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Research Article

Determinants of Biogas Technology Adoption in Rural Households of Aleta Wondo District, Sidama Zone, Southern Ethiopia

Tale Geddafa,[1] Yoseph Melka,[2] and Getachew Sime[3]

[1]*College of Natural Resource and Environmental Science, Oda Bultum University, Chiro, Ethiopia*
[2]*Department of Natural Resource Economics and Policy, Wondo Genet College, Hawassa University, Ethiopia*
[3]*Department of Plant Science (IPV), Hawassa University, Ethiopia*

Correspondence should be addressed to Tale Geddafa; gedefa44@gmail.com

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Biogas is environmentally sound and economically viable, clean, and renewable energy source. Despite its numerous benefits and dissemination efforts, the adoption of biogas technology has been low. The objective of this study was to assess factors determining adoption of biogas technology as an alternative energy source at household level in Aleta Wondo district, southern Ethiopia. A multistage sampling technique was employed to select sample households. A total of 148 sample households, 51 biogas technology adopters, and 97 nonadopter households were surveyed. The collected data were analyzed by inferential statistics and econometric model using STATA version 13.1. Results from the probit model showed that education level of household head, annual income level, livestock holding size, access to technical support, and level of awareness have significant positive influence on households' decision to adopt biogas technology. Other factors include poor performance of biogas plants associated to technical problems, and high installation costs unaffordable to the majority of rural population had a negative implication in adoption process. These are also the factors contributing to low adoption. Therefore, raising the population awareness on the benefits of biogas and assigning the biogas technicians who can give immediate maintenance services at "Kebele" level could extend the biogas technology.

1. Introduction

Nowadays, "the life of human being is highly based on energy consumption" [1, 2]. In daily lives, "energy provides vigorous benefits for cooking, heating, lighting, food production and storage, industrial production, education, and transportation. In modern times, no country has managed to substantially decrease poverty without increasing energy resources and its efficient utilization" [3].

For many sub-Saharan Africa (SSA) countries including Ethiopia, the energy demand is continuously rising as development progresses, and population growth is faster increasing. However, the modern domestic energy supply is unbalanced with its demand [4]. Around 83% of the total population in SSA countries and 91% in least developed countries have no access to modern fuels and renewable energy [5]. Like other SSA counties, Ethiopia is highly based on traditional biomass for domestic energy (for cooking, heating, and lighting); more than 93% of its population obtained energy from traditional biomass [6].

The need for clean, renewable, and modern energy sources is especially important in Ethiopia, where the use of traditional biomass energy causes environmental, health, and economic problems [7]. Therefore, biogas technology is alternative energy source that is clean and renewable. Biogas is produced by methanogenic bacteria acting on biodigestible materials in nonappearance of oxygen in the process known as anaerobic digestion, for cooking and lighting purposes [8]. It is sustainable and environmentally friendly energy. It is produced from locally available finished organic materials, which are very cheap. Biogas technology has several benefits such as use of clean energy for cooking and lighting, use of bioslurry as organic fertilizer for crop production, and income generation from reducing the use of purchasing fuels (firewood, charcoal, and kerosene) and chemical fertilizers [9].

According to a feasibility study conducted on domestic biogas in Ethiopia [10], there are convincing reasons to promote biogas technology in rural community of the country. First, the country has large livestock population particularly cattle and a favorable temperature. Second, rural communities lack modern electricity and renewable energy for lighting and cooking. Third, the overuse of biomass in traditional way negatively affects the environment by increasing the greenhouse gas emission. Fourth, dung is increasingly used as major domestic fuel, which causes reduction of soil fertility and agricultural productivity. Fifth, there is ever increasing scarcity of fuelwood sources and prices of chemical fertilizers and kerosene (for light). By understanding these challenges, "the National Biogas Program of Ethiopia (NBPE) was launched in 2009, for dissemination of domestic biogas technology through a subsidy modality for at least one million households in Tigray, Amhara, Oromia and southern Ethiopia regional states; due to their potential for biogas installation" [11]. The NBPE has been deployed in two phases with the first phase running from 2009 to 2013 and second phase from 2014 to 2017. Studies conducted so far reporting about accomplishments of the two phases is scanty in Ethiopia in general and southern Ethiopia in particular. Particularly, studies showing factors influencing the adoption of the technology by rural households are scanty. The main objective of the current study is therefore to identify factors that determine households' decision to adopt the biogas technology in the Sidama Zone, Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area. Aleta Wondo district, the study area, is one of the 19 districts in Sidama Zone of the southern Ethiopia. It has 27 rural *Kebeles* ("Kebele" is the smallest administrative unit of Ethiopia, similar to a ward, a neighborhood, or a localized and delimited group of people.) with the total of 32,309 households. It is located at 337 km to the south of Addis Ababa, the country's capital city and 62 km from Hawassa, the capital city of the regional state. It is located between 6° 35′ and 6° 40′ N latitude and between 38° 23′ and 38° 26′ E longitude (Figure 1). According to the Central Statistical Agency (CSA) of Ethiopia, Aleta Wondo has a land area of 567.2 km^2 with a population of 191,592 of whom 97,364 are males and 94,228 are females while 175,055 rural and 16,537 are urban population [12].

