together, by share new information with friends. This study in Bangladesh agreed that Many pico-solar light users talk of the opportunity to spend time together as a family, eat together and share experiences of the day. All SHS user respondents of (Urmee & Harries' ,2011) SHS increased their time spent in relaxation and their ability to get together at night and enjoy the high quality light. 85% of pico-solar light users across Africa said that having a solar light affected the activities they were able to do at night (Solar Aid, 2012-15). Access to electrical appliance and decreasing household air pollution initiates other non-adopter by indicating the best practice of beneficiary. This electrical appliance has no extra expenditure like other appliance that using dry cell like flash light and radio. Therefore, these result indicate that the probability of a household's SHSs adoption preference is based on the socioeconomic benefit of solar home system and but, they should better understand benefits of SHS to reduce global warming by decreasing individual footprint and deforestation. Because SHS have significant positive effect on climate change.

4.3. Social benefit of SHS

4.3.1. Solar home system used to improve health of rural community

The access to solar electricity in rural areas enables to keep human health of rural community. But, it was difficult to measure the kerosene effect on health of households. But, known that kerosene lamps cause respiratory problems.so the introduction of lighting from clean energy sources improves the residents' health. The survey data as shown in table 3, households before they install SHS their eye and lung affected by kerosene and firewood was 51.1% and 29.7% of respectively. In three kebele FGD health experts told the reason of affect mainly illumination and house air pollution of kerosene during their children done their homework and households using light at night time. In addition to this other disease related to breathing system slightly decreased may the reason households by installing SHS decrease the effect of kerosene lamp. Decrease in kerosene lamp usage translates into a perceived improvement of perceived air quality and, potentially, into a decrease in respiratory disease symptoms and eye problems (Grimm, 2014). Solar household systems can also keep families and communities safer by reducing the use of flame-base lighting, thereby reducing the risk of burns, accidents and fires. Due to its high combustibility, the use of kerosene as a lighting fuel also presents a serious fire hazard. The survey data also shows, before installation of SHS, 3.9% house blaze accident was occurred due to firewood and kerosene. This study similar with the study conducted in Bangladesh 23% of burns among infants were due to kerosene lamps (Orlandi et al., 2016). SHS in Bangladesh were found not to improve health outcomes directly, the consequent TV ownership and knowledge of disease led to improved health outcomes (Khandker et al., 2014). This information facility of households may increase the awareness of households on the effect of households' air pollutions. In addition to this, from 15 package of health office one was reducing air-pollution by disseminate renewable technology to households done by zone to health extension (GM clean Energy FuelEffiecient Technolgy, 2015).

Table 2: Kerosene effect on health

Kerosene effect on health	Response of respondent	Frequency	Percent
Kerosene effect on eye	Yes	117	51.1
	No	112	48.9
	Total	229	100.0
Kerosene effect on lung	Yes	68	29.7
	No	161	70.3
	Total	229	100.0

4.3.2. Solar home system used to improve education of rural community

FGD and interview result shows that as solar home system has better illumination, it has an advantage for teachers in rural area as they can deliver their action plan effectively. In addition to this, students are also advantageous as it allowed to work their homework at night time. Survey result indicates, before the introduction of SHS most of students were able to do their homework during the day time, and few were able to study at night using kerosene lamp, firewood or candle lighting for limited hours. About 80.8% household used SHS for reading and doing their homework. An increase in home study time was found in about half the households in Ethiopia that had acquired an SHS (Barnes et al., 2016), In three kebele, after purchasing a solar light, student in the same households improved their study and doing homework hours from 30 minute to 3 hours per night. While the study was not specifically on solar PV electrification, the findings may also apply to the linkage between solar PV electrification and children’s extended study, particularly after sunset when lighting services are most needed (Onsomu,2013). Maligawi kebele director in the interview told most of students have shown progress of result, decrease absence to school and increase motivation to do their homework after installation of SHS. This result in line with the idea of providing better study environments improving children's learning positive impact on the result of student and in Uganda students study hours increase per night from 1.47 to 2.7. It can be expected that facility of solar lamps may actually have a limited impact on children's achievement (Furukawa, 2014). The study time and doing homework hour result compare to the lifetime of SHS was not enough. May be working hour, human behavior, experience of study, society concept, culture and environment effect on study hour.

4.3.3. Solar home system opportunity to information facility

Information to rural community is used for better life and motivate to transmit their life style to modern way. Households used to SHS mobile television and radio. In FGD and interview, the community said that SHS increased the opportunity to access information through watching TV, listening to radio broadcast information, provided better communication opportunities through social medias and using internet by mobile phones. As they have said through these information medias, they improved their health quality by informed the effect of traditional light source, they are informed about new technological innovations and daily country situation. Households use SHS for getting information from different sources as shown on table 9.

