Factors Influencing Household Adoption of Solar Home System in Baso Liben District, Amhara Regional State of Ethiopia

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Abstract

Background: Although, solar energy is abundant, accessible, affordable, and ecologically and environmentally friendly, in rural Ethiopia the majority of households are still using pollutant kerosene for lightning. It is important to understand demand and supply-side factors affecting the adoption of the technology. For this purpose, this study investigates the factors influencing household adoption of solar home system (SHS).

Methodology: The data used for the econometric model was collected from randomly selected 228 adopters and 143 non-adopter households in Baso Liben district, Amhara region of Ethiopia. The logistic regression model was applied to examine the factors affecting household adoption of solar home system.

Results: The finding of this study shows significant variation in many socioeconomic and demographic characteristics between adopters and non-adopters of solar home system. The result of the binary logistic regression model indicated that as income of household increase, their propensity to adopt solar home system also increases. Likewise, participation in off-farm income activities, house type, educational status, training access, media access, and prior knowledge positively correlated with the adoption of SHS. On the other hand, gender and access to electricity are negatively associated with the adoption of SHS.

Conclusion: Policy measures should create awareness through training, education, and information access or better media availability, and improving the economic status of households through creating lucrative off-farm income-earning opportunities to achieve enhanced adoption of the solar home system.

Keywords: Solar home system, Adoption, Factors, Household, Rural

1. Introduction

Energy access to the human being is a precondition requirement for development and welfare as well as successful economic development and job opportunity (UNEP, 2017). Solar energy is among the cleanest, accessed with low prices and abundant sources of energy with a minimum ecological and environmental hazard. In the global context, the share of renewable energy in the production of power capacity grew to over 33% in 2018. From which hydropower accounted for about 60% of the production of renewable electricity. It is followed by wind power, solar PV, and biopower, which accounts for 21%, 9%, and 8% respectively (REN21, 2019). In Africa, about 48% of the population does not have electricity access still in 2017. Of which the largest share is Sub-Saharan Africa inhabitants, where 57% (about 602 million people) still live in dark (REN21, 2019). The continent also has a huge and abundant source of renewable energy. The capacity of the continent's annual solar radiation ranging from 5 to 7 kWh/m2 (Brüderle, 2010).

Regarding Ethiopia, electricity need is still huge. As the evidence showed, more than half of the total population of the country (56%), almost the same to that of Sub-Saharan Africa (57%), still doesn't have access to electricity (MoWIE, 2019). To spread electrification access throughout the country, the government has been implementing two strategies, namely extension of the national grid and provision of off-grid modern energy technologies (Abera, 2019). Ethiopia has great potential for solar energy as it receives solar radiation of 5,000-7,000 Wh/ m^2 depending on the locale and the season. The solar radiation averages 5.2 kWh/m2/day. The values vary with the seasons, ranging from 4.55 to 5.55 kWh/m2/day, and over space, ranging from 4.25 kWh/m2/day in the extreme western lowlands to 6.25 kWh/m2/day in Adigrat area (REEEP, 2014), and has a total solar energy reserve potential of 2.199 million TWh per annum (Deribew, 2013).

In addition to the poor accessibility of electricity, the energy sector of the country is too dependent on hydropower. This increases its vulnerability due to the increased risk of drought caused by climate change (Guta, 2017). As stated by Lighting Africa (2012), there is also a great disparity of power distribution in the country. In Ethiopia, as in most Sub-Saharan Africa countries, the gap between urban access and rural electric access is huge. About 96% of urban households of the country are connected to the grid (99.9 % in Addis Ababa), whereas only 27% of households living in rural areas of the country have access to electricity services. The problem is highly experienced in deep-rural areas, where 5% of people have been accessed with electricity. As noted by TERI (2014), such a problem is mainly emanated due to the difficulty and expensiveness of connecting the rural population living in isolated villages to a centralized electric grid. Due to this reason, most of the households in rural villages depend on Kerosene lamps for lighting and wood and charcoal for cooking, which causes adverse effects on the environment as it emits a lot of carbon and also damages the health of the people using it (Mekuria, 2016).

Many studies have assessed the determinants of solar home system adoption at the household level in different countries. For instance, some of the studies (Keriri, 2013; Gitone, 2014; and Regina, 2016 [in Kenya]; Tahir, 2017 [pakistan]; Guta, 2018; Anteneh, 2019; and Legesse, 2016[Ethiopia]) studied the socio-economic and demographic factors affecting household adoption of the solar home system. These studies have applied a predominantly binary model. Anteneh (2019) and Legesse (1016) revealed the effects of the level of education of the household, land size, number of cattle, level of income, and age of the head of household on solar home system adoption. Whereas Guta (2018) investigated the effects of much more variable in a broad sense such as, trees, and saving including the above-mentioned variables using logistic regression. Besides, other determinants such as institutional factors (Guta, 2018; Anteneh, 2019), level of knowledge, and awareness (Anteneh, 2019), an alternative source of energy (Legesse, 2016) have been investigated. However, there is a research gap in these empirical studies in addressing institutional factors such as awareness creation training given to the households either formally or informally. Housing types and size, which are among socio-economic factors that could affect households' willingness to adopt solar home system is not addressed properly. Moreover, there is also little information about how access to communication technologies could affect adoption.