2.2. Sampling Design and Sample Size. A multistage sampling technique was used for selecting sample households to be surveyed. First, the Aleta Wondo district was selected purposively for being the home of the largest number of biogas installations during the survey time. Afterwards, three *Kebeles* adopting biogas technologies were selected purposively from 27 rural *Kebeles* based on the availability of biogas plants and the number of potential biogas adopting households relatively with higher experience in biogas energy generation and utilization. Secondly, households in the selected *Kebeles* were stratified based on adoption characteristics into two groups, namely, adopters and nonadopters of biogas technology. Thirdly, 148 household heads of which 51 adopter and 97 nonadopter households were selected for survey. Finally, respondent households of both categories were selected randomly through simple lottery method.

2.3. Sources of Data and Collection Methods. Both qualitative and quantitative research techniques were applied in this study, including personal observations, focus group discussion, key informant interviews, and questionnaire survey to gather primary data. Secondary data were collected from relevant published and unpublished sources like books, journal articles, internet, CSA of Ethiopia, reports from the district energy office, and *Kebele* administration offices.

2.4. Methods of Data Analysis. Data entry was done by using Microsoft Excel. Inferential statistics and an econometric model were used for analysis of collected data using STATA version 13.1 at $\alpha = 0.05$. Socioeconomic characteristics of biogas technology adopter and nonadopter household heads were analyzed by independent sample t-test whereas chi-square test was used to analyze the effect of sex of household heads on biogas technology adoption. To analyze factors determining household decision to adoption of biogas technology, binary probit model was employed.

2.4.1. Model Specification. Adoption of biogas technology in this study is a dependent variable which represents whether or not a household adopt biogas technology ("1" if a household own biogas plant and "0" otherwise). Both logit and probit models are well recognized approaches in adoption studies when the dependent variable is dichotomous and the independent variables are any type [13]. However, probit model was preferred for this study because authors anticipated drawing the sample from normally distributed population (such that the error term is normally distributed).

Below was the probit model used [13]:

$$Y_i = \beta_0 + \sum_{j=1}^{k} \beta_j X_{ij} + \mathcal{E}_i, \quad (1)$$

where Y_i is the adoption of biogas technology (1 = household who own biogas plant,0 = otherwise), β_o is the constant term, $\beta_j(\beta_1 + \cdots + \beta_{11})$ is the coefficient of estimated parameters corresponding to each explanatory variable, $X_{ij}(B_1 + \cdots + B_{11})$ is explanatory variables and $\mathcal{E}_i$ is the error terms of the regression, X_1 is sex of household head, X_2 is age of household head, X_3 is education level of household head, X_4 is total livestock holding, X_5 is household size, X_6 is total land size holding, X_7 is household's annual income, X_8 is availability of water supply, X_9 is households' awareness on biogas technology adoption, X_{10} is availability of technical services, and X_{11} is availability of fuel wood.

Before the variables were taken into the binary probit model, multicollinearity problem among the explanatory variables and fitness of model were tested. Multicollinearity