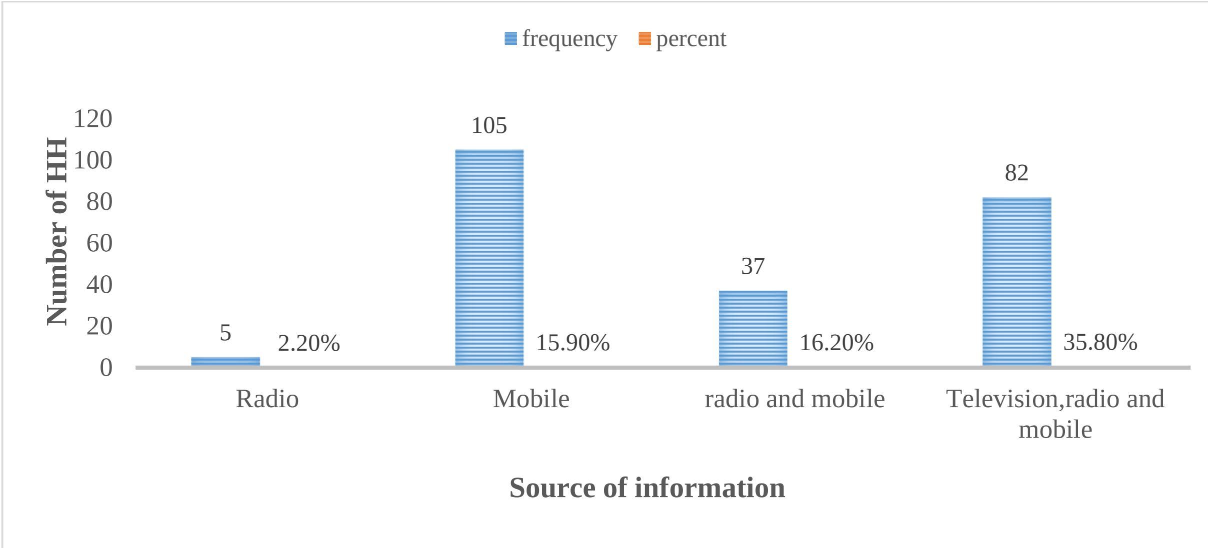

Figure 8: Households source of information

The study in Bangladesh, 95% of SHS users reported improved access to information through mobile phone, TV or radio about general news, health-related issues, weather and natural disasters (Urmee and Harries, 2011). The result shows almost all households found information facility by different source of information and solar home system able to satisfy the need of households.

4.3.4. Solar home system give opportunity for social unity

Good lighting an opportunity to strength social unity of households. The result from interview and from FGD of the qualitative data shows installing SHS open the opportunity to spend time together as a family, strength diversity, eat together and share experiences of their day to day life. The response of HH survey showed that, 70.6% agreed SHS had increased their social approach, stating that neighbors and relatives from other villages visits their houses more often to enjoy the clean lighting and strength their unity.

4.3.5. Advantage of SHS for saving women and children time

In most of rural community, women and children have the responsibility to buy kerosene and collect firewood. FGD it was possible to understand that meshami and maligawi kebele households spend half to one hour for purchasing kerosene and 1 to 2 hours to collect fire wood. From field observation, it has seen that before they install SHS most of the yerikichiti kebeles moves around 45 one and half hour to buy kerosene from market two times a weak. The survey data shows women working hour was saved to an average of 31.4 minute after installation of SHS. From interview, some women express SHS decrease the load of work and increase of the working comfort due to they do their work by good illumination at night time. Time saved through as they save their time access to solar home system can be taken towards education, social and family activities, and economic opportunities.

Table 3: SHS for saving women and children time and for entertainment

SHS used for women and children time	Response of respondent	Frequency	Percent
SHS used to consuming women and children	Yes	178	77.7
	No	51	22.3
	Total	229	100.0
SHS used to entertainment	Yes	173	75.5
	No	56	24.5
	Total	229	100.0

4.3.6. Solar home system for safety and security

In fact, night time is opportunity to accident and enemies. Good illumination is very important for safety to keep human and animal from danger. In the study area, survey data shows 90.4% HH use mobile and chargeable torch light for night movement and out of these 69% of house hold use it to gather their animal. Also most households said that, after installing SHS they feel secured in night time. This study in line with solar lights and SHS provide an increased sense of security to households that adopt them (Orlandi et al., 2016).

Table 4: SHS for safety and security

SHS used for security and safety	Response of respondent	Frequency	Percent
HH use SHS for gather their animal	Yes	160	69.9
	No	69	30.1
	Total	229	100.0
HH use SHS for night movement	Yes	207	90.4
	No	22	9.6
	Total	229	100.0

4.4. Solar home system benefit for rural Economic benefit

The economic impact of SHS was evaluated using household previous expenditure, new income generated by SHS, cost advantage of SHS compare to traditional energy source, improved economic activities as a result of electrical appliance.

4.4.1. The previous Households Energy Sources for Lighting

solar home systems (SHS) are assumed to substitute to kerosene lighting, dry cells or use of wood fuel. The previous energy source of light in the study area is stated in table 7. As shown in the table, kerosene was the most prevalent source of household lighting in the survey area and firewood takes the preceding energy source for light. The firewood source of light was 56.36% households were purchased from the local market and 43.63% collected by households themselves. In FGD some told, most of households preferred firewood previously in addition to light source they were used to protect themselves from cold weather. However, as Solar lighting provides much better quality of light than kerosene lamps, candles and firewood and, as they extend the number of hours in a day for domestic and productive activities it has got better attention. Reliable and clean lighting is the most basic service that comes with a SHS and is available to all customers (Bisaga & Parikh, 2018).

4.4.2. The Main Type of previous Energy Source for Lighting

Table 5: Previous Energy light source and its consumption

Previous Energy source for lighting	Frequency (number of user)	Percent	Monthly average day to day energy consumption per HH	Total monthly consumption in ETB per HH
Kerosene	112	49	2.5L	70
Fire Wood	55	24	240Kg (12binds)	100
Flash light	32	14	3 packed (6 pieces)	55.5
Diesel Generator	11	4.8	15L	427
Candle	18	8.2	22.5 pieces	160
Total	229	100		

Source: House hold survey and Gesha woreda trade industry desk file

4.4.3. The Expenditure of traditional energy and solar home system

The kerosene and wood price is increasing from time to time. Implicit economic benefit of SHS reduce Kerosene subsidy of government finance and, explicit economic benefit was avoiding expense of kerosene and fire wood expenditure rural households. The kerosene price was very expense in rural area than urban area due to the infrastructure and distance from the city. Due to this, which would have significant effects on the household economy. In Focus group discussion most people compare the solar home system and kerosene, once they installed SHS save their day to day consumption of kerosene and firewood. The average monthly expenditure of traditional light source was192.35 ETB in the study area.

