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Research article

Status of energy utilization and factors affecting rural households' adoption of biogas technology in north-western Ethiopia

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ABSTRACT

The National Biogas Policy of Ethiopia introduces plans for the implementation of biogas technologies in rural areas. However, rural households' decision to adopt biogas energy technology has been influenced by different socio-economic and institutional factors. This research was therefore undertaken to determine the actual energy consumption status and factors impacting the adoption of biogas technology by rural households in northwestern Ethiopia. Primary data from 182 randomly chosen households and 15 key informants were obtained. Different databases, such as journal articles, annual accounts, and unpublished papers, were used to gather secondary data. The data were analyzed using social science statistical package (SPSS 21st edition) tools using descriptive statistics, chi-square test, and independent-sample t-test. The results indicated that about 84.2% of the households have been using traditional biomass fuels (fuelwood, agricultural crop residue, dung cake, and charcoal) for baking *Enjera* and heating while the remaining 17.6% of the households have been using biogas energy. The kerosene lamp, battery cell, small size solar panel, and biogas were energy sources for lighting. The higher installation costs, inadequate water availability, shortage of cow dung, and lack of awareness were the main factors that hinder biogas installation in the study site. An independent sample t-test result revealed a statistically significant mean difference of the average time spent (in hours) to collect fuelwood per week between biogas technology adopters ($M = 9.563$, $SD = 4.697$) and non-adopters ($M = 11.887$, $SD = 4.703$; $t(180) = 2.539$, $p = 0.012$). In addition, findings of the binary logistic regression showed that education, access to markets, heads of cattle, and electronic media were the principal factors affecting biogas technology adoption significantly in the study area.

1. Introduction

Renewable energy sources are the sources of energy that are continuously and freely produced in nature and are not exhaustible since they are derived from a limitless source (Shahzad, 2012). Around 2.5 billion people worldwide are now mostly dependent on conventional biomass fuel for cooking, lighting, and heating. It is predicted that almost 1.4 billion people are at risk of being left without access to modern energy supplies by 2030 (Ghimire, 2013; Klasen et al., 2013). In addition, around 500 million households continue to use conventional biomass fuel for heating and cooking and have no access to modern energy sources in developing countries (UNDP, 2009; Bazilian et al., 2010). The widespread exhaustion of stocks of fuelwood will raise demand for fuelwood, according to Arthur et al. (2011), and the resulting social and environmental impacts urge the need in developing countries to search for alternative and clean fuel sources. Transforming today's use of biomass fuel into cleaner technologies in rural areas would improve the standard of living, health, and the environment. Furthermore, it would give an improved chance of sustainable economic development (Bajgain and Shakya, 2005).

In order to boost socio-economic growth in one region, the absence of adequate options in obtaining sustainable and environmentally responsible energy resources is called energy poverty. Energy poverty is often characterized as the inability to use modern cooking fuels and the absence of adequate electrical lighting for studies or various family sundown activities (Bridge, 2015). Energy scarcity in Ethiopia has a

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strong impact on the environment, the health sector, agriculture, and people's well-being. Energy deficiency also influences the standard and the delivery of education in rural Ethiopia. In comparison, relative to women who use electricity, women who use wood and charcoal for cooking are prone to multiple respiratory illnesses. Indoor emissions in homes will last as long as energy scarcity is not always reduce (Mandefro, 2020). Energy poverty is a big obstacle in rural areas of Ethiopia that hinders socio-economic growth activities since the socio-economic growth of the lifestyle of a person relies heavily on oil (Oum, 2019). Ethiopia is suffering from a significant domestic energy crisis, which can be seen in its relatively low per capita energy intake. About 95% of households in the Ethiopia use conventional biomass fuels as their main energy source for cooking, heating, and illumination, and only 5% of people have access to electricity (World Bank, 2006). Specifically, much of the country in Ethiopia's Amhara National Regional State (ANRS) is suffering from a significant deficiency in the availability of fuelwood and a shortage of modern energy sources. Around 90 percent of the population in this region lives in rural areas. With 64 percent generated from woody biomass, 14 percent from crop residues, and 21 percent from dung, biofuels produce 99 percent of the overall domestic energy production. The majority of rural households used traditional fuels like firewood, agricultural crop residues, and cow dung in all zones of the Amhara National Regional State (Olana, 2002).

Currently, the rapidly growing population requires more fuelwood which accelerates deforestation and forest degradation and it poses a pressure to sustainable forest resource conservation in Ethiopia (FDRE, 2011; Damte et al., 2012). The inaccessibility of modern fuel, scarcity of fuelwood, and associated problems are more severe in the north-western part of Ethiopia where most of the forest resources have been lost (Darbyshire et al., 2003). Due to the fuelwood crisis, forest resources are depleted and agricultural productivity is decreased all over the Amhara Regional State including the study area (Simur, 2012). People are highly dependent on traditional biomass fuels and they prepare food inside their homes. This brings indoor air pollution (IAP) and health problems including breathing, adverse pregnancy outcomes, and chronic respiratory diseases. As a result, women and their young children have died (WHO, 2006; Martínez and Alfonso, 2014). To address these energy-related problems, intervention steps have been taken by the government of Ethiopia to build and disseminate renewable energy technology, including better fuel-efficient stoves, solar power, and biogas technologies. Biogas technology is one of the steps of action that provides the technological possibility of a decentralized solution to the supply of modern energy facilities using energy supplies such as cow dung and human waste. It is also an integrated waste management system that helps to solve major environmental problems, such as soil degradation, deforestation, desertification, and indoor air pollution, and reduces greenhouse gas emissions (Rajendran et al., 2012; Kelebe et al., 2017). Biogas can be supplied by anaerobic digestion of vast volumes of urban, commercial, and agricultural solid waste. Biogas can be used for heating and producing electricity (Amigun et al., 2008). Biogas consists of between 40% and 70% CH_4 with the remainder being carbon dioxide (CO_2), hydrogen sulfide (H_2S), and other trace gases (Shin et al., 2005).

The biogas plant was introduced as early as 1979, at the Ambo Agricultural College in Ethiopia (Rajendran et al., 2012; Kelebe et al., 2017). Ethiopia's biogas sector began with the start of the National Domestic Biogas (NBPE) program in 2008, which has led to the dissemination of more than 8000 bio-digesters so far by the end of the first phase in 2013, around 60% of what was originally expected (Kamp and Forn, 2016). Furthermore, the National Biogas Program of Ethiopia Phase II has also been under implementation since 2014 then additional 12,538 bio-digesters were installed up to February 2019. Over 20,000 biogas plants were installed in Ethiopia for households, communities, and institutions during the last two decades. However, the two phases of the National Biogas Program of Ethiopia have not achieved the targeted biogas installation (Miklol Consulting and Research Plc, 2019). Therefore, it is necessary to understand why the progress of biogas technology adoption has been slow in rural Ethiopia as it is quite crucial for the next successful plans and dissemination endeavors (Kamp and Forn, 2015, 2016).

