



Research Article

Determinants of Renewable Energy Technologies Adoption and Energy Source Choice of Households in Boset District, Ethiopia

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Abstract | Renewable energy technologies are the best option for rural peoples until hydroelectric power is well disseminated in the country. Ethiopia has been faced with critical energy access and supply problems with poorly ventilated cooking places. The current study examined factors determining households' decision to adopt renewable energy technologies and energy source choice in Boset District. A two-stage stratified random sampling was employed to draw 210 respondents. The descriptive statistics and multinomial logit and the binary logit model were used to analysis the data . The descriptive result revealed that a total of samples 37 (17.6%) were adopter of modern energy sources, 50(23.8%) were adopter of both traditional and renewable energy technology, and 123 (58.6%) were user of traditional energy source. The binary logit model revealed that age, family size, education, income, number of livestock owned, land size holding, and training were significant to adopt technologies. The multinomial model indicated that age, family size, land size holding, Income, livestock ownership, education, and training have significant to modern and mixed energy choices in references to traditional energy. The study suggested that continues training and education are required to enhance households' awareness concerning renewable energy sources.

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Introduction

Energy deficiency at the household level is explained by lack of access to electricity and the reliance on the traditional use of biomass for cooking (IEA, UNDP, and UNIDO, 2010). It is estimated that 1.4 billion people around the world have no access to electricity with 85% of them are living in rural areas; and, 2.7 billion people i.e. 40% of the global population rely on traditional biomass energy for cooking (IEA, 2010), From the 620 -730 million people in sub-Saharan Africa countries do not have access to

electricity and clean cooking facilities respectively (IEA,2014). It is projected that 1.2 billion people around the globe will have no access to electricity and traditional biomass use is anticipated to increase to 2.8 billion people in the year 2030 (IEA,2014).

Area with the unventilated cooking places households, women and children are vulnerable to critical health problems such as pneumonia, chronic lung diseases, and lung cancer (WHO and UNDP, 2009; Hanawi et. al., 2020; Faller et al., 2020). Like many other developing countries, Ethiopia has been faced

with critical energy access and supply problems. It is estimated that only 23% of the country's population have access to electricity, of which 86% is urbanities and only 5% is rural residents (GTZ, 2015). According to Dereje (2013), traditional biomass energy sources such as firewood, dung cake, and agricultural residues are the major energy source that accounts for more than 90% of the country's energy supply. This extensive utilization of forest has led to the depletion of tree stock of the country 15 % (ENA, 2015).

Energy deficiency exacerbates in the rural part of the country. From the total of rural residents in the country, more than 95% meets their daily energy need from unclean and traditional energy sources (GTZ, 2015). In the study area, biomass energy source especially firewood constitutes the greater portion of domestic energy supply for both rural and urban areas followed by dung and charcoal consumption (BDFEDO, 2019). Ethiopia has endowed with abundant clean energy sources; however, their development and utilization remained very low (Dawit, 2014). Different empirical studies have been conducted so far by (Dawit, 2008; Alemu and Köhlin, 2008; Yonas et al., 2013; Yonas et al., 2015; Gebreegziabher et al., 2012) on the determinants of households' energy technology adoption and energy source choice in Ethiopia. The above-mentioned studies have either focused on identifying factors that influence the adoption of energy technologies or addressed the issue of household fuel choice focusing on urban areas.

With large area coverage and having the countries' largest share of the population, access to the modern energy source is the major impediment in rural parts of Ethiopia. Currently, renewable energy technologies are the best option for rural peoples until hydroelectric power is well disseminated in the country. Besides examining the determinant factors of renewable energy source adoption, it is to investigate rural households' energy source choice focusing on modern energy sources. Thus, this study was intended to fill the aforementioned gap by identifying factors affecting renewable energy technology adoption and rural households' energy source choice focusing on the utilization of modern energy sources.

Materials and Methods

Study Area: The study was conducted in East She-wa Zone in Boset district. The district covers an area

of 151,406.6 km² and divided into 32 rural and 4 town kebles. The total population accounts for 185,401 (111,572 male and 73,829 female) (BDFEDO, 2019). Boset has a one-season ('Meher') crop production cycle. Mixed agriculture is a common economic activity in the district. The district is known for its renewable energy source potential, especially solar energy. But, the energy source for the district is mainly from traditional biomasses; and, firewood constitutes a greater coverage of domestic energy supply both in rural and urban areas (BDFEDO, 2019). This study was conducted in 2019/20.