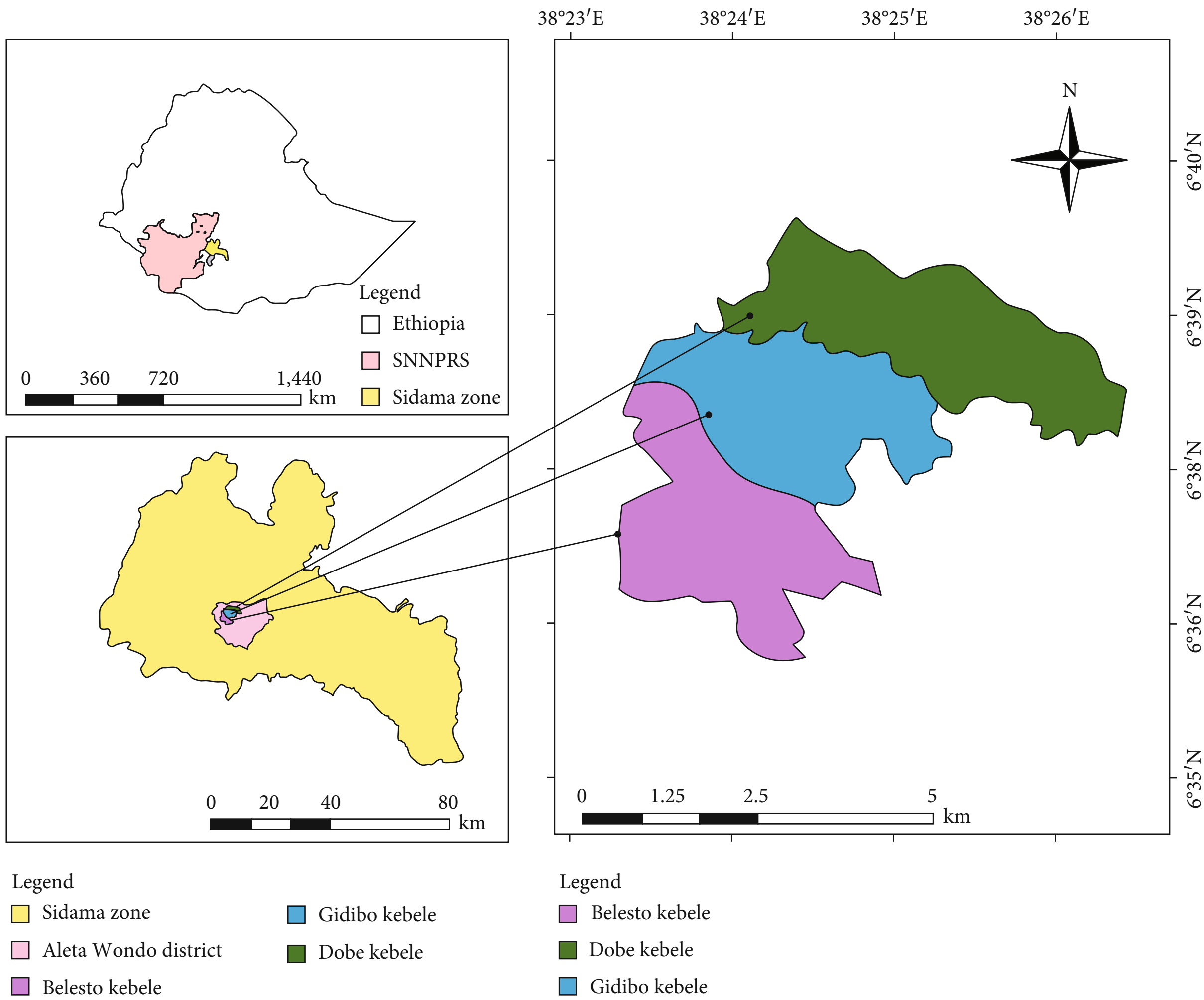

Figure 1: Map of the study area.

problem was tested by using Variance Inflation Factor (VIF) technique (for continuous explanatory variables) and Contingency Coefficient (CC) test (for dummy variables). As a rule of thumb, if values of VIF are greater than 10 and values of CC are greater than 0.75, the variables are often taken as a signal for the existence of multicollinearity problem in the [14]. Thus, Variance Inflation Factor is defined as:

$$\mathrm{VIF} = \frac{1}{\left(1 - \mathrm{Rj}^2\right)}, \tag{2}$$

where Rj^2 is the coefficient of determination among explanatory variables.

Contingency Coefficient is defined as:

$$\mathrm{CC} = \sqrt{\frac{x^2}{(n + x^2)}}, \tag{3}$$

where x^2 is the chi-square value and n is the total sample size.

Model fitness was tested by Akaike Information Criteria (AIC) and the Bayesian Schwartz Information Criteria (BIC) using. The smaller the AIC or BIC shows better fitness of the model.

The AIC is defined [15] as follows: $\mathrm{AIC} = -2L + 2P$, where L denotes the log likelihood evaluated under μ and P the number of parameters.