Therefore, this paper mainly focused on filling the observed gap by examining the effects factors influencing the household decision of the solar home system by controlling these key factors overlooked by previous studies. The result of the study will have development and policy significance by providing current and valuable evidence, which can be used by policymakers to make an informed decision in the formulation of effective development programs, and strategies related to addressing the rural energy crisis.

2. Literature Review

2. 1. Theoretical literature

In this paper, three theories that could support the idea of the paper are drawn. The first one is the theory of reasoned action which is developed by Fishbein and Ajzen in 1075**.** The theory proposed that rational thought grounds human behavior in it and the model uses the Principle of compatibility, which predicts that attitudes reflect behavior only in the extent of the two going to have the same valued outcome state of being (evaluative disposition) (Ajzen, 1985). Subjective norms and beliefs shape these attitudes, and situational factors affect these variables' relative importance. According to this theory, attitude and subjective norm are important determinants of the intentions of peoples to act such as adopting and using new technology such as the solar home system.

The second theory is innovation diffusion which is developed by Rogers (2003). The theory proposed that technology adoption behavior of individual such as solar home system is determined by his or her perceptions regarding relative advantage, compatibility, complexity and observability of an innovation which influence the rate of innovation adoption. These facts have a relation with those variables of the study such as level of knowledge and awareness of the household towards solar home system. The theory also portrays that Communication or interpersonal exchange of information is more powerful in convincing a social system to accept innovation.

The third one is the energy ladder and fuel stacking hypothesis, which shows the relationship between an increase in the economic well-being of the household and the type of fuel they tend to use. According to Hosier & Dowd (1987), it implies that as income raises households consume fuels that occupy higher rungs, ascending the energy ladder. Fuel stacking also explains the case where households simultaneously use a myriad of cooking fuel usually on both upper and lower stages on the energy ladder (Heltberg, 2003)

2.2. Empirical literature review

The level of awareness and knowledge highly determines the household adoption of solar home system (Naomi, 2014). Hence, an adequate level of awareness and correct information should be provided to bring a better understanding of both benefits and disadvantages of renewable technology (Rashid, 2012). Lack of adequate information of households on the negative health outcomes associated with the inefficient combustion of solid fuels impedes the growth of market demand for clean energy (Beyene, 2018).

One study conducted in Ethiopia revealed institutional barriers, for instance, lack of coordination among the health and energy sectors, ministerial departments, regional and national agencies, the public and the private sector, and national and international agencies (Beyene, 2018). Coordination among ministries to ensure a better understanding of clean energy to make it a priority is weak. The child and maternal health units of the Ministry of Health do not promote awareness of the health risks of household air pollution. As stated by Beyene (2018), key institutions have overlapping mandates and insufficient technical staff and instrumentation to provide diversified energy sources at different levels.

A study found that an increase in accessibility of credit enhances household adoption of new technologies (Khushbu *et al*, 2015). Training delivered to households affects the adoption of solar home system. A study conducted in Kenya found that there is a positive relationship between the individuals who had received informal or formal training on solar systems and use (Keriri, 2013). To be more confident about the innovations, training can help people towards the adoption and active usage of the technologies provided (Bizien, 2017), adds crucial value in the minds of trainees where they acquire this by performing practically the knowledge or the information they read and heard from different sources (Ali, 1997).

Many researchers investigated the effects of demographic and socioeconomic factors affecting households' willingness to adopt solar home system. Anteneh (2019) examined the determinants of household adoption of solar home system. The author showed that income, numbers of cattle, off-farm activity, marriage, and education level have a positive effect willingness to pay for solar home system, but age and family size has a negative effect. He also revealed that female-headed households are less likely to adopt solar home system compare to male-headed households and it is statistically significant.

Guta (2018) investigated the determinants of household adoption of solar home system. The finding showed that income of the household, landholding size, number of cattle, age of household head, family size, and education level of the head has a positive effect on solar home system adoption. The author also found that male-headed households are less likely to adopt solar home system compared to female-headed counterparts. This corresponds with Partick (2009), who found that female-headed households are more likely to adopt solar home system compared to male counterparts. Similarly, Legesse (2016) revealed that household income and the number of cattle have a positive effect on solar home system adoption. On the contrary, the age of household head, location of households from agricultural extension center, market, main road, and electric grid have a negative effect on the adoption of renewable energy sources.