Many other reports on the adoption of biogas technologies in Ethiopia were conducted (Lemlem, 2016; Getachew, 2016; Melaku et al., 2017; Woldesilassie and Seyoum (2017); Kelebe et al., 2017). Socioeconomic, cultural, institutional, and innovation characteristics make the households not adopt the technology (Chesang et al., 2016). Among these factors, the number of tropical livestock, distance from the market, and distance from the main road are important in determining the probability of adopting or not adopting fuel-efficient stoves (Legesse et al., 2015). The economic status of the household heads influences the adoption of fuel-efficient stoves (Kanangire et al., 2016). The amount of income has a positive impact on the adoption of fuel-efficient stoves, according to this report. In addition, education plays a major role in the introduction of emerging innovations, including fuel-efficient stoves (Lewis and Pattanayak, 2012; Legesse et al., 2015). Factors affecting household's adoption of clean and modern energy fuels and technologies include education, age, household size, income, and the price of fuel (Muller and Yan, 2018).

However, adequate studies have not been conducted on the current status of energy utilization and factors affecting rural households' biogas technology implementation in Gondar Zuria District. Most of the rural households still rely on traditional biomass energy sources, and they are not even familiar with the technology. Furthermore, the progress of biogas installation is low in the study site; only 66 households use biogas technology (Gondar zuria district water and energy office report, 2019). Moreover, it is very common to observe children and women competing for dung fuel in communal grazing lands due to scarcity of fuelwood and other domestic energy sources in the study site. Thus, it is needed to investigate why the progress of biogas technology adoption has been low. The goal of this study was to analyze the current state of energy consumption and factors influencing the adoption of biogas technology by rural households in the Gondar Zuria District.

2. Methodology

2.1. Description of the site

The research was conducted in the District of Gondar Zuria, Amhara National Regional State Central Gondar Zone, north-west Ethiopia, approximately 738 km from Addis Ababa. It is located at latitude 12°39′59.99″ N and longitude 37°19′60.00″ E (Figure 1). The Central Gondar Zone contains 11 districts, including the district of Gondar Zuria. Gondar Zuria District has 41 rural and 3 urban Kebeles according to the Gondar Zuria District Agricultural Development Office Survey. The district's total area is 48,204.39 km^2. The average monthly precipitation and temperature are 67.8 mm and 17.5–27.5 °C, respectively. At 1500–3200m a.m.s.l, the district falls into two agro-ecological areas named Woyina Dega (72%) and Dega (28 percent). The area's land use cover includes agriculture (56.5%), pastures (14.7%), trees and shrubs (10%), villages (5.3%), and miscellaneous land (13.5%) (Gondar Zuria District Agriculture Office, 2019). Around 9.6 percent is covered with forest in the Gondar Zuria district (Fenta, 2017). There are 38,383 households in the district, of which 30,325 are male and 8,058 are households headed by women. The district's total population is 230,033, of which 118,107 are males and 111,926 are females. Of the population, around 201,880 and 28,153 live in rural and urban areas, respectively. The population density of the district is estimated to be 205.9 inhabitants per square kilometer (Gondar Zuria District Finance and Economy Office, 2019). In the District, mixed farming is prevalent. The livestock population is equal to 207,000 TLU in the district. The average head of cattle per household is 5,

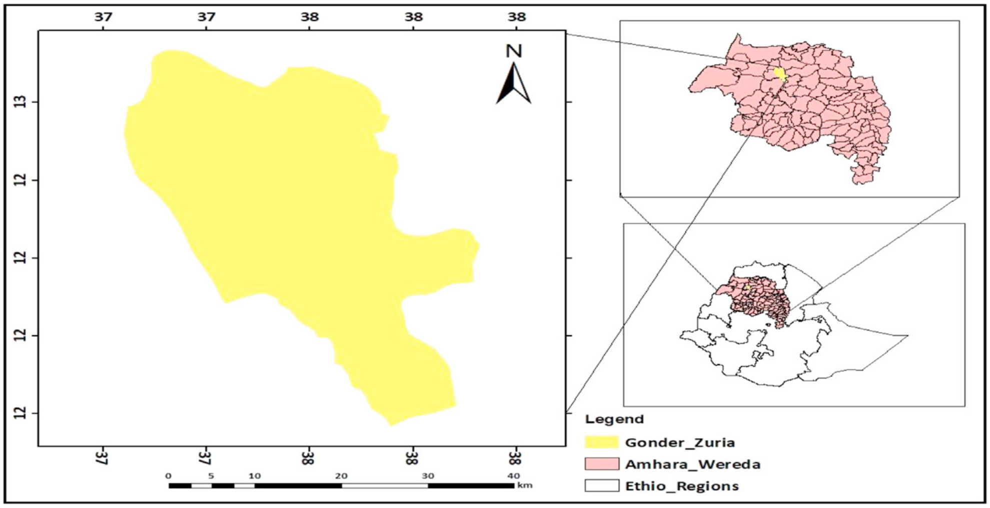

Figure 1. Map of the study area.

according to the Ethiopia Rural Energy Production and Promotion Centre survey (EREDPC) (2008).

2.2. Conceptual framework

The present study was focused on the status of rural households' energy utilization and identifying factors impacting the acceptance of biogas technologies by households. There was a need to examine the connection between different factors revolving around the adoption of biogas technology by households. Based on the literature review, the following factors were identified. The adoption of biogas technology by rural households has been determined by various socio-economic, demographic, and institutional factors and technology awareness. Socio-economic factors (backyard size, farm income, and farm organization membership), demographic factors (education, family size, gender, and age), and institutional factors (electronic media access, market access, and access to training and technology awareness) were included (Figure 2).

2.3. Data types, sources, and collection instruments

To collect the data, both primary and secondary data sources were used. The primary data on the socio-economic, institutional, and bio-physical situation of the sample households were collected through a semi-structured questionnaire, field observation, and interview with key informants. On the other hand, secondary data were obtained from documents such as journal articles, annual reports of Water, Mine, and Energy Office of the district, and other unpublished documents. The primary data were collected from 182 households and 15 key informants through a semi-structured survey and interview with key informants. The