Study Design: Cross-sectional survey design was employed which incorporates both quantitative and qualitative survey methods. The data collected for this study included both primary and secondary data sources. The primary data of the study was collected directly from technology adopters and non-adopters. And, it was also obtained through key informant interviews and focus group discussions. The secondary sources were woreda's finance and economic development and energy offices renewable energy technology dissemination report and other documents. Quantitative data was collected directly from respondents using a semi-structured questionnaire while qualitative information of the study was obtained through interviews and focus group discussions.

Sample size determination

The study used simplified formula provided by Fink and Kosecoff (1985), to determine required sample size.

$$N = \frac{(z)^2(p)(q)}{e^2} \dots (1)$$

Where;

P: Estimated characteristics of the target population proportion (expected prevalence); $Z_{\alpha/2}$: 95% confidence level corresponds to the value of 1.96; e: Proportion of sampling error tolerated at 0.05, q=1-p. Based on the information provided by the district finance and economic development office, the expected prevalence of technologies' dissemination in the district is 15% (BDFEDO, 2019). Thus, using P=0.15, the value of q becomes 0.85, taking these numbers in the above formula the sample size of the study becomes:

$$N = \frac{(1.96)^2(0.15)(0.85)}{0.05^2} \approx 196$$

By considering 7% non-response rate, the total sample size was $196+14=210$

Sampling technique

Two-stage sampling technique was employed to draw sample households. First, using information obtained from Boset District Energy Office, major, medium, and lower technologies' adopter kebeles have listed and stratified accordingly. Then, from each stratum, two study kebeles were selected using a simple random sampling method which resulted in a total of six kebeles. Finally, using the calculated sample size, all randomly selected kebeles are included in the study with their total number of households. Study participants from each kebele included in the study using probability proportional to their size (PPS). Each technology user and non-user has been selected using a simple random sampling method.

Method of data analysis

The study employed both descriptive statistics and econometric model to analyze the collected data. To run statistical analysis, data were coded and entered in to a computer program with statistical package for social studies (SPSS) software packages. Descriptive statistics was used to present data in the form of table percentage and frequency. Both binary logit and multinomial model were employed to investigate the issue under a question.

Binary logit model was used to identify determinants of adoption of renewable energy technology. The Logit model follows the same approach as the probit model, the difference being that in this case the inherent error in the model is assumed to distribute according to the function of logistic density. Logistic regression analysis has also been used particularly to investigate the relationship between binary response probability and explanatory variables. For bankruptcy prediction the binary response probability is usually the default probability, while a high number of explanatory variables can be used. The method usually fits linear logistic regression models for binary response data by the method of maximum likelihood (Hosmer and Lemeshow, 1989).

The logistic regression model is shown as the following form:

$$\ln\left(\frac{p}{1-p}\right) = \alpha + \sum_{i=1}^K \beta_i \chi_i + \varepsilon_i \dots\dots(2)$$

Where;

p = the probability of adoption of renewable energy; α = value of log odd ratio $(p)/(1-p)$, K = number of independent variable included into the model, $(p/1-p)$ = odds of adoption of renewable energy; X_i = vector of independent variables; β_i = parameter estimate for the independent variable. The logistic regression is powerful in its ability to estimate the individual effects of continuous or categorical independent variables on categorical dependent variables (Wright, 1995).

The multinomial logit regression (MNL) model introduced by Luce (1959) and is often used when the dependent variable comprises more than two categories. Mostly, the MNL is used to model nominal output variables in which the log odds of the outputs are modeled as a linear combination of explanatory variables. Nowadays, the MNL is a very common choice among applied researchers for analyzing the categorical response variable having at least three categories. If only two discrete choices have to be analyzed the multinomial logit model (Pundo and Fraser 2006). The multinomial logit model that is used in our analysis of data can be expressed as follow:

$$\Pr(Y_i = j) = \frac{\exp(\beta_j' X_i)}{\sum_{j=0}^J \exp(\beta_j' X_i)} \text{ For } j = 1, 2, \dots(3)$$

Where;

$\Pr(Y_i=j)$: Probability of choosing either modern energy or mixed energy; J : Number of choice of energy sources; $j= 1$: Modern energy; $j = 2$: Mixed energy sources; X_i : Vector of explanatory factors conditioning the choice of the j^{th} alternatives; β : Vector of the estimated parameter.