The economical comparison of traditional energy source and SHS was done by considering the local market cost of energy expenditure information obtained from survey, interview, focus group discussion and desk file which includes stakeholder discussions, sector knowledge of experts and sector desk file data. The data estimated expenditure of an average consumption of energy cost based on the study done by world energy congress,2011 and the results obtained would be used as a representative data for understand the benefits of the solar home system. Increasing of equipment cost is not considered for this calculation because increasing trend of kerosene can also increase the saving of owner. Also in the study only consider explicit not consider implicit economy i.e. the costs born from biomass fuel to medical, biomass fetching, time spent to buy/collect traditional light source not included. Since, rural households an average spends 6 pieces of dry cell batteries for radio,3 pieces for torch,6 pieces for flash light and 2.5 liters of kerosene for lighting an average day lumens were 4 hours per day. SHS of 10w was compared to traditional energy sources as the service of 10 w replaces lighting and radio services, which us used from the traditional energy sources. For this study as it gives as shown in table (4), the two years' price of kerosene with dry cell battery was almost equal to the total cost of SHS; the cost of candle with dry cell battery over 1.6 years was equal to the total cost of SHS; the cost of flash light with dry cell battery over 2.14 years was equal to the total cost of SHS and whereas the cost of firewood with dry-cell batteries almost by one year was equal to the cost of SHS. From those results, the use of SHS over long period (the life time of SHS was 20-25 years) is advantage over those traditional energy consumptions. In addition to this, SHS have higher quality of light, white and clear; it has an opportunity to use 3 lamps in different class at the same time, it creates opportunities for new income earning activities such as mobile and battery charging. Therefore, it can be concluded that for rural households it is better to purchase SHS than traditional way of energy consumption from economical point of view.

As, we compare 130w SHS with Generator, by considering both of them almost gives similar service. The expenditure of generator over two years was almost equal to the total cost of SHS. The lifetime of SHS was double from Generator and diesel generating systems in rural Ethiopia is a problem related to infrastructure, maintenance and covering running costs (Giday, 2015). Therefore, SHS is also more economical and affordable than generator. This study in line with (Orlandi et al, 2016). From this mention that higher investment cost in solar PV systems at low running cost versus low capital expenditures in diesel generators at high fuel cost (Gerlach et al., 2009).

Table 6: expenditures of previous energy and solar home system

Energy sources		**Investment cost (ETB)**	**Annual fuel cost (ETB)**	**Annual Maintenance cost (ETB)**	**Total cost (ETB)**	**Specification and service**
Solar home system	SHS(10W)	3,427	0	675	**4,102**	Lamps, Mp3 player/radio, phone charging/researchable battery
	SHS(130W)	24,570	0	725	**26,045**	Lamps, TV, charging electrical appliance
Traditional source of energy for light	Kerosene lamp and dry cell batteries	30	169.5	0	**2,034**	Lamp, Mp3 play/radio and torch
	Candle and Dry-cell batteries	0	229.5	0	**2,754**	Light and Mp3 play radio and torch
	Firewood and Dry-cell batteries	0	334.5	0	**4,014**	Light and Mp3 play radio and torch
	Flash light and Dry-cell batteries	50	157.5	0	**1,940**	Light and Mp3 play radio and torch
	Generator (3kw)annual expenditure	6,200	510	680	**12,950**	Lamps, TV, charging electrical appliance

Source: own computation and summary (2019)

4.4.4. SHS encouraged rural area microenterprise

SHS contributes on household giving extra lighting hours, better lighting quality for income-generating activities and productive work-hours in the home. In FGD and interview, it has opportunity cost in using SHS than other energy sources due to through solar, new enterprise was created, income of previous enterprise was increased due to increase in the duration of working time and new customer was attracted. In the study area, new enterprise was established like hair barberry and watching Television, charging mobile due to SHS. As the enterprises during interview said that their business hour was extended and their income was increased due to SHS lighting and television shows in working place. Survey data shows, from the total user 36 households used the solar for micro enterprise (7 barberries house, 6 watching Television and 23 mobile charging shop).

Figure 9: barber house by SHS in maligawi kebele

Excluding income through mobile charging, from watching TV and hair barberries enterprises get an average of 944.45 ETB per month.

4.4.5. SHS reduced charging appliance cost and generate new income

According to lighting global,2018 report annual expenditure for off-grid lighting and mobile phone charging in Ethiopia was estimated 84 USD (Lighting global, 2018). In interview households said that before installing their own SHS, they recharge their phone batteries at shops or neighbors who have solar home system at least once a day. Some respondent in the three kebeles told before they installed SHS they recharge their mobile battery 5 to 10 ETB per one phone. In the three kebeles there are 23 mobile charging shops (8 in maligawi, 6 in meshami, and 9 in yerikichiti). From survey data and interview, enterprise an average they charging 15 mobile phone per weak and from exaction mobile charging they get monthly an average of 550 ETB. In one household in average, there are about 1 to 3 phone owners and they charge their phones an average of four times per week. Therefore, in simple calculation SHS enables about 160-480 ETB saves in one house hold per month out of the relatives and neighboring user. The other economical use of SHS in the rural area was due to this system, electronics sellers were generated additional income by sells electrical appliance like TV, radio, mobile, rechargeable batteries to user.

4.5. SHS used for greenhouse gas emission reduction

Solar home system creates clean, renewable power from the sun and benefits the environment to reduce carbon footprint at home and abroad, reducing greenhouse gases around the globe. Households that purchase solar home system reduce household air pollution, deforestation and emission of fossil fuel from kerosene and firewood. This is due to an SHS has a reduces carbon footprint and solar energy supply have more positive environmental impacts than fossil and biomass fuels. An SHS can replace kerosene lamps, which emit substantial amounts of fine particulates and adversely effects indoor air quality. Kerosene lamps emit both carbon dioxide

(Tedsen, 2013). These Particles absorb sunlight and heat the atmosphere, increasing radiative forcing, and are a major climate warmer, second only to CO_2 (Monarchsolar,2017).

