Adoption of Biogas for Household Energy and Factors Affecting Livelihood of the Users in Rural Bangladesh

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Abstract

Domestic energy insecurity is a major threat to sustainable development in a developing country like Bangladesh. The present study aimed at estimating the factors that affect adoption of biogas plant and analysing the factors responsible for the improvement of livelihoods of the biogas users. The study was based on primary data collected from randomly chosen 50 biogas user households and 30 non users in Ghatail and Fulbaria upazilas (sub district) of Tangail and Mymensingh district respectively. Required data were collected adopting direct farm survey method during January to February, 2015. Binary logistic regression model was used to analyse the data. The findings of the study reveal that education, income, farm size, number of cattle and cost of fuel were positively associated with the adoption of biogas technology. The major findings of the logistic regression showed that respondents having education over 8 years had 20.78 times more possibility of adopting biogas technology than tthose who had education less than 8 years of schooling. The probability of adopting biogas plant by a household owning land above 0.60 hactare was 7.31 times higher than those households owning land less than 0.60 hactare. The results of the logistic regression model fitted for livelihood improvement revealed that a biogas user who supplied gas to other consumer is 11.66 times more likely to achieve moderate improvement in livelihood than the user who could not supply gas to other consumer. The findings also showed that environmental and econmic factors were the two vital factors influencing the adoption of biogas. This study highlighted on the strategies such as organizing training,publicity program, motivational activities on biogas technology; encourage more educated people to adopt biogas technology and expanding subsidy and loan provision,extending period of loan repayment to increase the likelihood of adopting biogas plants.

KeyWords : Adoption, biogas, rural household energy, livelihood improvement

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Introduction

Energy and human development are clearly linked. The economic prosperity and quality of life in a country are directly linked to the level of its per capita energy consumption and the strategy adopted to use energy as a fundamental tool to achieve the development goals (Singh and Sooch, 2004). The imbalance between the demand and supply of energy creates anarchical situation in Bangladesh. Fossil fuels are exhausted in Bangladesh due to over-exploitation for the purpose of mitigating the existing difficulties. Aaccess to sustainable energy is very critical in the economic development of our nation, because it touches basically all aspects of life; agriculture, health, industry and education, among others.

Bangladesh faces an abject shortage of energy where more than half of the country's population has no access to electricity (ADB,2013). Only 3% of the total population has access to natural gas, which supplies about 75% of the total commercial energy to different sectors in Bangladesh (Islam, 2006). Natural gas has mainly been delivered as a raw material for power generation, fertilizer production and some other industries and domestic sectors in Bangladesh. About 40% of the total gas is supplied to power plants were totally dependent on natural gas during 2009-10 in Bangladesh (BER, 2011). Natural gas reserves will eventually be depleted and it is assumed that the supply of nature has began to decline from 2012. Economically, it will not be feasible to supply gas to rural areas by pipelines. In villages there is almost no gas network at all. Bangladeshi's access to modern fuels is low, with less than 10% of the country's population having access. The majority of the population in Bangladesh depend on biomass fuel for cooking and heating. putting their health at risk from smoke inhalation. Nine out of 10 people in Bangladesh still burn traditional biomass (ADB,2013). More than 40 million tons of biomass fuel like cow dung, fire wood, agricultural residues, leaves, straw, rice husks etc are used every year (Haque, 2008). About 36.5% of total primary energy is derived from renewable energy sources (Gustafson *et al.*, 2015). The overuse of biomass and depletion of fossil fuel have increased amount of Greem House Gas(GHG) emissions in the atmosphere, creating global warming. Renewable energy can overcome the existing problem, improve living condition, enable social services and promote the unlocking of economic growth, also controlling the existing rocking of oil prices.