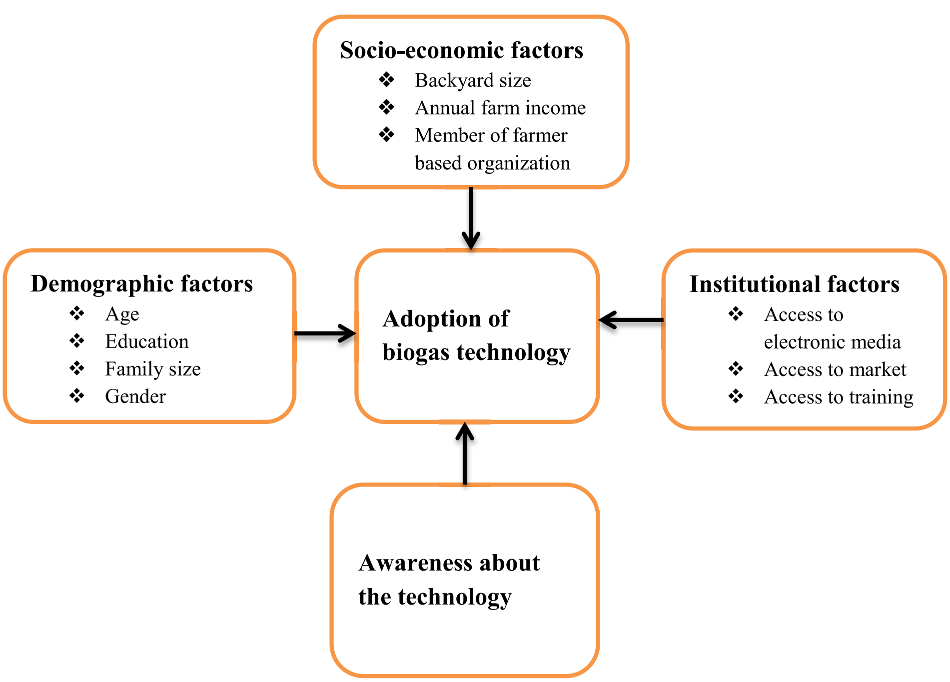

Figure 2. The study's conceptual framework.

key informants were selected purposively. About 15 key informants, including local officials (three), health extension workers (three), local women association leaders (three), water and energy office workers (three), and Kebele Development Agents (DA) (three), were interviewed. In order to validate and explain the data obtained by the above data collection techniques, triangulation was carried out. Throughout the entire course of the study, field observation was conducted to ensure the quality of the knowledge gathered. The data were collected at the same time to avoid seasonality issues during comparisons between households based on the parameters. The authors follow all ethical standards and principles throughout this work. Before the data collection, the participants received informed consent, anonymity, trust, confidentiality and privacy rights were respected. The authors completely inform participants of different aspects of the research such as the nature of the study, the participants' potential role, the objective of the research, and the identity of the researcher. All research participants voluntarily agreed to participate in the research without any pressure from financial gain or other forces.

2.4. Sampling procedure and calculation of the sample size

To pick sample households, a multi-stage sampling technique was used. First, the district of Gondar Zuria was deliberately chosen because it is a potential location for promoting domestic biogas technology in the provincial state of Amhara National Regional State. Second, out of 44 Kebeles in the district, only eleven Kebeles were purposively selected for this study since biogas technology is adopted in these Kebeles (Gondar zuria district water and energy office report (2019). Third, from eleven Kebeles adopting biogas technology in the district, three Kebeles with relatively higher levels of adoption were selected purposively. Fourthly, lists were collected from the Gondar Zuria district water and energy office of the biogas technology adopter and non-adopter household heads in the selected Kebeles. Then, for adopters and non-adopters of the technology, the overall sample size was determined independently. Accordingly, both household heads that were found in the three Kebeles were intentionally sampled for biogas technology adopters. Fifth, using the formula suggested by Yamane (1967), the number of sample households for non-adopters of the target population of three Kebele (Degola Chenchaye, Tseion Siguaje, and Chehra Manterno) was estimated at 92 percent confidence and 0.08 (8 percent) precision levels.

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

where n = desired sample size, N = number of households, and e = level of precision.

The number of non-adopter households for Degola Chenchaye, Tseion Siguaje, and Chehra Manterno was 1508, 760, and 1541, respectively, which was a total of 3809 households. Therefore, the sample size was:

$$n = \frac{3809}{1 + 3809(0.08)^2} = 150$$

Then, the probability proportional to the size of the sampling procedure was used to calculate the number of households sampled from each of the Kebeles chosen (Table 1). Finally, a basic random sampling method was used to pick the three Kebeles from non-adopter survey households. Accordingly, the sample size comprised 182 households, 32 biogas adopters who were purposively selected and 150 non-adopters who were randomly sampled from the three Kebeles. Furthermore, 15 key informants were selected purposively. These were 3 development agents, 3 health extension workers, 3 Kebele leaders, 3 Kebele women association leaders, and 3 water and energy workers in the district.

2.5. Definition of variables and econometric model specification

2.5.1. Dependent variables (Adoption)

Puzzolo et al. (2016) define adoption as “initial technology acquisition and use for less than one year from the acquisition.” Adoption was used as the dependent dummy variable in this study. A value of ‘1’ was assigned to those households that have owned a functioning biogas technology and ‘0’ for those that have not owned it. Biogas technology adopter households who bought the technology a year before were used as the sampling frames. The reason for selecting biogas adopters with a minimum of one-year-old biogas installations was to acquire clear-cut information about the issue. Furthermore, households were expected to have a relatively better experience and familiarity with the technology's benefits and drawbacks. This was done to estimate factors affecting households' decisions in the research region to implement biogas technology. Adopters were households who have owned functional biogas plants while non-adopters were those who have not owned functional biogas plants. This is because the binary logistic regression model requires a binary choice of the dependent variable.

2.5.2. Independent variables

The choice of independent variables was determined based on the literature reviewed on the factors that influence farmers' decisions to adopt biogas technology and the knowledge about energy sources and utilization in Gondar Zuria District. Household characteristics, farm characteristics, and institutional factors were hypothesized to explain the dependent variable. Accordingly, the following independent variables were considered as explanatory variables affecting decisions made by households to embrace biogas technologies. It includes age, family size, gender, education, annual total farm income, backyard size, access to training, access to agricultural extension services, access to market, heads of cattle size, access to financial facilities, access to electronic media, and access to appropriate and secure sources of water and technological knowledge. Table 2 depicts the variables hypothesized to determine adoption behavior, a brief description of each variable, and its hypothesized value about the adoption of biogas energy sources. Independent variables were determining whether a household adopts or does not adopt a biogas technology. For certain methodological problems, such as multi-collinearity, the hypothesized independent variables were measured. With the support of the variance inflation factor, the multi-collinearity of the separate continuous explanatory variables was found (VIF). In order to check the degree of interaction among dummy explanatory variables, the correlation matrix technique was used. The variables are said to be collinear when the

Table 1. Proportional sample size for each Kebele

Kebeles	Household size		Sample size taken	
	Adopters	Non-adopters	Adopters	Non-adopters
Degola Chenchaye	12	1508	12	59
Tseion Siguaje	8	760	8	30
Chehra Manterno	12	1541	12	61
Total	32	3809	32	150

‘Kebele’ is the smallest administrative unit in Ethiopia.

Table 2. Hypothesized factors that impact the decision of farmers to implement biogas technology at the study site.

