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Adoption of Renewable Energy Technologies and Energy Source Choice of Households

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Abstract

Renewable energy technologies are the best option for rural peoples until hydroelectric power is well disseminated in the country of Ethiopia where critical energy access and supply problems exist with a poorly ventilated cooking places. The current study examined the factors determining households' decision to adopt renewable energy technologies and energy source choices in Boset District. A two-stage stratified random sampling was employed to draw a sample of 210 respondents. Binary logit model has revealed that age, family size, education, income, number of livestock owned, landholding size, and training were significant to adopt technologies. On the other hand, multinomial model has indicated that age, family size, landholding size, income, livestock ownership, education, and training have significant role in the modern and mixed energy choices vis-à-vis traditional energy. The study has suggested that continued training and education are required to enhance households' awareness concerning renewable energy sources.

Keywords

Determinant; Adoption; Choice; Renewable energy; Technologies

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Introduction

Energy poverty 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 all over 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, 2014). Over 620 and 730 million people in sub-Saharan African 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 is expected to be used by 2.8 billion people in the year 2030 (IEA, 2014).

The women and children living in unventilated cooking places 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 facing problems of critical energy access and supply. It is estimated that only 23% of the country's population has access to electricity, of which 86% population is of urbanites and only 5% is of rural residents (GIZ, 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. Resultantly, extensive utilization of forest has led to the depletion of tree stock of the country by 15% (ENA, 2015).

Energy poverty exacerbates in the rural part of the country. Out of total rural residents in the country, more than 95% meet their daily energy needs from unclean and traditional energy sources (GIZ, 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) and 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 in urban areas.

Having large area and 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 distributed in the country. Besides examining the determinant factors of renewable energy source adoption, it is to investigate rural households' energy source choice focusing 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.

Material and Method

The study was conducted in East Shewa Zone of Boset district. The district covers an area of151,406.6 km^2 and divided into 32 rural and 4 town kebeles. 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 biomass; 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.

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Study Design

Cross-sectional survey design was employed incorporating 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. The data was obtained using the key informant interviews and focus group discussions. The secondary sources were Woreda's Finance and Economic Development and Energy Offices that provided access to renewable energy technology reports and other documents. Quantitative data was collected directly from respondents using a semi-structured questionnaire. Qualitative information of the study was obtained using interviews and focus group discussions.

Sample Size Determination

The study used formula provided by Anderson *et al*. (2007 to determine required sample size.

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

Where, p = Estimated characteristics of the target population proportion (expected prevalence), $Z_{a/2}$ = 95% confidence level that 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 comes:

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

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 were listed and stratified accordingly. Then, from each stratum, two study kebeles were selected using a simple random sampling method which resulted into a total of 6 kebeles. Finally, using the calculated sample size, all randomly selected kebeles were included in the study with their total number of households. Study participants from each kebele were included in the study using probability proportional to their size (PPS). Each technology user and non-user was 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 a computer program, i.e., SPSS package. Both binary logit and multinomial model were employed to investigate the issue under question. Moreover, data collected through key informant interviews and focus group discussions were analyzed using textual analysis.

Results and Discussion

The survey result shows that from a total sampled respondents about 193 (91.4%) respondents were male-headed households and the remaining 18 (8.6%) respondents were female-headed households. The mean age and family size of sample households were 41.98 and 5.52, respectively (Table 1).

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Table 1: Descriptive Statistics of Sample Respondents

Explanatory variables	*Minimum*	*Maximum*	*Mean*	*Standard Deviation*
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 Male	18 193		8.60 91.40

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

Table 1: 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

Out of the total of 210 households, 37 (17.6%) of them utilize modern energy sources, while 50 (23.8%) were users of both traditional and renewable energy technology as their main energy source. The remaining 123 (58.6%) were traditional energy source users (Table 3).

Table 2: 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:
Out of the total of ten (10) explanatory variables included into the model, seven (7) were found to determine the renewable energy adoption decision of sample households (Table 4).

Table 3: 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**	-.071020
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

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_adoption-	*Coef.*	*Std. Err.*	*Z*	*P>Z*	*Marginal Effect*
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	.476853

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

Discussion on significant variables to the determinants of adoption of renewable energy technologies is follows.