Bangladesh has many potential renewable sources while it needs proper management for using these traditional energies. Inefficient ways of burning are wasting the quantity of biomass fuel available. But biogas technology has potential for efficient use. In biogas plant, animal and agricultural wastes are used as raw materials and returns are used as fertilizer and gas, energy is obtained as a bonus (Kabir *et al.*, 2013). Findings of research showed that cow dung and poultry litter-based slurries contain notable quantities of plant nutrients which improve soil fertility and thus offer the potentials greatly reduce the use of chemical fertilizer and pesticides. Thus it reduces costs of production and saves income for farmer. Political, economical, social, and technological as well as environmental impacts can be increased from expanding biogas technology in Bangladesh. Only a small proportion of the area residents have adopted the technology (Pandey *et al.*, 2007). Majority of households (more than 90%) have persistently continued to cook with inefficient traditional wood fuel systems with consequent detrimental environmental effects. Utilization of biogas; modern and desirable eco-friendly form of appropriate technology remains low (Pandey *et al.*, 2007) and its adoption is slow.

It is not clear what factors motivate some households in rural areas of Bangladesh to adopt the technology while many others do not adopt. The question arises why is the adoption of this technology still low, and why people are not taking up the technology despite its enormous potential. The potential of this technology has thus remained untapped, and its socio-economic and environmental benefits have largely remained elusive. Therefore, present study was undertaken to assess the factors influencing the adoption of biogas technology in typical households of country and the factors influencing the livelihoods of the households.

Objectives

The overall objective of the study is to explore the factors influencing biogas adoption in rural areas of Bangladesh and assess the factors responsible for improving livelihoods of rural communities.

The specific objectives are;

i) to know the socio-economic characteristics of the biogas users and non-users in the study areas;
ii) to analyze the factors influencing adoption of biogas technology in the study areas;
iii) to determine the factors influencing the improvment of the livelihoods of biogas users in the study areas;
iv) to analyze the motivating factors for the adoption of biogas technology

Methodology

Selection of the Study Area

Fulbaria and Ghatail upazilas under Mymensingh and Tangail districts respectively were selected purposively because of convenience and availability of biogas plants.

Selection of Sample and Sampling Technique

A list of biogas users was collected from Grameen Shakti -an NGO working in the energy sector of Bangladesh. A total of 80 households were selected as sample of the study taking 25 households using biogas plant and 15 non- user households from each of the selected two upazilas. A simple random sampling (SRS) technique was used in selecting the sample.

Data Collection

The required data were collected from the selected respondents employing farm survey method with the help of pre-designed and pretested interview schedule. Data collection was administered by the researchers themselves through direct interview with the respondents during the month of January to February, 2015.

Analytical Technique

Both tabular and statistical techniques were used to analyse the data in order to fulfill the objectives set for the study. In this study tabular analysis was done to find the mean, variation, percentage averagevariation of income, expenditure, farm size etc. Two binary logistic regression models were employed to determine the factors which significantly affect the adoption of biogas plant and the livelihood improvement of the biogas users

Logistic Regression Analysis

Linear regression analysis is based on that the dependent variable is continuous. The logistic model expresses qualitative dependent variable as a function of several independent variables, both qualitative and quantitative. The binary logistic regression is used when the dependent variable is categorical and consists of two categories.

A) For binary logistic regression to determine factors affecting adoption of biogas plant- the dependent variable was categorized as:

0 : Non adoption

1 : Adoption

B) For binary logistic regression to determine factors affecting the livelihood of biogas users- the dependent variable was categorized as follows:

0.28-0.40 : Weak improvement (Lowest score = 0.28)

>0.40 : Moderate improvement (highest score= 0.64)

Also let X be an independent variable. Then the form of the logistic regression model is

$$\Pi(X) = P(Y = 1/X) = \frac{e^{\beta_0 + \beta_1 X}}{1 + e^{\beta_0 + \beta_1 X}}$$

and

$$1 - \Pi(X) = P(Y = 0/X) = \frac{1}{1 + e^{\beta_0 + \beta_1 X}}$$

A transformation of $\Pi(X)$ is called the logit transformation. This transformation is defined in terms of $\Pi(X)$ as below:

$$g(X) = \text{Logit } \Pi(X) = \ln\left[\frac{\Pi(X)}{1 - \Pi(X)}\right] = \beta_0 + \beta_1 X$$

The importance of this transformation is that g (X) has many of the desirable properties of a linear regression model. The logit, g (X) is linear in its parameters may be continuous and may range from $-\infty$ to $+\infty$.