Variable	Type	Description	Expected sign
Age	Continuous	Household head's status in years	±
Gender	Categorical	Sex of the head of the household 1 = male, 2 = female	±
Education	Categorical	Educational standard of the household head = 1 literate; 0 = illiterate	+
Family size	Continuous	Total number of household size	±
Heads of cattle	Continuous	Number of Tropical livestock unit	+
Total farm income	Continuous	Total annual income of the household in Ethiopian birr	+
Access to credit	Categorical	Having access to credit = 1; Otherwise = 0	+
Backyard size	Continuous	Household's total backyard owned in hectare	+
Market access	Categorical	Access to market: 1 = yes, 0 = no	+
Sufficient and reliable water source	Categorical	Having sufficient and reliable water source = 1; 0=no	+
Agricultural extension access		Getting facilities for agricultural extension = 1; otherwise = 0	+
Electronic media	Categorical	Have television and/or radio = 1 = yes; otherwise = 0	+
Training	Categorical	Access to Biogas Technology-related Training 1 = yes,0 = no	+
Awareness	Categorical	Households awareness about the Biogas technology	+
		1 = yes; 2 = no	

coefficient correlation matrix is greater than 0.4. The existence of multicollinearity was indicated when the correlation coefficient value may be quite excessive (greater than 0.4).

2.5.3. Model specification

To define and evaluate factors affecting the acceptance of biogas technology, the binary logistic regression model was used. The binary logistic regression model was used to identify the major factors determining the decision of households to implement biogas technology at the household level, according to Tabachnick and Fidell (2013). It is possible to define the logistic delivery function for the decision to implement biogas technology as:

$$\text{Logit (P)} = \ln\left(\frac{P}{1-P}\right) \tag{2}$$

$$\text{Let Pi} = \Pr\left(\frac{\text{Y} = 1}{\text{X} = \text{xi}}\right), \text{ then we can write the model as} \tag{3}$$

$$\Pr\left(y = \frac{1}{x}\right) = \frac{exp^{x'b}}{1 + e^{x'b}}; \quad = \ln\left(\frac{\text{Pi}}{1-\text{Pi}}\right) = \text{Logit (Pi)} = \beta_0 + \beta_1\text{xi} \tag{4}$$

Pi was the probability of households' adoption of biogas technology (dependent variable) and xi's were independent influences that influenced households' adoption of biogas energy. The βi parameter then gives the log chances (when xi = 1) of who is implementing the technology. The formula, in terms of chances, is written as:

$$\frac{\text{Pi}}{(1-\text{Pi})} = \exp(\beta 0 + \beta 1\text{xi}) \tag{5}$$

2.6. Methods of data analysis

The 21st version of the statistical package for social science (SPSS) was used to analyze the results. Descriptive statistics (percentages, frequencies, bar and pie chart, and means) were used to explain the types of energy sources utilized by sample households and barriers that hindered the adoption of biogas technology at the study site. Chi-square and unbiased sample t-tests have been used to show the association between the socioeconomic characteristics of sample households and the biogas technology adoption. The mathematical method used to forecast the relationship between independent and dependent variables is binary logistic regression. To determine their predictive potential when correcting the effects of other predictors in the model, all independent variables were evaluated in one block. Binary logistic regression was also performed to estimate the association between socioeconomic characteristics of sample households and biogas technology acceptance in the study field. This model's outcome has not been perceived as causal. However, it was used to show the relationship between response (i.e., adoption) and predictor variables.

2.7. Overview of the biogas technology, its costs, and performance

The construction cost of biogas plants varies depending on the location and season, but the average price of a single biogas plant is estimated to be ETB 13,000 (USD 582.7) for a 6 m3 gas plant, ETB 13,500 (USD 605.1) for an 8 m3 gas plant, and ETB 14,000 (USD 627.5) for a 10 m3 bio gas plant.

3. Results and discussion

3.1. Socio-economic aspects of survey households and the use of biogas technologies

To define the relationship between sales and the acceptance of biogas technologies, adopters and non-adopters, this study assessed the total farm income of biogas technology. Then, an independent sample t-test was used to compare the methods of adopters of biogas technology and non-adopter households in age, family size, annual total farm income, and average time spent to collect fuelwood in the study area. The mean of annual total farm income for biogas energy adopters ($M = 90213.840$, $SD = 40887.064$) and non-adopters ($M = 28807.400$, $SD = 24012.039$; $t\ (180) = 8.199$, $p < 0.001$) was found to be statistically significant. The result showed that biogas energy adopters have higher annual total farm income as compared to non-adopters. This implies that households with high income have decided to adopt biogas technology compared with households with lower income. The risk of biogas technology implementation rises with an increase in wages (Table 3). The key informants also reported that households with high annual farm income have a higher probability to adopt biogas technology than households with low farm income.

The result of an independent sample t-test revealed that the average time spent (in an hour) to collect fuelwood per week by biogas technology adopters ($M = 9.563$, $SD = 4.697$) and non-adopters ($M = 11.887$, $SD = 4.703$; $t\ (180) = 2.539$, $p = 0.012$) is statistically important. The result revealed that the time taken to collect fuelwood for adopters was less than the time taken for non-adopters to collect fuelwood. This showed the contribution of biogas energy to reduce the time needed for fuelwood collection mainly for women and children (Table 3). This result is supported by Youhannes (2015) who found that biogas users saved 144

Table 3. Age, family size, income, and time spent to collect fuelwood by the adopter and non-adopter household heads.

	Category	N	Mean	Std. Deviation	T	df	P-value
Average time spent (in an hour) to collect fuelwood per week	Adopter	32	9.5625	4.69686	2..539	180	0.012*
	Non-adopter	150	11.8867	4.70261			
Age in years of household head	Adopter	32	47.2188	11.72737	0.737	180	0.462
	Non-adopter	150	48.9533	12.15522			
Total farm income in Ethiopian birr	Adopter	32	90213.84	40887.064	8.199	180	0.000**
	Non-adopter	150	28807.40	24012.039			
Family size	Adopter	32	8.750	2.681	3.741	180	0.000**
	Non-adopter	150	6.733	3.152			

Note: *, and ** are statistically significant at 5% and 1% alpha level, respectively.

Table 4. Chi-square test for the relationship of biogas technology adoption with education level and wealth status.

Variables	Category					χ^2-value	df	p-value	Phi-value	p-value	Cramer's V
		Literate	Illiterate	Total							
Level of education	Adopter	30	2	32		29.727	1	0.000	0.404	0.000*	0.404
	No adopter	61	89	150							
Wealth status		Rich	Medium	Poor	Total						
	Adopter	27	5	0	32	22.627	2	0.000	0.353	0.000*	0.353
	No adopter	62	30	58	150						

Note: * is statistically significant at 1% alpha level.

min per day from fuelwood collection compared with non-users of biogas technology in Ethiopia. The average age of biogas technology adopter household heads ($M = 47.219$, $SD = 11.727$) and non-adopter household heads ($M = 48.953$, $SD = 12.155$; $t\ (180) = 0.737$, $p > 0.05$) was not statistically significant in the study site.