Abera (2019) examined determinants of lighting Energy transitions in rural Ethiopia, who revealed that landholding size, level of education, house type, and modern communication technologies have a positive influence on the adoption of renewable energy resources including solar. But family size has a negative effect on solar home system adoption.

De Groote et al (2016) investigated the heterogeneity in the adoption of the photovoltaic system in the region of Flanders (Belgium). The author explained that important housing characteristics such as house size, roof insulation, and quality of the roof are positively correlated with the solar photovoltaic installation. He also showed that as the age of the house increase, the rate of adopting solar home system decrease.

In the review of the above literature, numerous factors determining household adoption of solar energy are investigated. However, there is little information about the effect of determinants including, training, housing condition, and communication access on household adoption of SHS, particularly in rural Ethiopia.

3. Method and Data

3.1. Study area

The study was conducted in Baso Liben district, East Gojjam zone of Amhara region, northern Ethiopia. It has GPS coordinate of $10^0$09'60.00"N latitude and $37^0$34'59.99" E longitude. It is located 307 km northwest of Addis Ababa, the capital city of Ethiopia, 292 km from regional city Bahir Dar and 27 km from Debre Markos (Zone capital town). The total area of the district is about 113,284 hectares with two agro-ecological zones of woina dega (46%) and kola (54%). The district has 22 rural and 4 urban and semi-urban *kebeles* (The lowest administrative unit in Ethiopia) with the total population of 170,387. Of which the number of men and women accounts 47.4% and 52.6% respectively. Out of the total population of the district, only 7.9% of the population is urban resident and the majority (92.1%) is a rural settler.