Depending on the range of X for more than one independent variable the model can be generalized as

$$g(X)=\text{logit}(\Pi_i)= \beta_0 + \sum_{l=1}^{k} \beta_l X_{il} \qquad 1 =, 2, \ldots, k \text{ and } i = 1, 2, \ldots, n$$

Empirical Model

i) A binary logistic regression model to determine significant factors affecting the adoption of biogas plants can be expressed by the following equation

$$Y = g(X) = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8$$

Where,

X_1 = Age of the household head (in years)

X_2 = Years of education

X_3 = Family size (in number of family members)

X_4 = Annual income (in BDT)

X_5 = Farm size (in acres\)

X_6 = Number of poultry birds

X_7 = Number of cattle

X_8 = Fuel cost (in BDT)

Y = Adoption of biogas plant

Y = 1 if the household uses biogas and 0, otherwise

β_0 = intercept

β_1, β_2, ... β_8 = Regression coefficients

ii) The another binary logistic regression model to find out the factors influencing the livelihood of the biogas users can be expressed by the following function

$$Y = g(X) = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4$$

Where,

X_1 = Number of poultry birds

X_2 = Years of education

X_3 = Availability of consumers

X_4 = Time saved from biogas for other income generating activities

Y = Improvement in livelihood of biogas users

Y = 1 if the household experience 'moderate improvement' in livelihood and
0 if the household experience 'weak improvement' in livelihood

β_0 = intercept

β_1, β_2, β_3 & β_4 = Regression coefficients

Research Hypotheses (Null)

i. There is no significant association between household social economic factors and adoption of biogas technology

ii. Use of biogas technology leads to no significant improvement in livelihood (household health, income, education and time savings, etc.).

Measurement of Variables

From the data set, some desired dependent and independent variables were selected. These variables were well defined and do not contain a large number of missing observation.

Dependent Variables

Adoption of biogas plant was considered as the dependent variable of the study. Scores assigned as 1 and o to the responses of 'Yes' and 'No' respectively. Changes in livelihood improvement among the biogas users after adoption of biogas plants considered as the dependent variable of the study. Scores assigned as 1 and o to the response of 'Weak improvement' and 'Moderate improvement' respectively. While the change occurred was reported by the respondents and this can be regarded as perceived change in livelihood improvement.

Independent Variables (Influencing Factors)

The possible characteristics of the households that might influence the adoption of biogas plant were considered as independent variables. In this study, the independent variables were- age, years of education, family size, annual income level, farm size, number of poultry birds, number of cattle and fuel cost. Some of them are coded on the basis of median value for interpreting the results conveniently (Table.1).

In case of logistic regression model, the factors that might affect the improvement of livelihood of the biogas users were number of poultry birds, years of schooling, availability of consumers (customers) and saving time for other IGAs and they are considered as independent variables. These variables are categorized in the following Table .2.

Calculation of Livelihood Score

Livelihood score were calculated by assigning score on each of its components in (Table.3) as follows:

Livelihood score = [Financial capital (i.e., income from biogas + income from bio slurry + saving from electricity + saving from fuel cost) + Physical capital (i.e., biogas user categories + stoves users categories + generator user categories) + Human capital (i.e., Irritation of bad smell + recovery of disease problem and eye itches + number of frequencies of heating foods +training and experience) + Social capital (i.e., decision making ability + social prestige + social network + conflict resolution] ÷ 25

Results and Discussion

Age Distribution

Age of the respondents (biogas users and non-users) were classified into four categories- i.e. <30 years, 31-40 years, 41-50 years and 51-60 years. Age distribution of the respondents is shown in Table.4.