4.5.1. SHS used to decreasing household air pollution

In focus group discussion most of respondents agree that reducing the use of kerosene lanterns and firewood, and using solar energy can help reduce air pollution. The data shows 79.5% households agree that SHS decrease air pollution and 20.5% household's response implies they do not know about its relationship. By reducing the use of kerosene lanterns, solar energy can help reduce air pollution in the home (Kat Harrison, 2017). In Kenya found a 61% reduction in airborne particulate matter in the main living space of households that adopted a solar light (Lam et al., 2017). Due to their relatively low environmental impact, PV technologies for rural electrification yield long-term benefits in terms of pollution abatement and climate change mitigation (Feron, 2016)

Decreasing carbon emission is not only used to decrease air pollution, but it also decreases largest health-related risks for women associated with afflictions such as pneumonia, strokes and lung-cancer (Lighting global, 2018).

In addition to this, from the survey data, households those use candle as a source of energy in cloudy and off season time was 8.3%, from rechargeable battery 49.8% and mobile was 41. 9%. This indicates that, almost all households used air pollution free SHS appliance and it must be share to other rural area.

4.5.2. SHS used to decrease global warming

Greenhouse gas emissions from kerosene and firewood lighting contributes in increasing the amount of co_2 in the atmosphere. Installing Solar light has great contribution to minimize the global warming effect by decreasing the footprint of individual and group contribution.

The response of 57.2% household shows that solar has contributed in reducing global warming and 42.8% said that they do not know about the contribution. From this data, it has better to understand the household's individual footprint contributes to global warming.

4.5.3. SHS used to decrease deforestation

Only 40 years ago, some 40% of the Ethiopian land surface was occupied by forests and currently less than 3% remains, largely in the Kafa coffee biosphere reserve, which still boasts large areas of mountainous Afromontane cloud forest (Renforus, 2013). In Table (8) shows that 24% of households used to depend on wood to lighting and the main source of wood collecting area was forest. Tropical deforestation is one of the main source of anthropogenic greenhouse-gas emission (GM clean Energy Fuel Effiecient Technology, 2015). As show survey data 54.1% households agree that the positive effect of SHS in decreasing deforestation, while 40.6% do not know about the relationship and 5.2% do not agree that SHS could decrease deforestation. Most people in interview and FGD told the coverage of forest decrease from time to time due to deforestation to consumption of households and other purpose. The NABU organization desk file also in line with this survey data (Renforus, 2013). Fuel consumption in the Kafa region is very high compared to other rural regions in Sub-Saharan Africa countries (Elisabeth et al, 2014)

Figure 10: The highlight capture of forest in the study area,(a) photo taken at yerikichiti kebele of Gesha wereda ,(b) photo taken at (GM clean Energy Fuel-efficient Technology, 2015)

4.5.4. Contribution SHS to Decrease Greenhouse Gas emission

It is fact that SHS can significantly reduce CO_2 emissions into the atmosphere from kerosene and firewood. About 28.6 million tons of greenhouse gas emissions have been avoided through substitute the traditional lighting sources by energy efficient and renewable energy light source (Lighting global, 2018).The emissions offset or reduced by new PV capacity can be calculated by taking the amount of fossil fuel generation offset and multiplying by the average emissions rates for those fuels.

The calculation was based on IPCC default net calorific values, emission factors, carbon storage in forests and annual fire wood lighting consumption (Elisabeth et al., 2014).

E=FUELWOOD SAVED *fNRB*NCV*EF

based on IPCC default net calorific values emission factors and carbon storage in forests where:

E, emissions; fNRB, fraction of non-renewable biomass; NCV, net calorific value (for wet wood); EF, default emission factor (per unit of energy).

According to Elisabeth et al,2014 study to calculate the emission from firewood, in our case survey data shows an average households used 3 binds of firewood only for light per weak. From the interview and FGD an average of one bind wet firewood weight was estimated to 20kg. From this, monthly average consumption of firewood for light purpose was 240 kg.

Table 7: Parameters used to calculate carbon emission of firewood

Parameter	Value	Source
Annual wood savings for light	2880 kg	Table 8
Net calorific value fuelwood (wet basis)	15 kg/MJ	IPCC,2006
Emission factor fuelwood	112g.co_2/MJ	IPCC,2006
Fraction of non-renewable fuelwood	100%	Estimated (100% substitute fuelwood light)
Above ground carbon content per ha Kafa forest	95 tons	Elisabeth et al,2014

Source: (Elisabeth et al., 2014)

E= 2880 kg*1*15MJ/Kg*0.112Kg.co_2/MJ= **4838.4 kg** CO_2 = 4.8384 t CO_2,

The total Emissions in tones CO_2e from firewood =55* **4.8384 tCO_2= 266.112 tCO_2**

Therefore, in the study area the total Emissions reduction by firewood light source was annual rate of 4.8384 t CO_2 per households and, consider minimum SHS project life in 20 years an average one SHS able to offset 72.576**tCO_2** emission per households. From this, when 24% of total household's substituted firewood 485 *4.8384 t CO_2 =2346.624 t CO_2 reduced.

According to best practices methodology for quantifying GHG including guidance for public sector organizations, local governments and community emissions converting form (British Columbia ministry of environment,2014), emissions of fuel Calculated**: -**

The consumption of fuel for kerosene and generator based on study area data table (9) the annual average kerosene expenditure of households is 30L per HH and to generator is 180L per HH.

Table 8: Emission of kerosene from kerosene lamp and generator in carbon equivalent