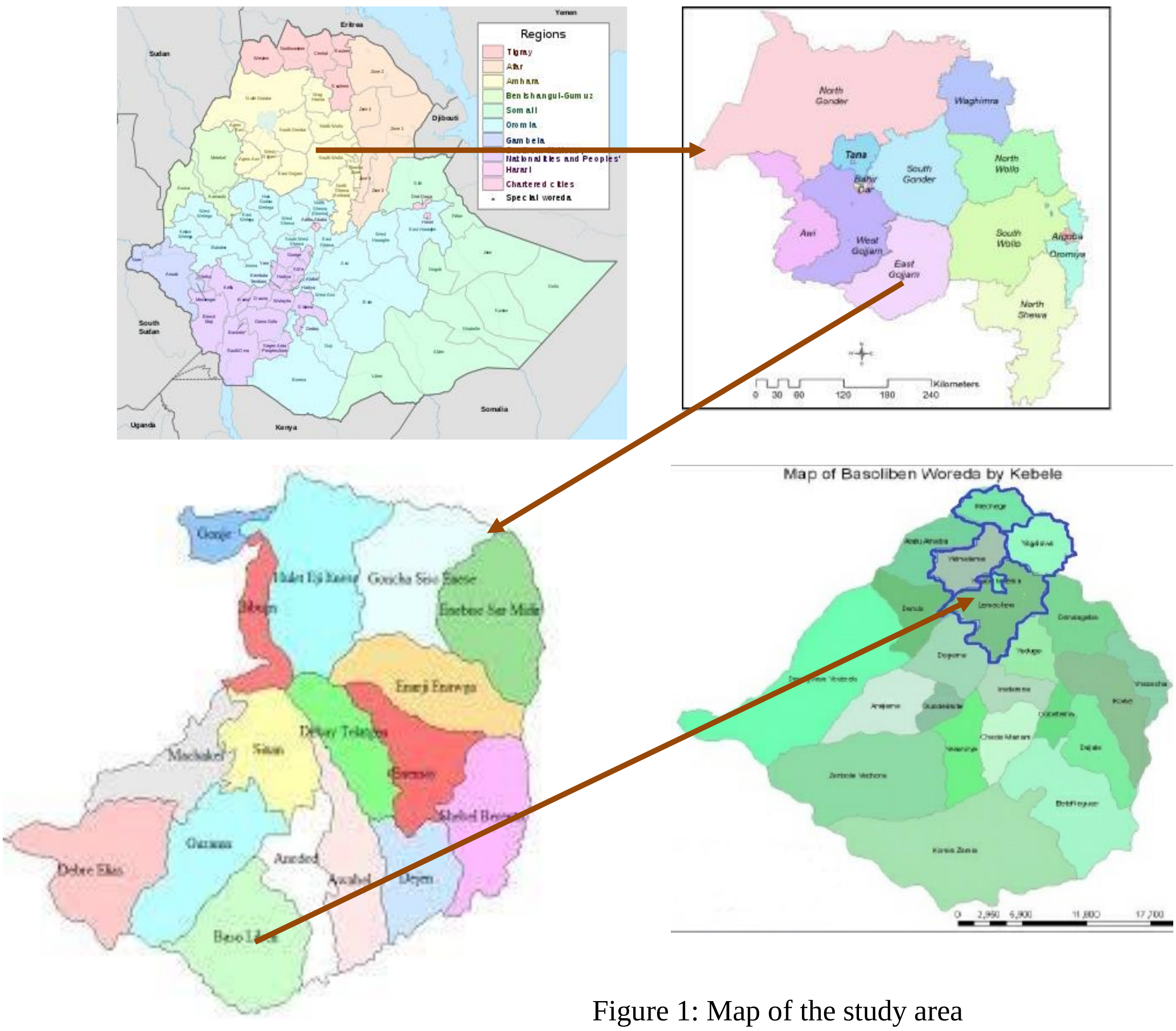

Figure 1: Map of the study area

3.2. **Data and Sampling**

To collect the data used for this paper, a cross-sectional research design was employed. Among 22 rural *kebeles*[1] of the District, 4 of them namely; Yelemelem Limichim, Yegelaw & Michig were purposively selected based on infrastructural accessibility, high adoption intensity, time, and other physical factors. Sample households were randomly selected from both adopted and non-adopted sides of households living in selected *kebeles* by proportionate their number. The total household of the selected *kebeles* was 5170 of which 3195 were solar adopter (766 from Yelemelem, 747 from Yegelaw, 512 from Michig and 1170 from Limmichim *kebeles*) and 1976 were non-adopters (571 from Yelemelem, 71 from Yegelaw, 513 from Michig and 821 from Limichim *kebeles*) (Baso Liben woreda survey report, 2019).

A total sample of 371 households participated in the study. Of which 228 were adopted (55 from Yelemelem, 52 from Yegelaw, 37 from Michig and 84 from Limichim) and 143 were non adopted households (41 from Yelemelem, 6 from Yegelaw, 37 from Michig and 59 from Limichim *kebeles*). The data collection was undertaken from 02 February to 06 March 2020 using structured and semi-structured questionnaires. During data collection, four enumerators were closely supervised by the researchers to ensure data accuracy and completeness. The qualitative data were analyzed using content analysis and the quantitative data were also analyzed using both descriptive and inferential statistics with the help of SPSS version 23.[1]

3.2. Empirical model of solar home system adoption

The study used a binary logistic regression model since the dependent variables are dichotomous. This means that it takes the value of 1 if someone adopts a solar home system and it has a value of 0 if not (Gujarati, 2004). The reason behind using this model in the study than the probit model is that the equations of the logit model are and it is directly interpretable as log-odds (Pindyck and Rubinfeld, 1981). This model is also used in previous studies by several researchers for the same issue, for instance, Guta (2018) and Yusuf and Adeyemi (2019). According to Park (2013), there are two models of logistic regression, binary logistic regression, and logistic regression

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[1] *Kebele: The lowest administrative unit in Ethiopia, which is composed of several villages.*

models. Binary logistic regression is used when the dependent variable is dichotomous (only two categories) and the independent variables are either continuous or categorical (Adepoju, 2019).

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

$P_i = E(Y) = {}^{1}/_{\mathrm{x}} = \frac{1}{1+e^{-(B_1+B_2X_i)}}$………………………………………………. **(1)**

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

When equation 1 is the logistic regression equation, let consider, $Z_i=B_1+B_2x_i$ or replaced by z_i in the first equation, then we obtained equation 2.

$P_i = \frac{1}{1+\mathrm{e}^{-\mathrm{z}_\mathrm{i}}} = \frac{\mathrm{e}^{\mathrm{z}}}{1+\mathrm{e}^{\mathrm{z}}}$……………………………………………………………….. (2)

In equation 2, Z_i exist between -∞ and +∞ and P_i is between 0 and 1. Where P_i shows the probability of households who use the solar home system, and X_i is the explanatory variable, (i) is an individual household observation (where pi equal to one the probability that households use the solar home system and 1-P_i, is the probability of households that can be categorized under not using. Then, the probability of households who do not use can be explained in equation 3 as follows:

$1 - P_i = \frac{1}{1+e^{z_i}}$………………………………………………………………… (3)

Equation 4 can be obtained by dividing the households who use to those who do not use solar home system. Therefore, the equation is;

$\frac{p_i}{1-p_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^{z_i}$ ….……………………………………………………… (4)

Using the natural logarithm of both sides of the equation, equation (5) can be obtained

$\ln\left(\frac{p_i}{1-p_i}\right) = ln = [e^{B_o} + \sum_{i=1}^{M} B_i X_i] = Z_i$ … … … … … … … … … ….............. (5)

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

$$Z(i) = B_o + B_1X_1 + B_2X_2 + B_3X_3 + \cdots . B_mX_m + u_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

Where Bo is the intercept, B_1, B_2, $B_3\ldots$ Are the slope parameters in the model. The slope coefficient indicates the change log-odds in favor of being adopting solar home system as an independent variable change. X_i Stands for the vector relevant characteristics of households whereas U_i is an error term.