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 because older people are more reluctant to accept new technologies and prefer to keep on using something they are familiar with. This result is similar to the studies conducted by Tigabu (2014).

Family Size:
The model result shows that family size affects adoption of renewable energy technology in a negative and significant way. The marginal effect indicates that, assuming everything constant, as family size increases by one unit the probability of adopting renewable energy technology decrease by 0.071 (7.1%). This may be because households with large family size hinder adoption of new technologies. In other words, household with larger family size means more labour available to collect free traditional fuels like firewood and dung, which might make households reluctant to adopt energy technologies. The finding of this study is in harmony with the finding of Yonas *et al*. (2015).

Education Level:
Education level of household was a significant determinant of adoption decision for 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 accord with the previous works of Kabir (2013) and Iqbal (2013).

Total Land Size:
Total landholding of households was a positive and significant determinant affecting 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 landholding size of households increased by one hectare. The study result is in harmony with the findings of Alemu and Köhlin (2009) and Iqbal (2013).

Livestock Holding (TLU):
Livestock holding has a 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 the livestock increases by one unit the likelihood to adopt renewable energy technology increases by 7%. Livestock is a mean through which households kept their wealth, especially in rural Ethiopia. So, households having large livestock ownership tend to adopt new technologies. This result is similar to the findings of Iqbal (2013) and Kabir (2013).

Total Income:
Total annual income of households affects the adoption of renewable energy technology positively and significantly. Households with high annual income were 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[1] the probability of adopting the technology increases by 22.7 percent. A similar finding was reported by Lay (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 (Table 5).

Table 4: Multinomial Logistic Result: Determinants of energy choice of sample households

Choice		*Modern Energy*				*Mixed Energy*		
Variables	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**
Ln income	1.107211	.0247193	2.06	0.040**	1.453524	.0923552	2.73	0.006**
_cons	-11.18369	.034212	-2.37	0.018	-14.1072	.05467	-2.8	0.004

Source: Computed from own survey data (2019- 2020)

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 has a value of -0.0023 and -0.0033 for modern and mixed energy choices, respectively. It indicates that, assuming other factors constant, the choice of modern and mixed energy sources decreases by 0.23% and

[1]Ethiopian currency having values equivalent to USD 0.023

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0.33% for one year increment in the age of the household 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 one-unit increment in family size occurs. This may be due to free labour availability to collect free traditional energy source or preparing food to all family members requiring 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:
The 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 the 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 one-grade increment in education, compared to traditional energy sources. The study finding is in line with the finding of Ouedraogo (2006).

Land Size:
For mixed energy choice, landholding size has shown a significant and positive relationship. The marginal effect of landholding size on the choice of mixed energy source indicates that, assuming everything is constant, an increase in landholding size increases the probability of choosing mixed energy as their main energy source by 7.9% compared to traditional energy sources. The model result shows that landholding size has direct relationship with the choice of energy sources. This 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 of keeping households' wealth in rural Ethiopia, the study finding confirms the energy ladder hypothesis of income/wealth that 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 centre.

Training:
It significantly determines 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 significantly determines both modern and mixed energy choices. The marginal effect of annual income on energy choice of households has a value of 0.0247 and 0.0923 for modern and mixed energy choices, respectively. It indicates that, assuming other factors constant, the choice of modern and mixed energy sources increases by 2.47% and 9.23% for one birr (Ethiopian currency) 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

The finding of this study indicates that the major determining factors of renewable technology adoption and modern energy source choice of rural households are age, family size, annual income, total landholding size, 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 the other. Besides, affordability and multi-purpose use of technologies were mentioned as major challenges for technologies' adoption during focus group discussions. Based on the finding of the study, the following recommendations are made. 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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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2
Conceived and designed the research or analysis	Yes	Yes
Collected the data	Yes	No
Contributed to data analysis & interpretation	Yes	Yes
Wrote the article/paper	Yes	Yes
Critical revision of the article/paper	Yes	Yes
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Supervision	No	Yes
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Research involving Plants
During the research, the authors followed the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora. Yes

Research on Indigenous Peoples and/or Traditional Knowledge
Has this research involved Indigenous Peoples as participants or respondents? No

(Optional) PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)
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