In case of biogas user, the average age was observed to be 38.92 years ranging from a minimum of 25 years to a maximum of 60 years. In case of non-users, the average age was 40.40 years having the range from 26 to 56 years. The overall average age of respondents was observed to be 39.48. It is evident that the biogas users having age between 31-40 years accounted for 52 per cent of the total respondent while the non-user having age between 31-40 years accounted for 50 per cent and there was no respondent above 60 years. It is also evident that the middle aged group represented the major portion of the respondents household.

Family Composition

In the present study family size was classified into three groups such as, small family consists of less than four members (<4 members), medium family consists of 4-8 members and large family consists of more than 8 members (>8 members).

More than half of the households were medium-sized family for both groups consisting of 4-8 members. Nevertheless, a good number, about 38% and 26.7% of total households were small families for both groups (Fig.1). Large families for both the groups, were not notably represented in the study areas.

Literacy Profile

The level of literacy is generally considered as an index of social advancement of a community. Actually, education is an influencing factor of the household heads towards the decision making processes. From The literacy point of view, the respondents were divided into five categories, i.e. illiterate, primary (1-5 years), secondary (6-10 years), high secondary (11-12 years), more than high secondary (<12 years).It is evident (from Table.5) that the average years of schooling for the biogas users and non-users was about 8.68 and 5.51 years, respectively, meaning that the biogas users were more educated than non-users. Particularly for biogas users, about12% of them had education above secondary level where as it was one half of the biogas users in case of biogas non users..

Farm Size of Biogas Users and Non-Users

According to the Department of Agricultural Extension (DAE), traditional farm households are divided into four categories based on the size of their farm holdings such as-marginal (less than or equal 0.2 ha), small (0.21-1.008 ha), medium (1.01-3.03 ha), and large (more than 3.03 ha). The following figure (2) shows the distribution of farm size for both biogas user and non-users. Major portion of the non users of biogas bolonged to the marginal (12.9%) and small (40.6%) farm category which was higher than the biogas users. No large farmer was found in the non user group in the study areas. The mean farm size of biogas users and non-users was 2.17 ha. and 0.48 ha. respectively. Farm size might affect the decision to adopt of a biogas plant. Primarily, the rich households adopted biogas plants as a result of motivation by service providers, although the size of plant was not considered or even if a small plant was chosen.

Occupation of the Respondents

The occupation of the head of a household from which he earnes major portion of the family income, was considered as the primary occupation. In this study, occupation was classified into business, farming, teaching, government services, and others. Other professions consists of NGOs work, carpentry, bus and taxi driving etc. Occupation of the households is one of determining factor for the adoption of biogas plant. Occupation status of the biogas users and non-users are shown in Figure 3. The occupation of the major part of the biogas users was business(44%) followed by agriculture(38%), teaching(10%), government service (6%) and others (2%). It was found that educated households and businessmen are devoted joining the biogas era, thus these people have a great impact on the motivation for biogas implementation.

Factors Influencing Adoption of Biogas

Among the eight variables included in the model, six variables had a statistically significant effect on the adoption of biogas technology. It revealed (Table.6) that age had a non-significant ($p > 0.05$) negative relationship with biogas technology adoption implying that older people were more risk averse and less willing to take on new innovations. This results agree with previous study by Somda *et al.*, (2002) and Walekhwa *et al.*, (2009) where farmers age was negatively related to the probability of adoption of biogas technology.

Logistic regression results revealed that education of the household head was positively related with adoption of biogas plant and significant at 1% level. Over 8 years of education obtained by a household had 20.78 times more possibility of adoption of biogas plant than that of a household less than 8 years of education. This result is quite similar in nature to some other adoption practices finding (Keyed *et al.,* 1990; Brush and Talor, 1992 ; Fleke and Zegeye, 2006) which also showed a positive correlation between years of schooling and probability of biogas technology adoption. Household heads having more education are supposed to be more progressive, more exposed to sources of information and therefore more informed, knowledgeable and environmentally aware of the existing difficulties of society, like the negative effects of fossil fuels on the environment (Walekhwa *et al*., 2009)..