Step	**Formula**	**Calculation**		
Convert the actual consumption to a common unit of measurement.	Actual Consumption (L) x Energy Conversion Factor (GJ/ L) = Converted Fuel Consumption (GJ)	30 L X 0.02531 GJ/ L = **0.7593 GJ**		
Calculate the emissions of each GHG using the appropriate emission factor	Converted Fuel consumption (GJ) x emission factor by GHG (kg/ GJ) = Emissions by GHG	**CO_2** 0.7593GJ x59.54 kg **CO_2** /GJ =45.208722 **CO_2**	**CH_4** 0.7593GJ x.0009 kg **CH_4** /GJ=0.00068337 kg **CH_4**	**N_2O** 0.7593GJ x 0.0043 kg **N_2O** GJ=0.00326499 kg **N_2O**
Convert the emissions of each greenhouse gas to CO_2e using the appropriate Global Warming Potential	Emissions by GHG x GWP = Emissions (kg CO_2e)	**CO_2** 45.2087**CO_2** x 1 =45.2087 kg **CO_2e**	**CH4** 0.00068 kg **CH_4** x 25 = 0.01708 kg **CO_2e**	**N_2O** 0.00326499 kg **N_2O** x 298 = 0.9729kg**CO_2e**
Sum across the gases to calculate total CO_2e emissions	**CO_2** + **CH_4** + **N_2O** (all in kg **CO_2e**) = Total **CO_2e** =	45.2087kg CO_2**e** + 0.01708425kg **CO_2e** + 0.97296702 kg **CO_2e**		
Convert total emissions from kg to tones for reporting purposes	Emissions in kg CO_2e / 1 000 kg/t Emissions in tones CO_2e	= 46.17kg CO_2**e** / 1 000 kg / t = 0.04617t **CO_2e**		
The total kerosene for lamp user	Emissions in tones CO_2e	112*0.046t **CO_2e** = 5.174t **CO_2e**		

Emissions in tones CO_2e		
The generator user (180L) estimate like kerosene Emissions in tones CO_2e	Emissions in tones CO_2e The total kerosene Emissions in tones CO_2e	6 *0.046t **CO_2e** =0.276t **CO_2e** 11*0.276t **CO_2e** = 3.036 t **CO_2e**
The total emission from kerosene tones CO_2e	Emission of kerosene lamp +emission of generator	5.174t **CO_2e+**3.036 t **CO_2e** **= 8.21 t CO_2e**

Source: British Columbia ministry of environment,2014

Therefore, in the study area the total Emissions reduction by kerosene light source was annual rate of 0.04617t CO_2e per households and, consider minimum SHS project life in 20 years an average one SHS able to offset 0.92 tCO_2 emission per households and 0.27 t CO_2e per households and, consider minimum SHS project life in 20 years an average one SHS able to offset 5.52 tCO_2 emission per households. In Bangladesh study shows with a kerosene CO_2 emission factor of 2.41kg/litre, this equals a monthly replacement of 0.091t CO_2 equivalent. One SHS in the study area will reduce 2.186352 tCO2 equivalent emission during its operating life of about 20 years (Harun, 2015).

The other traditional light source of rural households are candle and dry cell battery. The environmental effect of dry cell battery has its disposal further than kerosene and firewood flame of light. The landfill disposal of alkaline and zinc carbon batteries does not pose a significant health or environmental risk, modern alkaline and zinc carbon batteries do not contain materials that pose an environmental threat, and they are not regulated as hazardous waste(NEMA, 2012). GHG emissions per kilogram of battery are at most a few percent greater than direct CO2 emissions (Sullivan and Gaines, 2010). So, SHS replaced this type of battery by rechargeable one improve the eco-efficiency of battery contributes the most to cell cost and GHG emissions (Philippot et al.,2019).

As we can conclude that households installing SHS in rural kebele of Gesha wereda they reduced significant of amount GHG emission that through the environment.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The study focuses on solar home system and its benefit is for social, economic and environmental condition of rural area households. The study assessed the households' previous sources of energy for lighting and its effect, the benefit of solar home system by taking 229 household respondents systematically from the households' frame.

HHs before installed SHS they used as light source was kerosene, firewood, flash light, candle**,** and diesel generator. Households substituted the traditional light source by SHS socially improved their health, education, get information facility, keep their safety and security, saving their time and strength their social unity.

In economical point of view, they avoided day to day light expenditure, they able to substituted total traditional light cost almost by one to two years, created new job and improved their income through TV shows, hair barber, charging mobile phone. Although the initial cost of SHS was high relative to traditional source of energy, the annual expenditure of the latter is high. Beyond to this, the community electronics sellers benefited from selling appliance related to SHS like television, radio, mobile and rechargeable battery, and decrease the subsidy of government on kerosene.

In terms of GHG reduction substituted traditional light source by SHS HHs reduced significant amount of GHG emission that through to environment. As the traditional sources of energy are replaced by SHS, the locally as well as globally we are getting free air and household's footprint to gas emissions was also decreasing. Most of respondents agree on the benefit of SHS for decreasing household's air pollution, deforestation as well as GHG emission. The emissions reduction by firewood light source was annual rate of 4.8384 t CO_2 per households, for kerosene 0.04617t CO_2e per households and, for generator 0.276 t CO_2e per households and, consider minimum SHS project life in 20 years an average one SHS able to offset for firewood light 72.576**tCO_2**, kerosene 0.9234 tCO_2, generator 5.52tCO_2 emission per households. Also candle have their own small amount of greenhouse gas emission. That means small amount relative to traditional source of light but, compare to SHS better environmental friend than candle. Light dozens of candles would emit ten times as much greenhouse gas than simple lamp (Vancouversun,2009).

Generally, large-scale penetration of quality SHSs has helped rural households in terms of improved socio-economic conditions and reduced local air pollution, adverse environmental impacts and support to reduction of global emission.

5.2. Recommendations

On the study wereda most of rural kebele, which are far away from the center of wereda, does not access to national grid and they use traditional source of energy for lighting. So to solve the problem stakeholder should share the best practice trends of SHS user to other non –user to improve their awareness on the technology.

The Government provides appropriate credit access of solar home system to address the rural and remote area poor households. Because in the study area most beneficiary initiated to adopt the solar technology was rural electrification fund program (REF).

Stakeholder should strength the potential of local solar technicians through finance and skill improvements to minimize the maintenance cost of SHS.

In the study area most solar seller freely sold not warranted and qualified for installation and maintenance service solar PV available in market. This negatively affect the sustainability of the technology. Stakeholder should control illegal solar supplier and seller and support the legal supplier and seller of SHS to sustain the technology adoption.

Further study: The researcher recommends further study the benefit of large scale solar system and the barrier to disseminate large scale penetration of solar system to sustained use in rural households.