Results and Discussion

The survey result shows that from a total sampled respondents about 193(91.9%) respondents were male-headed households and the remaining 17(8.09%) respondents were female-headed households. The mean age and family size of sample households were 41.98 and 5.52 respectively (Table 1).

As it can be depicted in Table 2, from the total of 210 sampled households, 123 respondents (58.6%) were found to be non-adopters; while, 87(41.4%) were adopters of renewable energy technology. This implies the majority of the households were found to be non-adopters of renewable energy resources.

Table 1: Descriptive statistics of sample respondents.

Explanatory variables	Minimum	Maximum	Mean	Std. Dev.
Age of HH head (Year)	18	67	41.98	10.39
family size of HH(- Number)	2	10	5.52	1.68
	Category	Total Number	Percentage	
Sex	Female	17	8.09	
	Male	193	91.9	

Table 2: Renewable energy technology adoption of sampled households.

Adoption	Number of households	Percent (%)
Non-adopter	123	58.6
Adopter	87	41.4
Total	210	100.0

As can be seen from the Table 3, from a total of 210 households, 37 (17.6%) of them utilize modern energy sources. While 50 (23.8%) was user of both traditional and renewable energy technology as their main energy source. The remaining 123 (58.6%) are traditional energy source users.

Table 3: Energy source choice of households.

Energy choice	Frequency	Percent (%)
Modern energy	37	17.6
Mixed energy	50	23.8
Traditional energy	123	58.6
Total	210	100.0

Econometric model results

Binary logistic model results: The model revealed that in Table 4, from a total of ten (10) explanatory variables included into the model, seven (7) of them were found to determine the renewable energy adoption decision of sample households.

Discussion to significant variable to determinants of adoption of renewable energy technologies:

Age of household head: The relationship between the age of the household head and the adoption of renewable energy technologies has become negative and significant. The marginal effect with the value of - 0.0154 implies that, keeping other factors constant, as the age of the household head increases by one year

the probability of adopting renewable energy technology decreased by 0.0154(1.54%) . This might be due to older people are more reluctant to accept new technologies and prefer to keep on using something they are familiar with. This result is similar with the studies conducted by Tigabu (2014).

Table 4: Logistic regression result: Determinants of adoption of renewable energy technology.

_adoption-	Coef.	Std. Err.	Z	P >Z	Marginal Effect
_Isex_1	1.016705	.8179536	0.02	0.984	.0038569
Age	-0.93594	.0229955	-2.69	0.007***	-.0154378
Family_ size	-0.73747	.1000446	-2.24	0.025**	-.0710208
Education	1.39668	.1500088	3.11	0.002***	.0779177
Total_ land_ size	2.103738	.7582701	2.06	0.039**	.1734479
Livestock_TLU	1.354025	.1454835	2.82	0.005***	.0706841
Ln_ income	2.651386	1.130436	2.29	0.022**	.2274067
Amount_ credit	.9999627	.0000821	-0.45	0.649	-8.70e-06
Distance_ market	.981148	.0245233	-0.76	0.446	-.0044386
_Itraining_1	5.015261	2.434803	3.32	0.001***	.3474101
_cons	.0002495	.0009812	-2.11	0.035	

Source: Computed from own survey data (2019/20); ** And *** = significant at 5% and 1% level of significance, respectively.

Family size : The model result show that family size affects adoption of renewable energy technology in a negative and significant way. The marginal effect indicates that, assuming every thing constant, as family size increases by one unit the probability of adopting renewable energy technology decrease by 0.071(7.1%). This may be due to households with large family size were hinders adopt of new technologies. In another way, household with larger family size means more labor to collect free traditional fuels like firewood and dung, which might make households reluctant to adopt energy technologies. The finding of this study was in harmony with the finding of yonas et al. (2015).

Education level : Education level of household were significantly determine adoption decision of renewable energy technology of households. The marginal effect of 0.077 for education shows that keeping other factors constant, the probability of adopting renewable energy technologies increases by 7.7% for one grade increment in the educational level of the household head. The finding of this study is in concord with the previous works of Kabir et.al. (2013) and Iqbal et al. (2013).