The BIC is defined [16] as follows: $\mathrm{BIC} = -2L + p \log\ (n)$, where L denotes the log likelihood evaluated under μ, P is the number of parameters, and n is the number of rating classes.

3. Results and Discussion

3.1. Socioeconomic Characteristics of Respondents. The average age of the sample biogas adopter was 46.49 and 45.80 years for nonadopter household heads (Table 1). This age difference between the two categories was statistically insignificant. This indicated that age of household heads had no influence on the adoption of biogas technology. Besides, the average household sizes of biogas adopters and nonadopters were 6.71 and 5.92 persons, respectively (Table 1). Results from the statistical analysis showed that there was insignificant mean different between household sizes of both categories. The average household size in both categories appeared to provide adequate labor force for the daily operation of

Table 1: Socioeconomic characteristics of respondents ($n = 51$ adopters, and $n = 97$ nonadopters).

Variables	Adopters		Nonadopters		t-test	p value
	Mean	SD	Mean	SD		
Age of HHH	46.49	11.62	45.80	14.11	-0.29	0.77
Household size	6.71	3.04	5.92	3.08	-1.49	0.14
Education of HHH	5.86	3.42	3.63	3.41	-3.78	0.01***
Livestock holding	4.13	5.67	1.55	2.18	-3.99	0.01***
Annual income HHH	26, 152.94	23,810.97	14,073.11	15,598.15	-3.72	0.01***
Total land size (ha)	1.76	0.88	1.47	1.10	-1.63	0.11

*** indicates level of significance at 1%. HHH: household head.

Table 2: Results of sex of sample household heads, availability of fuelwood and water resource.

Variable	Category	Biogas adoption category		Total	Ch^2-test	p value
		Adopters	Nonadopters			
Sex of household head	Male	44 (86.30)	86 (88.71)	130 (87.80)	0.178	0.67
	Female	7 (13.71)	11 (11.30)	18 (12.21)		
Fuelwood availability	Yes	9 (17.60)	45 (53.60)	54 (36.52)	5.381	0.02**
	No	42 (82.42)	52 (81.40)	94 (63.51)		
Water availability	Yes	44 (86.33)	68 (70.11)	112 (75.73)	0.874	0.49
	No	7 (13.71)	29 (29.90)	36 (24.30)		

Figures in parenthesis are the percentage of respondents involved, and ** indicates level of significance at 5%.

biogas plant. The average education level of household heads of biogas adopters in years of schooling was 5.86 with standard deviation 3.42 which is greater than that of the nonadopters 3.63 grades with standard deviation 3.41 (Table 1). The average education level achieved between biogas adopter and nonadopter household heads was statistically significant ($p < 0.01$). This indicated that education level influences households' decision to adopt biogas technology.

The average livestock holding size (TLU) of biogas adopter households (4.13) was greater than that of nonadopters (1.55) and was statistically significant ($p < 0.01$) (Table 1). This showed that biogas adopter households with higher livestock size are better in deciding to adopt biogas technology than nonadopters. The size of livestock population in general and cattle population in particular is one of the most important factors that determine the availability of sufficient dung for the successful operation of biogas plants. Like in other parts in Ethiopia, cattle dung is the primary input as substrate in biogas plant operation. A 4 heads of cattle of local breeds are supposed to produce a minimum of 20 kg dung daily, which is needed to feed the minimum size of 4 m^3 biogas plant [11].

The average annual income of biogas adopter households was greater than that of nonadopter households (Table 1), which is statistically significant ($p < 0.01$). This showed that nonadopter households have financial constraint in deciding to adopt biogas technology than adopters. This is because most of the respondents are subsistence farmers that earn low income merely for fulfilling other basic needs for household members.

There was statistically insignificant mean difference in total land holding size between biogas adopter and nonadopter households (Table 1). The average land holding size of adopter and nonadopter households was 1.76 ha and 1.47 ha, respectively. This size was sufficient for biogas plant installation for both adoption categories. According to Karjalainen and Heinonen [17], a quarter an acre (0.101 ha) is adequate even for a large biogas plant installation whatever the size and the mode of plant.

Table 2 depicts that the majority (87.8%) of households in the study area are male-headed as compared to (12.2%) female-headed households. The dominance of male headship may affect the adoption of biogas technology because the decision on whether the household to adopts or not greatly rests on the household head. Though biogas technology reduces workload of women, in the rural Ethiopia for most cases, men control the household resources and decision-making processes [11].