It is evident (from the Table.6) that family size had significant negative relationship with the adoption of biogas technology. A household possessing the number of family member less than or equal to 5 was 47.62 times more likely to adopt a biogas plant than a household having the number of family member greater than 5. Because biogas does not warm food as quick as the line gas can, although it provides better service for small family member. It takes more times for cooking food for large family. This result is dissimilar with the research findings (of Waleahwa *et al.* 2009) who indicated that household size and biogas adoption have a significantly positive interrelationship with each other. Under these circumstances, larger household size would negatively influence the decision to adopt biogas technology. (Kebede *et al*. 1990).

Annual income level exerts a significant ($p<0.01$) association with the adoption of biogas plant. That is, as income increases, possibility of adoption of biogas increases. Household income proved to be key factor in a household's decision to install a biogas plant. The most probable effect of household income on the adoption of biogas energy is the financial ability to install a digester system, which is often cited as the single most important factor determining whether or not a household adopts biogas energy. The initial investment is usually considered a large amount for a rural household to afford and therefore biogas digesters remain the province of relatively wealthier households in Uganda. In Bangladesh, initial investment is also considered high but IDCOL provides a certain level of subsidy as well as soft loans to rural households to cover the initial high investment costs. Thus household do not suffer any monetary complications during the plant implementation period.

The findings of the present study showed that farm size had positive significant ($p<0.01$) effect on the adoption of biogas technology by the household (Table .6). The probability of adopting biogas plant by a household owning more than 0.60 ha. of land is 7.31 times higher than that of a household owning less than or equal to 0.60 ha.of land. Space requirements of biogas technology for setting up a biogas plant, rearing cattle, poultry and house become a crucial factor in the adoption of biogas technology. In order to run a biogas unit effectively and efficiently, all three components (bio-digester, animal units and fodder component) need to be closed to each other for easy provision for feedstock to the bio-digester and effective monitoring of routine operational and maintenance activities. For this, a household must surpass minimum landholding threshold that can accommodate a digester.

Based on these grounds, it can therefore be concluded that households with larger farm size would have higher probability of adopting a biogas plant. Both theoretical and practical studies of adoption showed a positive association between farm size and the probability and extent of adoption (Brush and Taylor, 1992).

Number of cattle has a positive significant ($p<0.10$) association with the adoption of biogas plant. The odds ratio 4.46 indicates that the likelihood of adopting biogas plant of a household having number of cattle greater than 4 is 4.46 times more than a household having number of cattle less than or equal to 4. Actually, cattle dung is one of the main sources of raw materials for biogas production in Bangladesh. Other sources include poultry litter, crop residues, industrial residues and municipal waste are available but are not considered for collection and use in biogas production. Adeoti *et al.* (2000) found that two head of cattle per household are adequate for gas production in a family-size digester.

Adoption of biogas plant exerts no significant ($p>0.05$) association with the number of birds. Though a household having number of birds greater than 1035 is more likely to adopt a biogas plant than a household having number of birds less than or equal to 1035 birds. However, this study found poultry to have no significant influence on adoption of a biogas plant.

It revealed that there was a positive and significant relationship between fuel cost and adoption of biogas plants at 10% level of significance. The likelihood of adopting biogas by a household whose monthly fuel cost is higher than BDT. 1195 is 14.24 times more than that of adopting biogas by a household whose monthly fuel cost is less than or equal to BDT.1195. The fuel cost is another influencing factor in adopting biogas. The sourcing of fuel wood is time-consuming and expensive day by day because the forest is not available as it was before.

Motivational Reasons for Biogas Adoption

It was found in the study that economic, environmental, technological, and social factors were the reasons behind motivating the potential households toward biogas adoption in rural areas. It is evident (from Table.7) that rural people are often motivated by considering the environmental factors, (66%) to install a biogas plant in and around a household. About 64% of the respondents were motivated to adopt biogas in order to reduce deforestation as well as CO_2 emissions. About 78% of total respondents were motivated toward biogas plants due to the health benefits, especially for women and children.