Table 5: *Multinomial Logistic Result: Determinants of energy choice of sample households.*

Choice Variables	Modern Energy				Mixed Energy			
	Coef.	dy/dx	Z	P>z	Coef	dy/dx	Z	P>z
Sex Male	-1.220198	-.1589791	-1.19	0.234	.1624919	.0990379	0.13	0.898
Age	-.0605755	-.002315	-1.90	0.058*	-.064682	-.003376	-2.1	0.030**
Family Size	-.2945361	-.0054745	-1.60	0.110	-.403639	-.026485	-2.2	0.026**
Education	.4660993	.0179083	3.16	0.002**	.4962204	.0258144	3.49	0.000**
Total land size	.5773503	-.0049131	1.32	0.187	1.032406	.0791591	2.40	0.016**
Livestock in TLU	.4133841	.0215668	3.28	0.001**	.3524681	.0129972	2.82	0.005**
Amount Credit	-.0001896	-.0000242	-1.47	0.141	.0000593	.000019	0.58	0.560
Distance to Market	-.0449613	.0004865	-1.30	0.193	-.082000	-.006345	-2.4	0.016**
Training Yes	1.194264	.0449281	2.00	0.046**	1.37473	.0812816	2.28	0.023**
Lnincome	1.107211	.0247193	2.06	0.040**	1.453524	.0923552	2.73	0.006**
_cons	-11.18369		-2.37	0.018	-14.107		-2.8	0.004

Source: *Computed from own survey data (2019/20)*

Total land size: Total land holding of household were positive and significantly affect renewable technologies' adoption. The marginal effect value of total land size was 0.173 on the adoption of renewable energy technologies. That means, keeping other things constant, the probability of adopting renewable energy technologies increased by 17.3 percent as the land size holding of households increased by one hectare. The study result is in harmony with the findings of Alemu and Köhlin (2009) and Iqbal et al. (2013).

Livestock Holding (TLU): It is positive and significant relationship with the adoption decision of households. The marginal effect with a value of 0.07 indicates that, keeping other factors constant, as livestock increases by one unit the likelihood to adopt renewable energy technology increases by 7%. Livestock is one means through which households kept their wealth, especially in rural Ethiopia. So, with large livestock ownership households tend to adopt new technologies. This result is similar to the findings of Iqbal et al. (2013) and Kabir et al. (2013).

Total income: Total annual income of household affects adoption of renewable energy technology positively and significantly. Households with high annual income found to be more adopters of the technology than those households with lower annual income. The marginal effect of income on the adoption decision of households has a value of 0.227. This implies that, holding other factors constant, as the income level of a household increases by one birr the probability of adopting the technology increases by 22.7 percent. A

similar finding was reported by Lay et al. (2012) and Ouedraogo (2006).

Training: Access of training on energy technology adoption was positively and significantly related to adoption of renewable energy technology. The marginal effect of this variable is 0.347 implying that the probability of renewable energy technology adoption for trained households increases by 34.7 percent as compared to untrained households. The result of this study is similar to the finding of Abadi (2006).

Multinomial logistic model results

This model estimates the effect of each covariate/variable on the energy choice of sampled households. (That is modern, mixed, and traditional). And, traditional energy is used as a reference group).

Interpretation of significant variables as follow

Age of household head: As depicted in the Table 5 Age of household head has negative and significant association with both modern and mixed energy choices. The marginal effect of the household head on energy choice of households have a value of - 0.0023 and - 0.0033 for modern and mixed energy choices respectively; which indicates that assuming other factors constant the choice of modern and mixed energy sources decreases by 0.23% and 0.33% for a one year increment in the age of the households head compared to traditional energy sources. The finding of this study is similar to the work of Waweru (2014).

Family size: For a mixed energy choice, family size

has shown a negative and significant relationship. The marginal effect that is -0.026 shows that keeping other factors constant, the probability of choosing a mixed energy source decreases by 2.6% relatively, as a one-unit increment in family size. This may be due to free labor availability to collect free traditional energy source, or preparing food to all family members require huge energy which might not be satisfied either by modern or mixed energy sources that obliged households to pursue using traditional energy sources. This study finding is similar to the work of [Waweru \(2014\)](#).