$$Z_i = B_o + \sum_{i=1}^{M} B_iX_i + U_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(7)}$$

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

3.3. Identification of explanatory variables

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

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

Empirical studies concerning demographic variables are inconclusive and still debatable. Regarding gender of household head, there are two contrasting groups, which means the first group argued that male-headed households are more likely to adopt solar home system (for instance Anteneh, 2019) and in the other side, female-headed households are more likely to adopt solar home system (Guta, 2018; Partick, 2009). Therefore, in this study gender of the household head is expected to have either a positive or negative influence on SHS adoption. Some literature revealed that older household heads are less likely to adopt solar home system compared to younger ones. That means it has a negative influence on the household's willingness to adopt a solar home system (Anteneh, 2018; Legesse, 2016). But other studies found that households' age has a positive influence on solar home system adoption because it might be related to the fact that older household heads may be wealthier as they accumulate more productive resources that enable them to invest in the solar home system (Guta, 2018). In this study age of households' head is hypothesized to affect SHS adoption either positively or negatively. Likewise, family size is expected to have either a positive or negative influence on SHS adoption. Studies indicated that family size has a negative effect on solar home system adoption (Gitone, 2014; Anteneh, 2019; Abera, 2019). This is because households with large family sizes spend more resources in upholding their children rather than investing in a solar home system. The other study also revealed that household size has a positive effect on solar home system adoption (Guta, 2018). But marital status is expected to have a positive influence on SHS adoption. A study stated that married household heads are more likely to adopt a solar home system than either single or divorced household heads (Anteneh, 2019).

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

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

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

Distance from home to different infrastructures including the main road, market, and agricultural extension center is also considered as key factors expected to affect solar PV technology adoption. Legesse (2016), found that both distances from home to the main road and agricultural center have a negative effect on households' willingness to adopt for the solar home system. This is due to the reason that the average distance of households to agricultural extension centers might affect their information accessibility regarding solar and other agricultural extension services that would influence their product. Likewise, the distance from home to the surrounding market negatively affects solar home system adoption (Legesse, 2016). That means since solar products are found in market areas, households who close to the market are more adopters. Therefore, distance from home too, main road, agricultural extension center, and market are proposed to negatively influence SHS adoption. Similarly, households' access to electricity is expected to negatively affect SHS adoption. A study revealed that poor access to electricity in developing countries facilitates solar energy adoption (Tahir et al., 2017). Table 1 shows a detailed description of the variables used in the model and hypothesized effect on SHS adoption.

Table 1. Description of Explanatory Variables and their expected effect on the adoption household of solar home system

Variables	Description	Expected sign	Sources
log income	Continuous variable, Birr	+	Guta, 2018; Anteneh, 2019; Legesse, 2016
land	Continuous variable, number	+	Abera, 2019; Legesse, 2016 (+), Guta, 2018
Cattle(TLU)	Continuous variable, number	+	Anteneh, 2019; Legesse, 2016
Off-farm income	Dummy, 1= If the household has off-farm income, 0= otherwise	+	Obayelu A., 2017 Anteneh, 2019
Gender	Dummy, 1= male, 0= female	±	Guta, 2018; Anteneh, 2019 Partick, 2009)
Age	Continuous variable, year	±	Guta, 2018; Anteneh, 2019; Legesse, 2016
Family size	Continuous variable, number	±	Gitone, 2014 , Anteneh, 2019; Guta 2018, Abera, 2019
Marriage	Dummy, 1= married, 2= single, 3= divorced, 4= widowed	+	Anteneh, 2019
Education	Dummy, 1=Literate, 0= Otherwise	+	Abera, 2019 ; Guta, 2018; Anteneh, 2019;
House	Dummy, 1=traditional(terraced), 2= one-room tin-roofed house, 3= two-room tin-roofed house, 4= three and above room tin-roofed house	+	De Groote et al. 2016, Abera, 2019
Prior info.	Dummy, 1= if the household has prior	+	Naomi, 2014

	information/knowledge about solar energy, 0= otherwise		
Training	Dummy, 1= If household got training, 0= otherwise	+	Keriri ,2013; Bizien, 2017; Ali, 1998
Credit	Dummy, 1= If household got access to credit, 0= otherwise	+	Khushbu et al, 2015
phone	Dummy, 1= if household has a cell phone,0 if not	+	Abera, 2019
Media	Dummy,1= Yes, 0= otherwise,	+	Abera, 2019
Distmarket	Continuous, kilo meter	-	Legesse, 2016; Anteneh, 2019; Keriri, 2013
Distagriext.	Continuous, kilo meter	-	Legesse, 2016
Distroad	Continuous, kilo meter	-	Legesse, 2016
Electricity access	Dummy, 1= if household got access to electricity, 0= otherwise	-	
Kebele-dummy	Kebele dummy (0= Michig, 1= Yelemelem, 2= Limichim, 3= Yegelaw)	±	

4. Result and Discussion

4.1. Descriptive analysis

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

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

In the same way, concerning educational level, as shown in table 2, 40.7% of the household heads were illiterate who couldn't read and write. The other 47.71%, 10.24%, 0.8%, 0.3%, and 0.3% were *basic education*[1], primary education, secondary education /9-10/, preparatory education /11-12/ and TVET and above the level of education respectively. In the model, this variable is included as literate (households who attended formal education) and illiterate (households who didn't attend formal education). The analysis indicated that more educated households' heads were solar home system adopters compared to non-adopters. The chi-square test showed that there is a statistical association between the education level of household heads and the decision to adopt SHS.