Income generation as a result of saving time through biogas adoption which was also recognized as a notable reason for installing a biogas plant. About 66% of total households looked forward to the income generation from time savings associated with biogas use. Subsidy also was a productive incentive to easily motive the general household. Nevertheless, 64% of rural households are convinced through receiving a subsidy. Naturally, an adequate number of livestock is a primary requisite for adopting a biogas plant. About 60% of total households are persuaded by having an adequate number of livestock. Publicity is a very important tool for expanding technology innovation but still biogas technology is far away from having advertisement activities to convince rural households. Local government could serve a notable function taking responsibility for extending renewable energy activities in their territory. But this study did not observe any activities by local government to boost renewable energy practices in the sampled areas of Bangladesh, while neighboring biogas users played a promoting role in expanding biogas technology.

Table 8 also shows the proportional difference between motivating factors for adoption of biogas users. Environmental factor is a vital and key factor influencing the adoption of biogas users. About 65% of household are convinced by lessons on the environmental benefits of biogas technology. The second strongest factor is the economic aspects for motivating rural households representing 53.5% followed by social(32%) and technological factor (27.5%) for adoption of biogas. Table 8 shows two-sample proportional value of a z-test of environmental, economic, social and technological factors. Thus, the result showed that there is no significant difference between the motivating factors environmental and economic issues. But there exists a significant proportional difference between social and technological factors compared to the environment factors for adoption of a biogas plant.

Factors Affecting Livelihood of Biogas Users

After adopting biogas technology by the users, an overall livelihood improvement was estimated by using binary logistic regression model, where weak and moderate improvement was occurred

Among the four variables in the model, two of these indicated a statistically significant effect of biogas technology on livelihood of biogas users. These are availability of consumers and time saving for other activities such as handicraft, rearing livestock more efficiently etc. On the other hand, number of birds and years of schooling are not statistically significant. Availability of consumers and times saving for other activities are positively related with change in livelihood of biogas users at 1% level of significance.

A biogas user having number of birds more than 735 is 1.94 times more likely to attain moderate improvement in livelihood as compared with the user experiencing weak improvement in the livelihood having less than or equal to 735 birds. A biogas user whose years of schooling is higher than 8.5 is 2.28 times more likely to experience moderate improvement in livelihood as compared with a user experiencing weak improvement whose years of schooling is less than or equal to 8.50 . There exists a significant positive relationship between availability of consumers and change in livelihood. The odds ratio implies that a biogas user who can supply gas to other consumer is 11.66 times more likely to achieve moderate improvement in livelihood as compared with a user experiencing weak improvement in livelihood who cannot supply gas to other consumer due to unavailability of consumer. Biogas users who spent time in extra income generating activities (IGA) is 8.26 times more likely to have moderate improvement as compared with the user experiencing weak improvement in livelihood who spent no saving time in other IGAs.This result is similar to the findings of research by Dahal(2005) found that a biogas plant can save on average 3 hrs per day in time for fuel wood collection in addition to reducing the time needed for cooking. It is a simple principal that biogas production can relieve people of the hard job of fuel collection as well as the continuous attention required during the cooking period. The findings showed that there exists significant relationship between the adoption of biogas plant and the livelihood improvement of the user households.

Conclusion

The study identified some important factors which significantly influenced biogas technology adoption decisions of households in rural Bangladesh.and improvement of the livelihood of the biogas user. The study shows that the probability of a household adopting biogas technology increases with decreasing of age of head of household, increasing household income, increasing number of cattle owned, decreasing household size and increasing cost of fuels. Bangladesh being richly endowed with dairy livestock has enormous quantities of cow dung that can be transformed into a renewable energy which could go a long way in meeting household energy needs. As our country faces acute shortage of energy for domestic consumption, biogas energy has the potential to solve the most serious problem of energy supply in rural areas, where people use forage and forests wood as fuel. Biogas adoption could help alleviate serious shortage of energy accross the whole country especially in rural areas. It could be a good source of renewable energy technology instead of traditional cooking system through protecting the soil from degradation. This technology could be adopted in the potential areas due to its efficient role in the improvement of livelihood such as income ,health, education of the children and saving of time.The study also emphasizes on the strategies such as organizing meeting, awareness building program, publicity through mass media to encourage more people to adopt the technology. Government and donor agency should provide loan at an easy terms and condition, providing the scope for extending repayment period and reducing the installment to increase the likelihood of adopting biogas plant for household energy consumption.