The primary energy source for baking and cooking in study area is firewood. However, its availability is very low that only 36.5% of households had easy access to fuelwood while 63.5% had no access (Table 2). Before few decades, almost all sample households responded that they collect firewood from natural forests in their surroundings; nevertheless, the forestlands have recently been changed to farmlands. Such anthropogenic activities have caused scarcity firewood sources and have opted the communities to use crop residues, dung cakes, and leaves. This adjustment in managing fuels sources has led to reduced soil fertility and agricultural productivity. Adopter households had scarcity of fuelwood (17.6%) than nonadopters (53.6%), which carriages them to adopt biogas technology (Table 2). Adoption of biogas technology was higher for households with problem of fuelwood than those with plenty of fuelwood [18]. Water supply is another critical requirement for adoption of biogas technology because it serves both livestock keeping and biogas plant operating. In the study area, 75.7% of households had access to adequate water supply while 24.3% were with short supply of water (Table 2). This shows that availability of water source was not a factor influencing households' decision to adopt biogas technology. This is because there is an adequate water supply in the study area, and most households have access to water sources at or nearby homesteads.

3.2. Factors Determining Adoption of Biogas Technology. The multicollinearity problem was tested using VIF (Table 3) and CC (Table 4) techniques, and the data set showed absence of a multicollinearity problem. Fitness of the data with the model was tested using AIC and BIC method (Table 5), and the probit model fitted the data set and the dependent variable. Among the eleven independent variables included in the model, education level, annual income, livestock holding size (TLU), technical availability, and level of awareness had statistically significant and positive influence on the adoption of biogas technology (Table 6). However, sex of household head, age of household head, household size, land-holding size, availability of water sources, and availability of fuelwood sources were statistically insignificant in determining households' decision to adopting biogas technology (Table 6).

3.2.1. Educational Level of Household Heads. Table 6 indicates that an increase in educational level of a household head increases the probability of biogas technology adoption significantly ($p < 0.05$). This means, as education level of a household head increases by one year, the probability of the household to adopt biogas technology increases by 24.16%. This indicates that as household's education level increases, the ability to gather information, understand (their perception), and consequently the decision to adopt biogas technology also increases. A similar finding by Riddell and Song [19] showed that highly educated households tend to adopt new technologies faster than those with less education.

3.2.2. Annual Income of Households. Table 6 depicts that the annual income of household's has a significant ($p < 0.01$) positive influence on decision to adopt biogas technology. The probability of households to adopt biogas technology decreases as their annual income increases by one unit (Ethiopian Birr). This manifests that household's economic status influences the decision to adopt biogas technology. Higher income earning households have better economic capacity to install biogas plants as opposed to their counterparts. High installation costs pose a challenge to the majority of rural population. Nevertheless, the result contradicts with [18] which conducted in Tanzania and reported that annual income of households head had a negatively significant with biogas adoption implies that lower income household heads were more likely to adopt biogas technology than higher income because of the low-income earners received higher percentage of subsidy than higher income earners.

3.2.3. Livestock Holding Size (TLU) of Households. Cattle dung and toilets are the primary input for feeding biogas plants in study area. Table 6 illustrates that livestock holding size has a positive significance ($p < 0.05$) in influencing the adoption of biogas technology. Keeping other factors constant, an increase in a unit of cow or cow equivalent

Table 3: Variance inflation factor of continuous explanatory variables.

Variable	VIF	1/VIF (tolerance)
AGEHHH	2.10	0.48
TLANDSIZE	1.90	0.53
FAMSIZE	1.79	0.56
HAINCOME	1.55	0.64
EDULVHHH	1.50	0.67
NOTLU	1.38	0.72

Source: own survey result (2017).

Table 4: Contingency coefficient for dummy explanatory variables.

Variables	Sex	Water	TECHAV	Bioaware	FWDAV
Sex	1				
WATERAV	-0.02	1			
TECHAV	0.04	0.00	1		
Bioaware	0.04	-0.24	-0.07	1	
FWDAV	0.07	0.08	0.20	0.04	1

Source: own survey result (2017).

Table 5: AIC and BIC statistical results for goodness of fit.

Type of model	AIC	BIC
Logit	91.48	124.44
Probit	90.37	123.34

Source: own survey result (2017).

Table 6: Results of binary probit estimation for the determinant factors of biogas technology adoption.