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APPENDICES

Appendix I: The capacity, cost of solar home system and its description

Solar home system types(W)	Description of the system(including appliance)	
	Cost of SHS	Delivery service
10	3,427	3 lamps,Mp3 player, phone charging
20	6,900	4lamps,Mp3 player, phone charging
30	8,670	4lamps,Mp3 player, phone and charging
40	9,760	4lamps,Mp3 player, phone charging and torch
50	15,610	4 lamps and 15.6" TV with receiver
60	17,250	5 lamps,19" DC TV with receiver and torch
80	18,000	5 lamps and 19" TV with receiver
100	19,770	6 lamps,19" DC TV, decoder
120	21,500	6 lamps,19" DC TV with receiver and decoder
130	24,570	6 lamps,19" DC TV, receiver, decoder and torch

Source: kaffa zone water, mines and Energy office desk file of solar supplier agreement with SNNPR document,2018.

Appendix II: Expenditure of traditional energy source and solar home system cost

Energy expenditure	**Solar home system**		**Traditional source of energy**					**Source of data**
Types of energy source	SHS(10W)	SHS(130 W)	Kerosene lamp and dry cell batteries(annual expenditure)	Candle and Dry-cell batteries	Firewood and Dry-cell batteries annual expenditure	Flash light and Dry-cell batteries annual expenditure	Generator annual expenditure(single phase 3kw power,220v and 8.3A)	
Investment cost (ETB)	3,427	24,570	Traditional wick lamp 30	0	0	50	6,500	Appendix I and Interview
Total cost Monthly (ETB)	0	0	Investment cost lamp 30,kerosene expenditure dry cell battery for radio 6 pieces 63,for torch 3pieces, 31.5	Candle expenditure 135, dry cell battery for 6radio pieces 63,for torch 3pieces, 31.5	Firewood expenditure 240, dry cell battery for radio 6 pieces 63,for torch 3pieces, 31.5	dry cell battery for flash light 3 packed 63, 6 radio pieces 63,for torch 3pieces, 31.5	Investment cost 6,200,for fuel 6,120	Table 8 and interview
specification and service	3 lamps, Mp3 player, phone charging 2–5 Ah battery can power a LED lighting fixture (200–300 lumens) up to 8 hours/day and panel average lifetime 20-25 years.	lamps,19" DC TV, receiver, decoder and torch and panel average lifetime of 20-25years	One lamp and Mp3 play /radio service and average life time of 2 years	Light and Mp3 play/radio service and torch	Light and Mp3 play /radio service torch	Light and Mp3 play /radio service torch	lamps, TV, charging electrical appliance average life time of 10 years	Appendix II(D); Judith et al. 2016
Annual Maintenance cost(SHS battery change an average in 4 years ETB	battery cost 18 Ah gel lead acid battery 700 ETB), and for other service in two years 10W was average of 1000 ETB	Battery 95 Ah gel lead acid battery was 900) for other service in two years 130W was 2,500).	0	0	0	0	In 3 months change oil (480 ETB),2 years' full maintenance (300 ETB)	interview to solar seller and energy expert, table 8 and Cermi-UlB, 2014.
Total cost(up to life span)	**5,127**	**27,900**	**2,034**	**2,754**	**4,014**	**1,940**	**12,950**	

Source: own construct (2019)

Appendix III: Questionnaire, Questions for Interviews and Focus Groups Discussion in English language

Questionnaire on study The contribution of solar home system to socioeconomic and greenhouse gas emission reduction rural kebele of Gesha wereda.

A. Basic information on house holds

1.Gender A. Male ☐ B. Female ☐

2.age A.18-29 ☐ B.35-50 ☐ C. over 50 years ☐

3.marital status A. Married ☐ B. single C. divorced D. Widows

4. Literacy level

A. Illiterate (cannot read and write) ☐

B. Literate (can read and write) ☐

5. Total family size________________ (in number), number of sons______ number of daughter____________

6. How many children attending school are there in your household? (in number)

B. Socioeconomic information

7. how many watt is your solar panel capacity? _________(watt), the total price including installation________(ETB),

8.In average how many time use in one day? _____________in winter________in summer ________ (in hour), year of installation___________ (E.C).

9. By what mode of system you purchase SHS?

Mode of purchasing	Year of loan	Monthly loan credit/ETB birr/
Micro finance		
Ref program		
Direct purchasing		

10. What are the sources of household lighting and its expenditures before SHS installation?

Energy source	Energy source use for lighting? For appliance	Investment cost for Energy source?(in Ethiopian birr)	Energy expenditure(in Ethiopian birr/moth)	How may hour use energy for light in one	Monthly purchasing amount of energy source	How many meter far the shop of energy
Kerosene						
Fire Wood						
Dry Cell Batteries						
Diesel Generator						
Other source						

11. Do you agree that SHS makes it easy & extend time to read in the evening?

Yes ☐ No ☐

12. Has the women use of time changed after installation of SHS? yes ☐ No ☐

If yes, how many time they consumed?__________________(in minute)

13. How many years have you been using SHS? --------------------- Year.

14. What are the solar electricity consuming activities in your household?

Light ☐ Listening radio ☐

Watching TV ☐ Household works under lights ☐

Reading/ Studying under lights ☐

Charging of mobile phone ☐ Income generating work under ☐

Other electricity consuming activities ____

15. what is the source of energy in cloudy and off seoson time

kerosene ☐ mobile ☐ rechargable battery ☐ candle ☐

16. Number of mobile user_______________ by what time interval charge mobile_____________

17.Is their any appliance that you buy related to installing shs? yes ☐ No ☐

If the answer is yes what is the appliance?Televison ☐ Radio ☐
Mobile ☐ recharged battery ☐

18.by what amount of money increase the income of households after installing SHS?

Appliance	Number of user /month/ including in your house	Amount of money (in Ethiopian birr/moth)
Mobile charge		
Enterprise income (new and addition income by installing SHS appliance)		
By watching TV		
Other		

19.Is their any income generatin activity before installing SHS?if yes what are the activity do after installing SHS ?