A Pearson chi-square independence test found that there was a statistically important association between educational degree and chance of biogas technology adoption ($\chi^2 = 29.727$, $N = 180$, $df = 1$, $V = 0.404$, $p < 0.001$). Large proportions of people (91 out of 180 households) were literate. Among the literate households, 30 of them were adopters of biogas technology. On the other hand, about 61 literate households were non-adopters. Among 91 sample households who were illiterate, 89 of them were found to be non-adopters and the remaining two households were found to be adopters of biogas technology. This implies that out of 32 households that were adopters, 94% of them were literate and the remaining 6% of adopters were illiterate. On the other hand, 41% and 59% of the non-adopter households were literate and illiterate, respectively (Table 4). According to the result, there are a large number of literate adopter households as compared to non-adopter households. Furthermore, Cramer's V-value (0.404) indicated that the association is moderately strong. It was concluded that education has a great implication on biogas technology adoption in the study area. This result is supported by Asfaw (2014) who found a significant relationship between educational status and improved fuel-efficient stove adoption in rural Ethiopia. Similarly, Shallo et al. (2020) found a strong connection between household heads' educational level and the decision to implement biogas technology in Ethiopia. To classify the wealth status of respondents, a participatory wealth ranking method was used. The assessment of the value of household assets and their farm size were considered to classify biogas technology in affluent, adopted, and non-adopted households and medium and poor wealth categories. Community leaders said that a farmer is considered rich if he/she has 8–12 cows and farmland of 10 ha (cultivating 3–4 ha); medium with 5–6 cows and farmland of 7 (cultivating 1–3 ha) hectares; and poor with 2–3 cows and farmland of 3 (cultivating only 1 ha) hectares or less in their area. During the classification, the ranking system considered the price of the livestock as well as the farm size. There was a significant association between wealth status and biogas technology adoption. The result revealed that there was a statistically significant relationship between wealth status and technology adoption ($\chi^2 = 22.627$, $N = 180$, $df = 2$, $V = 0.353$, $p < 0.001$). This shows that out of 32 biogas adopters, a significantly larger proportion from the rich income class (84.4%) used biogas technology compared with only 15.6% from medium-income status households. Among non-adopters, it was 40.7% for the rich, 19.6% for medium, and the remaining 38.7% for the poor category. About 84.4% of the respondents used biogas technology from the rich income category and the remaining 15.6% from the medium category (Table 4). This result is in line with the findings of Asfaw (2014).

3.2. Households' awareness and attitudes towards biogas technology

First, rural households must perceive and recognize biogas technology and its importance before they adopt the technology. To get essential information and insight into rural households' adoption of biogas energy sources to satisfy their energy demand and reduce energy-related health problems, looking at their awareness and attitudes towards biogas alternative energy technology is crucial. Hence, knowledge about households' awareness and perception of a relevant topic to be addressed was the basis of biogas technologies in the study field. For this purpose, the respondents were asked dichotomous ("aware/not

Table 5. Awareness of sample households about biogas technology.

Level of awareness of biogas technology	Frequency	Percent
Aware	61	33.5
Not aware	121	66.5
Total	182	100.0

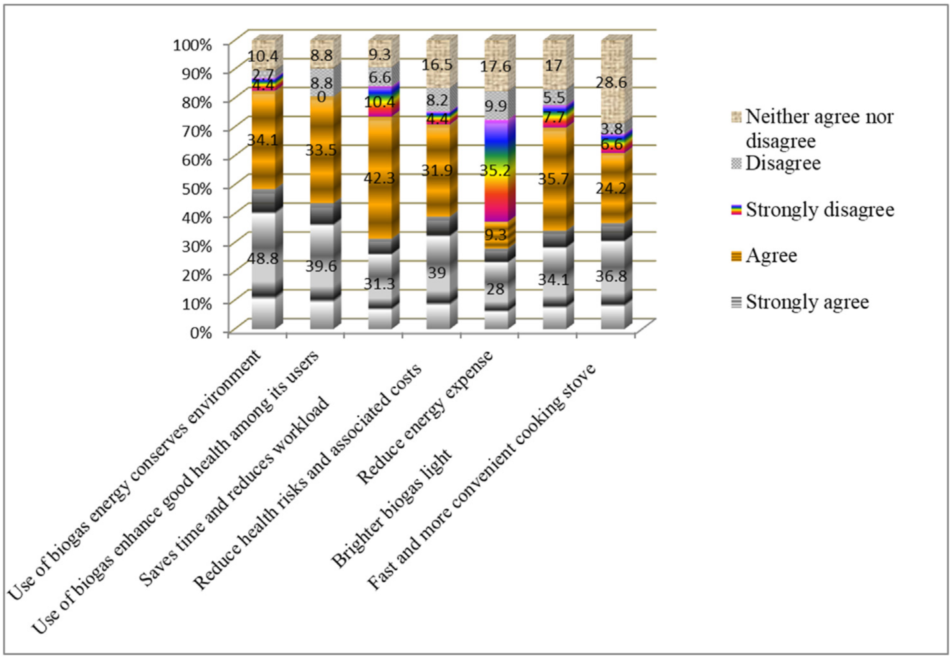

Figure 3. Households' attitudes towards benefits of biogas technology in the study site.

aware" response) questions about biogas technology. The results revealed that 33.5% of the sample rural households have awareness about the technology while 65.5 % of them have no awareness of biogas energy sources (Table 5). As presented in Table 5, about 61 households reported that they have awareness about biogas technology. Out of 61 households, 32 of them have adopted biogas technology. This suggests that the bulk of respondents at the test site are not aware of biogas technology.

Figure 3 depicts that out of 61 respondents who reported that they are aware of biogas technology, about 48.8%, 39.6%, 31.3%, 39%, 28%, 34.3%, and 36.8% of the respondents strongly agreed to use biogas energy to conserve the environment, enhance good health among its users, save time and reduce workload, reduce health risks and associated costs, reduce energy expense, provide brighter light, and provide energy for a fast convenient cooking stove, respectively. Furthermore, about 34.1%, 33.5%, 42.3%, 31.9%, 9.3%, 35.7%, and 24.2% of the respondents agreed to use biogas energy to conserve the environment, enhance good health among its users, save time and reduce workload, reduce health risks and associated costs, reduce energy expense, provide brighter light, and provide energy for a fast convenient cooking stove, respectively. According to the interviewed respondents, their source of knowledge about the benefits of biogas technology was mainly agricultural extension workers and neighbors. The result revealed that about 34.1% of the respondents strongly agreed on the benefit of the biogas technology to conserve the environment, and the highest percent of strong disagreement was regarding its benefit to conserve the environment, in which 4.4% of the respondents strongly disagreed followed by 2.7%. From this result, it can be understood that the perception of households towards biogas energy is positive. Furthermore, the results showed that 35.2% of the respondents strongly disagreed about the use of biogas technology to reduce energy expense. Similarly, about 10.4%, 4.4%, 7.7%, and 5.6% of the respondents strongly disagreed to use biogas to save time and reduce workload, reduce health risks and associated costs, provide brighter light, and provide energy for a fast convenient cooking stove, respectively. The results also indicated that about 10% of the respondents disagreed with the use of biogas energy for reducing energy expense followed by enhancing good health among its users (8.8%) and saving time and reducing workload (6.6%). Accordingly, the bulk of respondents firmly agreed on the advantages of biogas energy in all statements except reducing energy expense. This implies that a large proportion of households' attitudes towards biogas energy were positive (Figure 3). This result is supported by Youhannes (2015) who found that