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List of Tables

Table 1 Coding score on the categories of factors affecting biogas adoption

Years of education	Categories	0-8	>8
	Scores	0	1
family size	Categories	0-5	>5
	Scores	0	1
farm size	Categories	0-1.49	>1.49
	Scores	0	1
number of poultry birds	Categories	0-1035	>1035
	Scores	0	1
number of cattle	Categories	0-4	>4
	Scores	0	1
Fuel cost	Categories	0-1195	>1195
	Scores	0	1

Table 2 Coding score on the categories of the influencing factors of livelihood

Years of education	Categories	0-8.5	>8.5
	Scores	0	1
number of poultry birds	Categories	0-735	>735
	Scores	0	1
Availability of consumers	Categories	Yes	No
	Scores	0	1
Time saving for other income generating activities	Categories	Yes	No
	Scores	0	1

Table 3 Coding score on the livelihood components of the biogas users

Financial capital	income from biogas	Category	High (>BDT. 8000)	Moderate (BDT.1000-8000)	Low (<BDT.1000)
		Coding score	2	1	0
	income from bio slurry	Category	High (>BDT. 8000)	Moderate (BDT.1000-8000)	Low (<BDT.1000)
		Coding score	2	1	0
	saving from electricity	Category	High (>BDT. 8000)	Moderate (BDT.1000-8000)	Low (<BDT.1000)
		Coding score	2	1	0
	saving from fuel cost	Category	High (>BDT. 8000)	Moderate (BDT.1000-8000)	Low (<BDT.1000)
		Coding score	2	1	0

Physical capital	biogas user	Category	Large (>3plants)	Medium (2-3 biogas plants)	Small (one biogas plant)	
		Coding score	2	1	0	
	stoves users categories	Category	Large (>10 stoves)	Medium (5-10 stoves)	Small (3-5 stoves)	Marginal (<3 stoves)
		Coding score	3	2	1	0
	generator user categories	Category	Large (>1 generators)	Medium (1 generator)	Small (no generator)	
		Coding score	2	1	0	

Human capital	recovery of disease (respiratory problem and eye itches)	Category	Both	One of them	None
		Coding score	2	1	0
	number of frequencies of heating foods	Category	4 times or more	3 times	2 times
		Coding score	2	1	0
	training and experience	Category	Yes	No	
		Coding score	1	0	
	Irritation of bad smell	Category	Yes	No	
		Coding score	1	0	

Social capital	decision making ability	Category	Increased	Unchanged
		Coding score	1	0
	social prestige	Category	Increased	Unchanged
		Coding score	1	0
	social network	Category	Increased	Unchanged
		Coding score	1	0
	conflict resolution	Category	Increased	Unchanged
		Coding sore	1	0

Table 4 Distribution of age according to the biogas users and non-users

Age group	Users		Non-users		All	
	No	Percent	No	Percent	No	Percent
<30 years	9	18	5	16.7	14	17.5
31-40 years	26	52	15	50	41	51.3
41-50 years	8	16	6	20	44	17.4
51-60 years	7	14	4	13.3	11	13.8
All age	50		30		80	
Maximum	60		56		60	
Minimum	25		26		25	
Average	38.92		40.40		39.48	
Standard deviation	8.983		7.915		8.577	