Activity	Before installing SHS	after installing SHS	Income activity after before installing of SHS (ETB/month)	Monthly income generating after installing of SHS(ETB/moth)
Mobile charge				
Hair Burberry				
small hotel				
By watching TV				
Small shop				
Other				

20. Do you use SHS for student education? Yes ☐ No ☐

If the answer is yes,in avarage by what amount of time student stady and doing home work time increase in one weak?________(in minute)

21. Do you agree that installation of SHS creates facilities for women entertainment time in household?

YES ☐ No ☐

22. Do you agree that installation of SHS makes easy for the family to get news and information?

YES ☐ No ☐

23.By what appliance you get information A.television ☐ B.mobile ☐

C.radio ☐

24.Do you agree that installation of SHS creates facilities for entertainment in household?

YES ☐ No ☐

25. Do you agree that installation of SHS helps socialization with relatives/neighbors in the evening? Yes ☐ No ☐

26. Do you agree that installation of SHS increases perception of safety in the evening?

Yes ☐ No ☐

27. In the past had there been any accidents in your house relating to use of kerosene or others energy sources?

Yes ☐ No ☐

If yes, which of the following? Kerosene ☐ Candle ☐ Solar Home System ☐ others ☐

28. In the past had there been any heath problem relating to use of kerosene or others energy sources?

Yes ☐ No

If yes, which of the following? Kerosene ☐ Candle ☐ Solar Home System ☐ others___________

29. What benefit are your main reseon to choice SHS ?(tick them)

Main reseon to choice SHS	
Socail benefit	
Health care and better lighting	
Improving education	
Access to information	
Socailazation	
Economic benefit	
Avoid kerosene and firewood expenditure	
Avoid appliance expenditure like battery cell,mobile charge	
Increase enterprise income	
Economic benefit	
Decrease house air pollution	
Decrease deforestation	

C). Environmental information

30. Do you agree that installation of SHS decrease house holds air pollution?

Yes ☐ No ☐

31. Did you think installation of SHS decrease deforestation?

Yes ☐ No ☐

32.Did you think installation of SHS decrease carbon footprint?

Yes ☐ No ☐

33.Did you think installation of SHS contribute to decrease global warming ?

Yes ☐ No ☐

Guiding Questions for Interviews with Key Informants

1). What type of energy sources are most of the households using for their lighting at night?

2). Do you think kerosene and fire wood affect human health?

3). what is the benefit of solar home system to health center?

4). Do you think kerosene and fire wood cause to fire accident?

5). Do you think kerosene and fire wood negative impact on global warming?

6). Can you tell me the benefit of solar home system to health?

7). Do you think solar home system benefit safety and security of rural community?

8). Do you think solar home system make facility to information?

9). Do you think solar home system consume time of women?

10). Do you think solar home system improve education?

11). Is that solar home system opportunity to expand enterprise in rural area?

12). Can you tell me the advantage of solar home system to minimized consumption of appliance kerosene and wood fire?

13). Is their solar home system benefit to reduce air pollution of households?

14). Do you think a people installing of SHS contribute to decrease carbon footprint?

15). Is there anything you feel I didn't or should have asked related to solar home system would like mention?

Guiding Questions for Focus Group Discussions

1). What are major Energy source use for lighting for rural area in the past and present?

2). Do you think kerosene and fire wood affect health, student study time, households air condition?

3). why people choice solar home system for lighting?

3). do you think solar home system benefit for information facility, safety and security?

4).in your experience, solar home system benefit for consuming women time?

5). do you think solar home system decrease the consumption of kerosene and appliance to rural area?

Is there difference between work time of SHS user and non-user?

6). Do you think solar home system expand enterprise in rural area?

7). what are the environmental contribution of social home system to rural community?

8). Do you think solar home system decrease household air pollution and global warming?

9). Is there anything you feel I didn't or should have asked that you would like to mention?

Appendix IV: Questionnaire, Questions for Interviews and Focus Groups Discussion in Kafigna language

Soolaro Maccenaochi, ikkonomina kitamitooch imibeeti gaacoon kice qihe echenao

I. macce gaacoon ciinimi Inde qihenao

1.Animo A. Anaamo B. Maache

2. Eeno A.18-29 ☐ B.35-50 ☐ C. over 50 years ☐

3.shaagi hiino A. shaagito ☐ B. shaagaano ☐ C.biichito ☐

4.doye daqo A. shemoona koorona hakimo ☐ B.shemoona kooroona hakkaano ☐

5.kexxoochi beeto ashi haaddo______________(haddoona), Anaamo______ maache___________

6. ambiche bushiisho doyo doyibeete? (hadoona)______________________

II. Maccoona ekonomi Qihoon ciinimoona

7. ceechoochi maacenao gaachebeeti ineriji shaaho? 7. Solare iiqo ambichoone? (watt), ambiche birewoona kemene_______.

8.heeyooch wode aboon ambiche saato gaachene? ____qaawooba__yooyooba _______ (saatoona), atane bi becheto__________ .

9. ame hinoona soolaro kemene?

Keme hiino	Erete woche gooro	Agenoona qochebeeti birewo /tophiye birr/
Mayikire		
taate programoona		
Kemechinao wane		

10.solaro kemoye shiichi/aafi/ ceechoochi maacenao gaachebeeti ineriji shaaho?

Ceechoochi gaacibeeti inerji shaaho	Ceechoochi gaacibeeti inerji shaaho?	Inerji technolojin kotochi kechiti gijjo?(topiye birewona)	Ceechooch kechibeeti gijjo?(topiye birewona)	Dubeeti qiicoon shuuniye gijjo ?(topiye birewona)
Kuraazo				
Mixo				
Batire xaqqo				
Generatoro				
Solaro(__))watt				
Baroo beegaata				

11. solaro doyechinaochi shemoochi gaaciye getoon mashamine? mashamiyo ☐

mashamaache ☐

12. solaro maachenao gooroon shimihe geton mashamine? mashamiyo ☐ mashamaach ☐

ne mashamigaata amoomi gooro shimehe? _______________ (daqiqoona)

13. solaro gacheyo ne koteto ambiche nato tunete? ____________________

14. solaroona ne gaachebeti qiico amenaone?