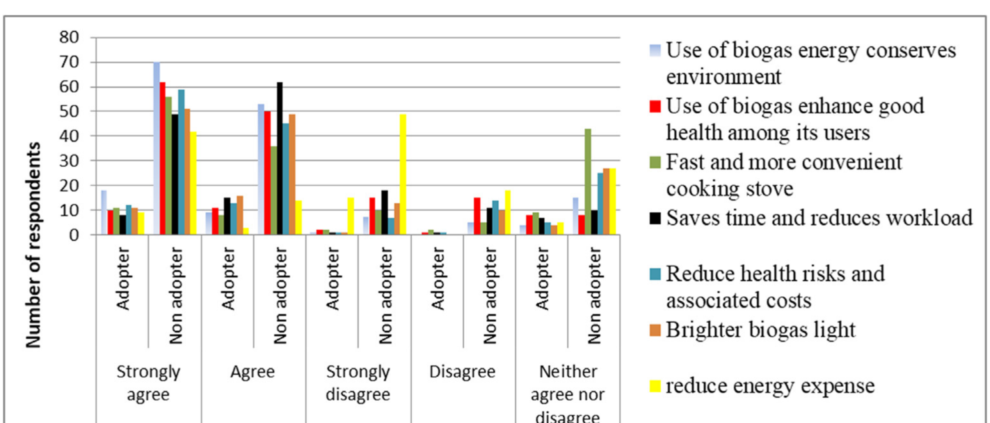

Figure 4. Households' attitude towards biogas technology.

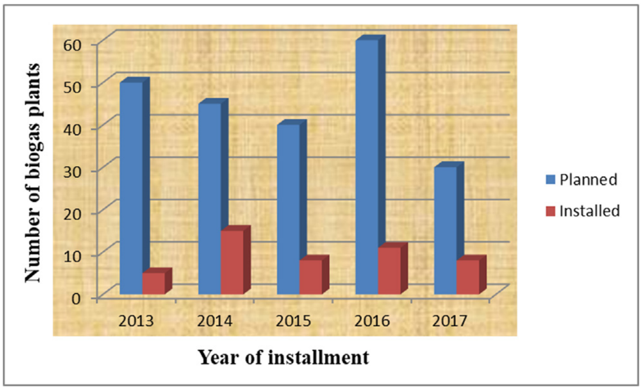

Figure 5. Number of biogas plant planned and installed in the study district.

the majority of the respondents in Ethiopia have a positive outlook toward biogas technology.

Out of 32 biogas technology adopters in Gondar Zuria district, about 18 biogas adopter respondents strongly agreed that using biogas energy can conserve the environment. Out of 150 non-adopters, about 70 non-adopter respondents of biogas technology also strongly agreed that using biogas energy can conserve the environment. Moreover, about 18, 10, 11, 8, 12, 11 and 9 of the biogas adopter respondents strongly agreed to use biogas energy to conserve environment, enhance good health among its users, provide fast and more convenient cooking stove, save time and reduces workload, reduce health risks and associated costs, provide brighter biogas light, and reduce energy expense, respectively (Figure 4). The result also revealed that about 5, 15, 5, 11, 14, 10, and 18 respondents who have no biogas plant disagreed that using biogas energy can help to conserve the environment, enhance good health among its users, provide fast and more convenient cooking stove, help to save time and reduce workload, reduce health risks and associated costs, provide brighter biogas light, and reduce energy expense, respectively. The majority of the respondents who had no biogas plant had a positive attitude towards the use of biogas energy to conserve the environment, enhance good health among its users, provide fast and more convenient cooking stove, save time and reduces workload, reduce health risks and associated costs, provide brighter biogas light, and reduce energy expense.

3.3. The number of built and proposed biogas plants in the district

Figure 5 shows the plan of biogas plant installation and already installed biogas plants in the Gondar Zuria district over the past five years. It was planned to build 50, 45, 40, 60, and 30 biogas plants in the district, but 5, 15, 8, 11, and 8 biogas plants were built in 2013, 2014, 2015, 2016, and 2017, respectively. It indicates that it was planned to build a total of 225 biogas plants within five years. However, only 32 biogas plants have been built so that only 14.22% of the plan was achieved. Households in Gondar Zuria district receive installations in 2013–2017 G.C (Figure 5). Any households with four or more local breeds of cattle living within thirty minutes walking distance from a water supply and able to pay 60% of the investment expense in cash or credit were the participants in the initiative. This includes building input costs such as sand, broken and dry stone, and labor costs. The remaining 40 percent of the biogas plant's building costs were financed by the federal government (10 percent) and the regional government (5 percent), and the Africa Biogas Cooperation Initiative financed the remainder of the bill. Subsidies have been granted in the form of equipment that is essential for the proper running of a biogas plant (lamp, stove, iron bar, gas hose, and cement). A total of about 66 households received biogas technology from 2013 to 2017 G.C in the district (Gondar zuria district water and energy office report, 2019).

3.4. Reasons not to adopt biogas technology

The results in Table 6 show that the majority of the respondents (37.4%) reported that higher installation cost of biogas technology was the main reason not to adopt the technology, and 25.8% of the respondents reported that the second reason not to adopt biogas was lack of awareness about the benefits of biogas energy. The remaining respondents (16.5%) reported that lack of sufficient and reliable water was another obstacle for not adopting the technology followed by the low number of cattle and family reluctance which covered 11% and 9.3 %, respectively. The results revealed that the higher installation cost of biogas technology was the main challenge faced by the respondents. The key informants also reported that the higher installation cost of biogas technology was a major challenge faced by rural households not to install the technology. According to the key informants, inadequate water availability, low numbers of cattle, shortage of feeding (cow dung), and lack of awareness about biogas technology were also the main obstacles that hindered biogas installation and slowed down the adoption rate of rural households in the study area. This result is in agreement with the findings of Gebreegziabher (2007) who found that the high investment cost hindered the widespread biogas production diffusion in Ethiopia. A study conducted by Mwakaje (2008) also showed that the high initial costs, insufficient supply of water, poor digester efficiency, and poor follow-up were major challenges for Tanzania's widespread use of biogas technology. Furthermore, Erick (2018) and Quadir et al. (2010) reported that a high technology installation cost was the main obstacle to install biogas plants in Kenya and many developing countries, respectively.