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

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[2] *Basic education: Able to read and write.*

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

Out of the total sample, 91.4% of them reported that they have prior information about the solar home system; whereas 8.6% of respondents confirmed that they have no prior information about the solar home system so far. The chi-square test showed that there is a statistical association between prior information/knowledge and the decision to adopt solar energy. This result matches with Legesse (2016), who proposed that the majority (84.3%) of respondents have information about the benefits of renewable energy sources such as solar and biogas while 15.7% of them have no information in Ambo district.

About 55.26% of the respondents received informal /awareness creation/ training on how to utilize solar home system products in their homes. The remaining 47.74% of respondents replayed that they had never received neither formal nor informal training regarding the solar home system. The training was delivered by the energy office of the woreda and solar energy product distributors /agents/ jointly. The chi-square test indicated that there is a statistical association between training and SHS adoption.

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

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

Table 2: Descriptive statistics of adopters and non-adopters on categorical /dummy variables

Explanatory variables	Category	Adopters		Non-adopters		Chi^2 test
		No.	**%**	**No.**	**%**	
Sex of HH head	Male	211	92.5	126	88.1	0.150
	Female	17	7.5	17	11.9	
Marital status	Single	3	1.3	1	0.7	0.196
	Married	204	89.5	120	83.9	
	Divorced	10	4.4	7	4.9	
	Widowed	11	4.8	15	10.5	
Education level	Illiterate	66	28.9	85	59.4	
	Basic education	129	56.6	48	33.7	
	Primary education	28	12.3	10	6.9	
	Secondary education/9-10/	3	1.3	-	-	
	Preparatory education/11-12/	1	0.4	-	-	0.000***
	TVET & above	1	0.4	-	-	
Participation in o**ff farm** income earning activities	Yes	30	13.2	7	4.9	0.012**
	No	198	86.8	136	95.1	
House type	One room & tin roofed	4	1.8	26	18.2	0.000***
	Two rooms & tin roofed	90	39.5	86	60.1	
	Three and above rooms & tin roofed	134	58.8	31	21.7	
Credit accessibility	No	2	0.88	11	7.69	0.001**

	Yes	226	99.12	132	92.31	*
Training access	Yes	183	80.26	22	15.38	0.000***
	No	45	19.74	121	84.62	
Prior info/knowledge	Yes	227	99.6	112	78.3	0.000***
	No	1	0.4	31	21.7	
Own cell phone	Yes	149	65.4	41	28.7	0.000***
	No	79	34.6	102	71.3	
Media access (radio or TV, or both)	Yes	217	95.2	87	60.8	0.000***
	No	11	4.8	56	39.2	
Electricity access	Yes	4	1.75	10	6.99	0.010***
	No	224	98.25	133	93.01	

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

Regarding landholding, the majority (98.7%) of the households owned land, whereas 1.3% of households had no land. As shown in table 3, the average landholding size of the two groups indicates that adopters had more land size (1.579 hectares) than non-adopters (1.343 hectares). This difference shows a statistically significant at 1%.

The majority of the households (97.3%) owned cattle (in tropical livestock units). Whereas 2.7% had no cattle. As indicated in table 3, there is a significant difference between the number of cattle of adopters and non-adopters, where adopters had a higher mean (3.872) than non-adopters (2.678).

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

As shown in table 3, the mean distance of households who adopted SHS was 2.69 km whereas the mean distance of respondents who didn't adopt was 3.42 Km. The p-value for the distance of households' home from the main road indicated that there was a significant mean difference (P<0.01) between the mean of the two groups. Regard to the distance of households' home from agricultural extension center, the mean of adopters (2.79) was relatively less than from the mean of non-adopters (3.36). It indicated that most of the non adopters live relatively far from the agricultural extension center than adopters. The p-value for this also shows a significant mean variation (P<0.01) between the two groups. The analysis also shows that the mean distance of adopters (5.02km) and non-adopters (5.88 km) from the market area showed that most of the non-adopters were relatively far from the market area (town) where they couldn't get information and chances of observing solar home system products. The p-value of the t-test for this also shows a significant mean difference (P<0.01) between the two groups.