Variable	Coef.	Std. Err.	z	$p > \|z\|$	Marginal effect
SEXHHH	-0.66	0.58	-1.13	0.26	-0.21
AGEHHH	-0.01	0.02	-0.04	0.97	-0.00
HHSIZE	0.16	0.10	1.58	0.12	0.05
EDULEVHHH	0.94	0.38	2.46	0.02**	0.24
HAINCOME	0.01	9.87	2.70	0.01***	6.82
TLU	0.27	0.12	2.33	0.02**	0.07
TLANDSIZE	0.39	0.25	1.60	0.11	0.10
TECHAV	2.08	0.42	4.88	0.01***	0.53
WATERAV	0.65	0.52	1.25	0.21	0.17
Bioaware	0.32	0.07	4.35	0.01***	0.08
FUELWDAV	-0.09	0.42	-0.24	0.81	-0.02
_Cons	-5.52	1.97	-2.80	0.005	

***1% level of significance and **5% level of significance. Number of observation = 148. Log likelihood = −34.737321. LR chi^2 (10) = 121.16. Pseudo $R^2 = 0.6356$. Prob > $chi^2 = 0.0000$. Overall percentage of correctly predicted = 82.699.

Table 7: Conversion factor used to estimate tropical livestock unit (TLU).

Livestock category	Conversion factors
Horse	1.1
Oxen	1.00
Cow	1.00
Heifer	0.75
Calf	0.25
Donkey	0.70
Sheep	0.13
Goat	0.13

Source: Storck et al. [20].

(Table 7) increases the likelihood of adopting biogas technology by 6.9%. This demonstrates the significance of livestock in providing the necessary feedstock for daily operation of biogas plants. Household heads owning larger cattle size have higher probability of adopting biogas technology than their counterparts (Table 6). Moreover, cattle size could limit the size of biogas plants to be installed by households. A previous finding reported that having smaller cattle size poses households to install the smallest plant size ($4\,m^3$) in Bangladesh [21].

3.2.4. Availability of Technical Services. Table 6 indicates that having access to technical service was positively and significantly ($p < 0.01$) correlated with biogas technology adoption. As household's access to technical service increases by one unit; the probability of the household head to decide in adoption of biogas technology increases by 53.3%. This implies that adequate provision of technical services to households and access to standby energy technicians for construction and maintenance service may foster the reputability and popularity of biogas technology adoption. Households at grassroots having access to trained technicians providing adequate construction and maintenance services for biogas plants promote household ability to adopt biogas technology and to sustainably produce and utilize biogas energy [22].

3.2.5. Awareness of Households towards Biogas Technology Benefits. The coefficient on biogas awareness was positively and significantly ($p < 0.01$) associated with biogas technology adoption (Table 6). The empirical results further indicated that the probability of households having awareness about biogas technology for deciding to adopt the technology was higher by 8.1% compared to households lacking the awareness (Table 6). This indicates that households with more opportunity of attending relevant trainings and have better awareness are more likely to adopt biogas technology than their counterparts. Awareness is the first stage in technology adoption process, in fact, in sensitizing potential adopters about a new technology. For a successful implementation of a new programme involving new technology, provision of awareness through training, workshop, seminar, and demonstration is key requirement [23].

4. Conclusion and Recommendations

Although biogas technology implementation had continued through incentives of the national programme, the rate of adoption was found low among the rural households in Aleta Wondo district. The empirical results illustrated that education level of household head, household annual income, livestock holding (TLU) size, availability of technical service, and level of awareness pose a significant positive influence on households' decision to biogas technology adoption in the study area. Therefore, based on the above conclusion, the following recommendations are drawn:

(i) Awareness on the benefits of biogas energy and bio-slurry production and utilization needs attention by government and donors

(ii) The NBPE accompanying with water, mineral, and energy office of the district should be assigned the biogas technicians who can give immediate maintenance services at "*Kebele*" level in the earliest time possible to sustainably utilize the technology

(iii) The study result found that households (who cannot afford the initial investment costs) are often motivated by subsidy and loan of NBPE and NGO (SNV) to engage the low income households in to adoption. Similarly, the technology is vastly adopted by households with subsidy than that of without subsidy. Accordingly, the subsidy that provided by NBPE and NGO (SNV) should be continued for a certain period of time, until the households familiarized to biogas benefits.

Data Availability

The authors want to declare that they can submit the data at any time based on publisher's request. The datasets used and/or analyzed during the current study were available from the authors on reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

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