Education: Has a positive and significant influence on both modern and mixed energy choices. The marginal effect 0.0179 and 0.0258 of education for both energy categories indicates that keeping other factors constant, the probability of choosing modern and mixed energy sources increases by 17.9 and 25.8% respectively relative to a one-grade increment in education compared to traditional energy sources. The study in line with the finding of [Ouedraogo \(2006\)](#).

Land size: For mixed energy choice land size holding has shown a significant and positive relationship. The marginal effect of land size holding on the choice of mixed energy source indicates that assuming everything is constant, an increase in land size holding increases the probability of choosing mixed energy as their main energy source by 7.9% compared to traditional energy sources. The model result show that land size has been direct relationship with the choice of energy sources. The study result is in agreement with the findings of [Alemu and Köhlin \(2009\)](#).

Livestock Holding (TLU): For both modern and mixed energy source choices livestock ownership, has shown a significant relationship. The marginal effect of households' livestock holding on the choice of modern and mixed energy sources with a value of 0.0215 and 0.0129 respectively indicates that, keeping other factors constant as a livestock holding in TLU increases by one unit the choice of modern and mixed energy as main energy sources increases by 2.15% and 1.29% respectively compared to traditional energy sources. Since livestock possession is one-way keeping households' wealth in rural Ethiopia, the study finding confirms the energy ladder hypothesis of income/wealth affects modern energy choice of households ([Heltberg, 2003](#)).

Distance to market: An increase in the market distance led to a decrease in the probability of choosing mixed energy over traditional energy sources. The marginal effect value of -0.006 indicates that assuming everything constant the choice of the mixed energy source as the main fuel decreased by 0.6% for a one kilometer increment in the distance of the market center.

Training: It is significantly determine both modern and mixed energy choices. The marginal effect of training for both energy categories was 0.044 and 0.081 respectively. This implies that keeping other factors constant, the probability of choosing modern energy over traditional energy increased by 4.4% for trained households compared to untrained households and, the likelihood of choosing mixed energy over traditional energy increases by 8.1% for households' who are provided with training compared to untrained one. This means that households provided with training know more about the positive benefits of utilizing renewable energy technologies and modern energy sources which motivate them to choose cleaner energy sources to meet their daily energy needs.

Annual income: It is significantly determine both modern and mixed energy choices. The marginal effect of annual income on energy choice of households have a value of 0.0247 and 0.0923 for modern and mixed energy choices respectively; which indicates that assuming other factors constant the choice of modern and mixed energy sources increases by 2.47% and 9.23% for a one birr increment in income level of households compared to traditional energy sources. The study finding concord with [Alemu and Kolhin \(2008\)](#) and [Ouedraogo \(2006\)](#). Besides, the finding of this study proves the energy ladder hypothesis, which confirms that as the income level of a household increases their preference to clean energy sources would increase.

Conclusions and Recommendations

The finding of this study indicated that the major determining factors of renewable technology adoption and modern energy source choice of rural households are; age, family size, annual income, total land size holding, livestock ownership (TLU), education, and training of the household head. These factors affect the adoption decision and modern energy source choice

of rural households one way or another. Besides, affordability and multi-purpose use of technologies' were mentioned as a major challenge for technologies' adoption during focus group discussion. Based on the finding of the study the following recommendations are forwarded. Stakeholders should strengthen and provide different educational opportunities like adult education and training for rural households to make them more informed about the benefits of utilizing cleaner energy sources. Concerned bodies should facilitate credit and subsidy schemes to make renewable energy technologies affordable for the rural poor. Efforts should be made by concerned bodies so that households engaged in different income generating activities like- irrigation schemes, to improve their income level and thereby enhance adoption and utilization of modern energy sources and reduce energy poverty at the household level. Due emphasis should be given by stakeholders for technological research to revise and adjust renewable energy technologies' limitations.

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Novelty Statement

Adoption of renewable energy is a new technology used in Boset district, Ethiopia. Thus, the findings smooth the way to use energy and available energy sources by identifying determinants of renewable energy technology adoption and energy sources.

Author's Contribution

Both authors designed the research work, drew questionnaire, supervised data collection, analyzed the data and wrote up the research report.

Conflict of Interest

There is no conflict of interest among the authors of the manuscript.

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