Table 3: Descriptive statistics and test of mean differences of adopters and non-adopters on continuous /discrete variables

Explanatory variables	Adopters		Non-adopters		P-value
	Mean	Std. Dev.	Mean	Std. Dev.	for t-test
Age of HH head	48.06	10.201	52.29	10.947	0.000***
Family size	4.78	1.519	5.15	1.477	0.020**
Land holding size	1.579	0.790	1.343	0.632	0.002***
Household's income	88992.69	37476.82	66107.45	34806.10	0.000***
cattle (TLU)	3.872	2.133	2.678	1.475	0.000***
Dist.road	2.69	2.20	3.42	2.19	0.002***
Distagri.ext in km	2.79	1.46	3.36	1.79	0.001***
Dist market	5.02	1.69	5.88	1.74	0.000***

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

4.2. Econometric results of determinants of solar home system adoption

Table 4 below summarizes the results of logistic regression on the determinants of household adoption of SHS. The response variable was either adopting or not adopting the solar home system. Those households who had solar home systems were considered as "adopters" and those who had not considered as being "non adopter".

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

The Hosmer and Lemeshow test is applied to estimate the overall model fit. Since the p-value is greater than statistically significant ($p<0.05$), the estimated model has an adequate fit for the purpose. For this study, the correct model predictions for adopters and non-adopters were 90.8% and 85.3% respectively, and the overall correct model prediction was up to 88.7%.

Table 4 shows from the total of 18 explanatory variables included in the model, 9 of them were found to have a statistically significant effect on households' decision to adopt SHS. These variables include; income, participation in off-farm income, educational status of households' head, housing type, prior information/knowledge about SHS, gender, training access, media access, and electricity access/connection to the grid. Kebele dummies were also included in the model to control for spatial heterogeneities.

4.2.1. Income level of household

The income of the household is found to be one important factor in households' decision to adopt a solar home system. The study showed that the income of households has a positive and statistically significant ($P<0.1$) effect on solar home system adoption (see Table 4). The odd ratio of the binary logistic regression model indicated that as income of household increase by one Birr, the probability of adopting a solar home system increase by a factor of 3.018. The Walder statistics (3.071) also indicated the strong association between income and solar home system adoption. This implies that as households become economically strong their propensity to invest in renewable energy technology also increases. This result is consistent with Guta (2018), who revealed that as the income of the household become higher, their purchasing power increase and as the same time their demand for solar home system becomes higher. It also agrees with (De Groote et al., 2016), who argued that the income of households is important and has a significant effect on solar home system installation. Generally, the observed positive correlation in the model estimation indicates the fact that when households got richer, they can adopt new technologies such as solar.

4.2.2. Participation in off-farm income earning activities

Participation in off-farm income-earning activities is among the main socio-economic factors that influence households' decision to adopt SHS. As shown in table 4, the result of logistic regression indicates that off-farm income has a positive effect on solar home system adoption with a statistically significant level ($P<0.1$). The odd ratio showed that households who participate in off-farm income-earning activities are more likely to adopt solar by a factor of 4.182 as compared to those households who have no off-farm incomes. The Wald statistics (3.404) also indicated that there is a strong association between off-farm income activities and solar home system adoption. This implies that households who participate in additional off-farm income-earning activities are more economically powerful to invest in SHS for domestic purposes compared to counterparts who do not participate.

4.2.3. Housing type of household

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

4.2.4. Gender of the household head

The gender of the head plays a significant role in determining households' decisions to adopt SHS. The result of this study indicated that male household heads are less likely to adopt the solar hole system by a factor of 6.172 ($P<0.05$) compared to female-headed counterparts. This is because women are more responsible for the fulfillment of household energy sources in rural Ethiopia. This result corroborates with a previous study by Partick (2009), who revealed that women are more active in the participation of environmentally friendly technologies than men. It is also supported by Guta (2018), who found that women are more willing and highly attached with household energy utilization than men in a household, but contrasts with the finding of Anteneh (2018), who revealed that male household heads were more likely to adopt solar home system than female counterparts.

4.2.5. Educational status of household heads

The education status of household heads is one of the key factors determining households' willingness to adopt SHS. According to the model estimation, education status was found to have a positive influence on SHS adoption at statistically significant ($P<0.05$). The odd ratio indicated that literate household heads are more likely to adopt SHS by the factor of 21.212 (0.05) compared to illiterate household heads. The Wald statistics (5.505) showed that education has a strong association with the adoption of a solar home system.