3.5. Types of energy source and current status of energy utilization

Figure 6 depicts that about 35.2% of the respondents used fuelwood for cooking and heating purposes. About 22.5% of them have used agricultural crop residue to bake *Enjera* and heating. Nearly 19% have used cow dung cake for cooking and heating. Moreover, about 17.6% of the respondents have used biogas energy sources and the remaining 6% of the respondents have used charcoal for heating purposes. This implies that a larger proportion of sample households were dependent on traditional biomass fuels. Moreover, those biogas technology adopters have used other energy sources for their livelihood activities. However, biogas adopters spent lower time collecting firewood than non-adopters of biogas technology. For example, the time taken to collect fuelwood for adopters was 9.6 h per week which was significantly less than the time taken for non-adopters to collect fuelwood which was 11.9 h per week. This implies that the time needed to collect fuelwood was not the same

Table 6. Reasons for rural households to avoid using biogas technology.

Reasons not to adopt biogas energy	Frequency	Percent
Lack of awareness about the benefits of biogas energy	47	25.8
Family reluctance	17	9.3
Higher installation cost	68	37.4
Low number of cattle	20	11.0
Lack of sufficient and reliable water	30	16.5
Total	182	100.0

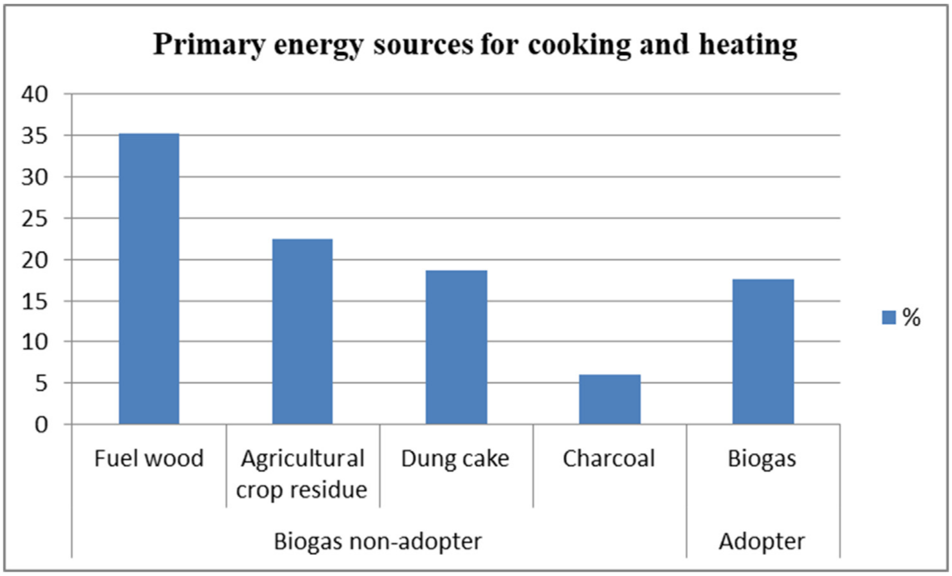

Figure 6. Types of energy utilized by rural households for cooking and heating in the study area.

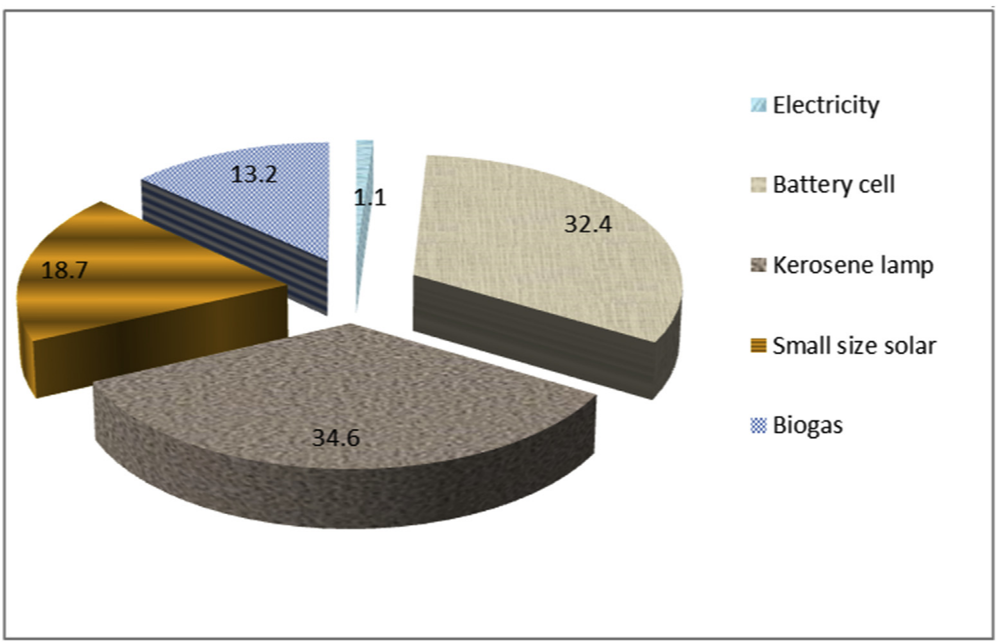

Figure 7. Types of energy utilized by rural households for lighting.

for biogas technology adopters and non-adopters (Table 3). Alternative energy sources like biogas technology had the lowest energy consumption in rural households in the study sites (Figure 6). The result of this study is supported by the findings of Refera (2017) who reported that the majority of households use firewood and agricultural residue for cooking and heating. A study by Diriba (2012) also showed that about 77 percent of Ethiopia's annual intake of biomass, including fuelwood was accompanied by animal dung (13 percent) and crop residue (9 percent), respectively.

About 35%, 32.4%, and 18% of the respondents have used kerosene lamps, battery cells, and small size solar panels for lighting, respectively. Furthermore, the result indicated that about 13.2% of the respondents have used biogas energy for lighting purposes. Nearly 1% of sample households have used electricity for lighting purposes (Figure 7). This result is in line with the findings of Refera (2017) who revealed that the majority of respondents used kerosene lamps, and only 20% of the respondents used small size solar panels for lighting. However, the consumption of electricity and biogas energy sources were found at the lowest level.

3.6. The determinants of households' biogas technology adoption

The multicollinearity test result revealed the presence of a multicollinearity problem between backyard size, access to sufficient and reliable water source, awareness of the technology, and access to training explanatory variables. Due to this, these independent variables were not

Table 7. The binary logistic analysis result.

Parameters	Values
No. of observations	182
Omnibus tests of model coefficients	x^2 = 85.792; df (10); Sig.0.000
Hosmer and Lemeshow test	x^2 = 10.769; df (8); Sig.0.215
-2 log likelihood	83.469
Cox & Snell r squared	0.376
Nagelkerke r squared	0.621
Percentage of total prediction	89.6%

Table 8. Effect model of binary logistic regression.