Telavizhino ☐ ciino ☐ radiyoono waayo

shemooch ☐ kexxoochi shuuno shuunooch ☐

mobiloon chargo ceechooch ☐ ikike gijjo danimi shuunoon shuunooch ☐

baro beegaata _____________________________________

15.solaro ceecho imo qayigaata amoone ne gaachaabeeto?

kurazo ☐ mobayilo ☐ batire ceecho ☐ shaamo ☐

16.kexxoochi ambiche asho mobayilo gaachehe?______________ame gooroona charjo gedene?____________

17.soolaroona yeshe kemeti qiico beete? beete ☐ aloone ☐

If the answer is yes what is the appliance?Televison ☐ Radio ☐

Mobile ☐ charged battery ☐

18.solaro bechetoye guubi ne shuune gaamicho ambichoona dicite?

Qiice shaaho	Gachechi haddo	Gijje haddo (
Mobayile charjo		
Shingixe shuunoona (andire shinixe haddo)		
Telavazhine bekiyoona		
Baroo begata		

19.solaro ne bechoye aafi shuuno beete?solaro ne bechitoye guubooch ?

Shuune shaaho	Solaro ne bechoye aafi	Solaro ne bechitoye gubi	Solaro ne bechoye aafi daneti gamicho	Solaro ne bechitoye gubi daneti gamicho
Mobayile				
Qeli				
Mayoona				
Telavazhine				
Suqoona				
Baroo				

20.solaaro doyechinao sheme gooroon dichoon mashamine?mashamiyo? ☐

Mashamaach ☐ ne mashamigaata ________ (daqiqoona)

21. solaaro machenaochi kashee goorooch gaaciye getoon mashamine ? mashamiyo ☐

mashamaachi ☐

22.soolaaro macenao kete gomoona qiho danooch gaaciye ?

gaaciye ache

23.qiho ne danooyichi ne gaacabeeti qiico amoone? A.televizhion

B.mobayilo C.radio

24. soolaaro macenao kete gomoona qiho danooch gaaciye ? gaaciye

gaacaache

25. soolaro macenao ikitinoon uumiye hinoon dichiye getoon mashamine? Mashamiyo mashamaach

26. soolaro macenao digitinoon xumoona quyooch gaciye imi shaligoon mashamine?

mashamiyo mashamaachi

27. ebiye aafi qaaqoona kurazoona mico shagi arihe?

mashamiyo mashamaachi

28. ebiye aafi qaaqe cufoona tuneba kurazoona iwe irito shagi arihe?

Ariyo ariyaache arigaata ame shaahe biiyo ——————

Kurazoona shaamoona baro beegata

29.soolaro kacooch naboo tuneto amoone?

C) kitamitoon ciinimi qihoo

29. solooro kechi maaci beeti cufoon giishiye geta gaboon mashaime?

Mashamiyo mashamaach

30. soolare becho macenao ayere toomooch gawikeebeeti kariboone cufooni giishiye imi gaboon mashamine? mashamiyo mashamaach

31.soolare becho agetoochi bekebeeti gaamoon giishiye getoon mashamine ? mashamiyo

mashamaach

32. soolare becho michi kuxxoon giishiye getoon mashamine ? mashamiyo

mashamaach

Guiding Questions for Interviews with Key Informants in kafigna language

macenaoni solare gaace toomooch echoochi qaniti echenao

1). Wode aaboon ceechooch ne gaachebeeti ceecho amoone?

2). Kuraze ceecho ashi iwitinoon gondoone geta gabine?

3). Solaro ashi iwtinochi ame gaaco imiye geta gabiyin?

4). Kuraze ceecho ashitinona ashi kechi tomoochi mixo dewiye geta gabine?

5). Kuraze cufuna michi cufo agete kitamite toomochi mixo dewiye geta shaligine?

6). Solaro iwitinoochi iimibeeti gaacoon biriyo hakine?

7). Solaro digitinoona ashitinoon quyooch iimibeeti gaacoon biriyo hakine?

8). Solaro andire qihenaoni danooch ame gaaco imiye geta shaligihin?

9). Solaro machenaona bushishe gooroon shimeye geta shaligihin?

10). Solaro doyechinao doyoon umiye geta gabiyin??

11). solaro gishishoona shingixenaochi gijjon dichiye geta shaligihin?

12). Solaro baribare gacoochi hechibbeti qicenaochi kechibeeti gijoon shimeye geta gabine?

13). solooro kechi maaci beeti cufoon giishiyoochi gaaciye?

14). soolare becho agetoochi bekebeeti gaamoon giishiye?

15). Bare solaroona yeshebeeti shaligoona xiishiyoo begata?

Guiding Questions for Focus Group Discussions in kafigna language

1). Ebi kitamitoochi woode asho ceechooch ebiye aafina andi goorooch gaachebeeti ceeche shaaho amoone?

2). Solaro ashi iwitinoochi,doyooch,kitamite xalitinooch gaaco amoone?

3). Macenao amoochiye solaroon boono kacibeeto?

3). Solaro qiho danona mace digitinoon quyoochi amo gomona gaaciye?

4).ebiye aafi itooshi yagoona solaro machenaona bushishe gooroon shimiye geti gabiyote ?

5). Solaro kuraze gaazoona bari bare ceechona batirexaqooch kechibeti giijoon shimeye geta shaligine?

6).solaro gishishoona shingixenaochi gamiyoon dichoona andire shuune mallo daniyooch gaaciye?

7). solooro kechi maaci beeti cufoon giishiyoochi gaacoon birib?

8). solooro kechi maaci ageete kitamite gaamoon giishiyoochi gaaciye?

9). Bare solaroona yeshebeeti shaligoona xiishiyoo begata shaadibot?

galleto!!