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

4.2.6. Prior information/knowledge

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

4.2.7. Training access

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

4.2.8. Media access

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

4.2.9. Electricity access

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

Table 4: Results of logistic regression model on determinants of households' adoption of solar home system

Variables	Coef.	S.E.	Wald	P-value	Odds ratio
Logincom.	1.105	.630	3.071	.080*	3.018
Offarmparticip	1.431	.775	3.404	.065*	4.182
TLU	.066	.155	.182	.669	1.068
Land	-.533	.351	2.309	.129	.587
Credit	-1.714	1.112	2.378	.123	.180
House with two rooms	2.282	.880	6.730	.009***	9.799
House with three& above rooms	2.827	.980	8.327	.004***	16.899
Gender of head	-1.820	.754	5.830	.016**	6.172
Age of head	-.030	.021	2.143	.143	.970
Family size	-.184	.144	1.635	.201	.832
Education status of head	3.055	1.302	5.505	.019**	21.212
Prior info.	6.305	2.690	5.494	.019**	547.032
Own cellphone	.402	.433	.861	.354	1.494
Media access	1.831	.685	7.155	.007***	6.242
Training access	2.888	.409	49.899	.000***	17.949
Distance to road	-.042	.117	.129	.719	.959
Distance to farm extension	.061	.146	.173	.677	1.063
Distance to market	-.068	.135	.257	.612	.934
Electricity access	-2.263	1.004	5.082	.024**	.104
Kebele dummies	yes				
Constant	-19.867	7.159	7.702	.006***	.000
Hosmer & Lemeshow test	0.870				
Nagelkerke R^2	0.742				
Model prediction	88.7				
-2log likelihood	201.537^a				
No. of observation	371				

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

5. Conclusion

Using clean and renewable energy sources has paramount importance to reduce adverse health and environmental impacts of using detrimental energy sources especially for citizens from low-income countries like Ethiopia. It is important to understand the underlying factors affecting household adoption of SHS. Previous studies on the factors influencing household SHS adoption overlooked key variables and did not look at the situation in the study area. To fill this gap, the study used data collected from 228 adopters and 143 non-adopters from four kebeles of Baso Liben district, Amhara regional state to investigate factors influencing SHS adoption of rural households. In the study area, only 3.8% of households had electricity access. Recently, many rural households of the study area have a propensity to adopt SHS. Out of the total sample household respondents, 61.5% adopted SHS. Based on the finding, adopters and non-adopter households are varied in many demographic and socioeconomic variables.

Binary logistic regression results indicated that variables including income level, off-farm income activity, housing type, household heads' education status, training access, media access, and prior knowledge are statistically significant and have a positive effect on SHS adoption. On the contrary variables including gender and electricity access are statistically significant but negatively affect SHS adoption. Since economic variables such as income level of household and participation in off-farm income-earning activities are strong predictor variables, appropriate policy options targeted on improving household economic status to reduce poverty is viable to increase their capacity to invest in the solar home system. Diversification of income sources of rural households through creating different opportunities for off-farm income-generating activities is better to enhance their economic level, which increases their propensity to adopt SHS technology. Improvement of rural households' income level grows not only their willingness to adopt solar but also improves the overall wellbeing of the family. The availability of basic needs including house type could affect the decision to use solar. Mostly, regarding housing type, the number of rooms, and roof quality may influence to install solar. Therefore the improvement of households' economical wellbeing leads them to have better housing type that positively enhances SHS adoption. Efforts targeted on improving educational status have multiple benefits for the rural community. Education boost up households’ consciousness level in social, economical, and cultural spheres; helps to generate different income opportunities, and increases awareness that leads them to use clean and modern energy sources rather than using energy sources which are relatively cheap but have detrimental health and environmental effects. Households who got training about the solar home system are more likely to use solar as a source of light for their home. Therefore, rural households should be provided training about the utilization of SHS and its importance properly. Media plays a significant role in accessing accurate and timely information for rural society. It is possible to motivate, aware, or educate most of the rural households at a point in time. Therefore, rural households should be aware to use information sources including radio and other media alternatives as necessary. Moreover, appropriate information should be released using different Media including radio, pamphlets, and brochures for rural households to aware them about the utilization of renewable energy source such as solar as well as their health and environmental values.

This research used cross-sectional data to examine factors influencing SHS adoption. However, investigating the effects of major determinants on solar energy adoption that encompasses a wide range of rural geography and community using longitudinal data is required. Moreover, using an appropriate model, further researches might be conducted on the effects of product-specific attributes including product quality and price on household adoption of the solar home system.

Abbreviations

CSA: Central statistical Agency

HH: Household

ICF: International Care Facility

MoWIE: Ministry of Water Irrigation and Electricity

PV: Photo Voltaic

REEEP: Renewable Energy and Energy Efficiency Partnership

REN: Renewable Energy Policy Network

SHS: Solar Home System

TERI: The Energy and Resource Institute

UNEP: United Nation Environmnet program

VIF: Variance Inflation Factor

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Availability of supporting data

All relevant data are incorporated into this manuscript. So, there is no other data to be supplemented.

Competing interest

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Authors' contribution

AM collected the data, estimated the model, and prepared the draft manuscript. DD critically read the manuscript, made suggestions and provided valuable inputs to finalize the manuscript. All authors read and approved the manuscript.

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