Variables	*B*	*S.E.*	*Wald*	*df*	*Sig.*	*Exp(B)*
Age	-0.049	0.028	3.047	1	0.081	0.952
Education	4.548	1.142	15.869	1	0.000***	1.012
Gender	-0.988	0.740	1.783	1	0.182	0.372
Family size	0.133	0.134	0.990	1	0.320	1.143
Agricultural extension access	1.487	1.547	0.924	1	0.336	4.423
Annual income	0.000	0.000	0.961	1	0.327	1.000
Market access	2.265	0.949	5.697	1	0.017*	1.040
Credit access	1.119	0.590	3.594	1	0.058	3.062
Heads of cattle	0.263	0.074	12.584	1	0.000***	1.300
Electronic media	-2.889	0.926	9.731	1	0.002**	0.056
Constant	0.882	1.637	0.290	1	0.590	2.415

Note: *, **, and*** are statistically significant at 5%, 10%, and 1% alpha level, respectively.

considered in the study of the final binary regression model. Accordingly, the effect of the 10 variables considered in the model was calculated by binary logistic regression. The Wald chi-square result ($X^2 = 85.792$, $df = 10$, at p-value 0.000) indicated that there is a significant association between predictor variables correlated with the adoption of biogas technology, and model estimation was observed at a significance level of 5 percent. The Wald chi-square p-value ($p = 000$) indicated that the model was well-fitted at $p < 0.001$ significance level. Furthermore, Hosmer and Lemeshow's test revealed that the p-value ($p = 0.215$) was not statistically important. This implied that the model was well-fitted at p greater than 0.05 alpha levels. In the model, the statistics of -2 Log-likelihood is 83.469, so it can be said the model is good. Cox and Snell R square showed that 37.6% of the variation in the dependent variable is explained by the binary logistic model. The Nagelkerke R square value was 0.621 which indicates that there is a moderately strong relationship of 62.1% between the predictors and the prediction (Table 7). Furthermore, it is seen in Table 7 that the overall percentage of cases is perfectly predicted by the model of binary logistic regression. Overall, the model predicted 89.6% of the cases correctly.

Binary logistic regression results revealed that only education, market access, heads of cattle, and electronic media were found to influence biogas technology adoption significantly in the study area. The findings found that schooling had a favorable and important factor correlated with the acceptance of biogas (coefficient = 4.548; p = 0.000; odds ratio = 1.012) (Table 8). This means that these literate households are more likely to embrace biogas technologies by a margin of 1.012 compared with illiterate households. This is possibly because emerging technology is more likely to be embraced by educated households. The low levels of literacy mostly impede the productive flow of knowledge about emerging technologies for decision-making. The results of studies by Getachew (2016) and Kelebe et al. (2017), who found a positive correlation between the level of education and the implementation of biogas technology in Ethiopia, affirm this outcome. The findings also found that market access (coefficient = 2.265; p = 0.017; odds ratio = 1.040) had a favorable and statistically important effect on rural household decisions on biogas adoption. This indicates that farmers with access to the market were more likely than farmers without market access to adopt biogas technology by a factor of 1.040 at the study site. This is because market access is very important to increase the awareness and knowledge of rural households about new technologies through information sharing. Furthermore, it is easy to gain access to sand, cement, and stone inputs for biogas plant installation. Access to the market for households was also dramatically impacted by the introduction of biogas technologies at a 5 percent level of significance in the study site. This outcome is consistent with the results of Getachew (2016), Kelebe et al. (2017), and Woldesilassie and Seyoum (2017), who found a promising relationship in Ethiopia between the number of cattle and the adoption of biogas technology.[67]

The household head size of cattle had a statistical effect on the decision of households to implement biogas technology (coefficient = 0.263; p = 0.000; odds ratio = 1.300) and had a favorable association with adoption. This reveals that a rise in the number of cows owned by a household unit by one head of cows brings about a change in the household's likelihood of obtaining biogas innovation by a factor of 1.3. This is because cattle dung is the primary input for biogas digesters in Ethiopia. Therefore, the technology demands a larger number of livestock ownership. Household heads with a larger number of cattle are more likely to embrace biogas technologies than households owning a lower number of cattle. This outcome is consistent with the results of Getachew (2016), Kelebe et al. (2017), Woldesilassie and Seyoum (2017), and Kelebe et al. (2017), who found a promising relationship in Ethiopia between the number of cattle and the adoption of biogas technology. The findings of binary logistic regression also revealed that access to electronic media, including radio and TV, had a statistically significant negative relationship (coefficient = -2,889; p-value = 0,000; odds ratio = 0,056) with the decision of households to implement biogas technology in the field of research. This suggests that households that have not accessed electronic media such as radio and television tend to be less likely than households with access to electronic media to embrace biogas technology.

4. Policy implications

The most common source of fuel in the study area is fuelwood followed by crop residues and animal dung. Biogas technology is not common in the study sites though there is an increasing trend of using traditional biomass fuels. The prominent factors which hinder households' use of biogas energy are higher installation cost, inadequate water availability, low numbers of cattle, shortage of feeding (cow dung), and lack of awareness about biogas technology. In addition, the capacity of rural households to install biogas technology is influenced by the socio-economic characteristics of households, household demography, annual farm revenue, and consumers' access to electronic media. This shows the fundamentals of governance, and households are funded by NGOs with a large spectrum of institutional policy and technology assistance. Ethiopia's future national biogas policy should concentrate on raising awareness of the socio-economic and environmental benefits of electricity from biogas. The experts should devote their efforts to raise awareness through delivering training, panel discussion, and visiting model biogas adopter households. Moreover, facilitating the availability of affordable financing electronic media and market access, particularly for biogas technologies, may enhance the willingness of households to embrace renewable energy technologies. The scarcity of water is a common problem in the area and in order to provide both sufficient and secure water services, policy-driven efforts are thus essential. Therefore, including these activities in the existing formal extension channels of the Ethiopian National Biogas Program and the Ministry of Water, Mine, and Energy for rural households can be useful.

5. Conclusion

This research was conducted in the district of Gondar Zuria in northwestern Ethiopia to determine the current state of energy usage and identify the key factors affecting the decision of households to implement biogas technology. Fuelwood, crop residues, cow dung, and charcoal are the most common traditional biomass fuel used by households in the study area for cooking and heating. The majority of the respondents used kerosene lamps followed by battery cells and small size solar panels for lighting. The key informants reported that higher installation cost, inadequate water availability, low numbers of cattle, shortage of cow dung, and lack of awareness about biogas technology are the main barriers that hinder biogas installation and slow down the adoption rate of rural households in the study site. Thus, there is a need for creating awareness of biogas electricity, which offers socio-economic and environmental benefits to rural households. Furthermore, to overcome the constraints of high installation costs improving affordable financing in order to enhance the decision-making and planning of households for adoption, services are essential. The model of binary logistic regression found that education, retail access, cattle heads, and electronic media had a substantial effect on the decision of households to implement biogas technology. Future planning strategies for biogas energy should concentrate on improving market access, improving access to information on biogas energy, and improving accessible water supplies to increase the ability of rural households to implement biogas technology in the study district.

Declarations

Author contribution statement

Mequannt Marie & Fikadu Yirga: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Hossein Azadi & Getnet Alemu: Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

The data that has been used is confidential.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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