Sources: Field survey

Table 5 Literacy status of the biogas users and non-users

Literacy level (Year of schooling)	Users		Non-users		All	
	No	Percent	No	Percent	No	Percent
Illiterate	2	4	6	16.7	8	10
Primary (1-5 years)	8	16	9	50	41	21.3
Secondary (6-10 years)	30	60	12	20	42	52.5
Higher secondary (11-12 years)	4	8	1	13.3	5	6.3
Above higher secondary (>12 years)	6	12	2	6.7	8	10
Total	50	100	30	100	80	100
Average	8.68		5.51		7.51	
Median	8.5		5.5		7	
Standard deviation	3.594		3.945		4.003	

Sources: Field survey

Table 6 Logistic Regression Estimates of biogas plant adoption

Variables	Coefficients	Standard error	Wald statistics	p-value	Odds ratio	95% Confidence Interval for odds ratio	
						Lower	Upper
Constant	-6.261	2.512	6.210	-	0.002	-	-
Age	-0.058	0.043	1.778	0.182	0.944	0.867	1.027
Education (Ref.-Illiterate)	3.034**	1.347	5.077	0.005	20.788	1.484	291.184
Family size (Ref.- >=5)	-3.871***	1.287	9.048	0.003	0.021	0.002	0.260
Annual income	.000021***	.000	7.893	0.325	1.000	1.000	1.000
Farm size (Ref.- >=1.49)	1.989***	0.781	6.492	0.024	7.307	1.582	33.741
No. of poultry birds (Ref.-1035)	0.904	0.919	0.968	0.011	2.470	0.408	14.956
No. of cattle (Ref.- >=4)	1.495*	0.862	3.012	0.083	4.462	0.824	24.151
Fuel cost (Ref.- >=1195)	2.656**	1.134	5.483	0.019	14.243	1.542	131.585

Source:Authors calculation based on the data

-2 log likelihood = 56.46

Model chi-square value = 49.39 (p< 0.01)

Ref. stands for reference category

* Significant (p<0.10), ** significant (p< 0.05) and *** significant (p< 0.01)

Table 7 Biogas adoption perception corresponding to different motivating factors (in percent)

Main factor	Motivating factor	Yes	No	Percentage	Mean
Economic	Subsidy	32	18	64	53.5
	Credit	18	32	36	
	Economic benefit	27	23	54	
	Number of livestock	30	20	60	
Social	Health benefits	39	11	78	32
	Neighbors plant owners	27	23	54	
	NGOs	14	36	28	
	Publicity	0	50	0	
	Local government	0	50	0	
Technological	Time and energy savings	33	17	66	27.5
	Fuel shortage	15	35	30	
	Service providers	6	44	12	
	Training	1	49	2	
Environment	Forestation	32	18	64	65
	Soil fertility	33	17	66	

Source: Field Survey,2015

Table 8 Significance test of proportional difference of the motivating factors

Factors	Proportion	Proportion difference[a]	z-value	p-value
Economic	0.535	0.115	1.898	0.057
Social	0.320	0.330***	5.662	0.000
Technological	0.275	0.375***	6.250	0.000
Environmental	0.650	-	-	-

Source: Field Survey,2015. *** stands for significant ($p < 0.01$) difference

[a] Difference is taken from environmental factor

Table 9 Logistic Regression Estimates of livelihood improvement of the biogas users

Variables	Coefficients	Standard error	p-value	Odds ratio	95% Confidence Interval for Odds ratio	
					Lower	Upper
Constant	-3.549	1.085	0.001	0.029	-	-
Number of poultry birds (Ref. - >=735)	0.663	0.797	0.405	1.941	0.407	9.257
Years of education (Ref.- >=8.5)	0.825	0.776	0.287	2.282	0.499	10.443
Availability of consumers (Ref.- >=0)	2.456***	0.854	0.004	11.656	2.186	62.145
Time saving for other income generating activities (Ref.- >=0)	2.111***	0.818	0.010	8.256	1.661	41.030

Source: Authors calculation

-2 log likelihood = 22.65,

Model chi-square value = 46.59 ($p< 0.01$),

Ref. stands for reference category, *** Significant ($p< 0.01$)

List of Figures

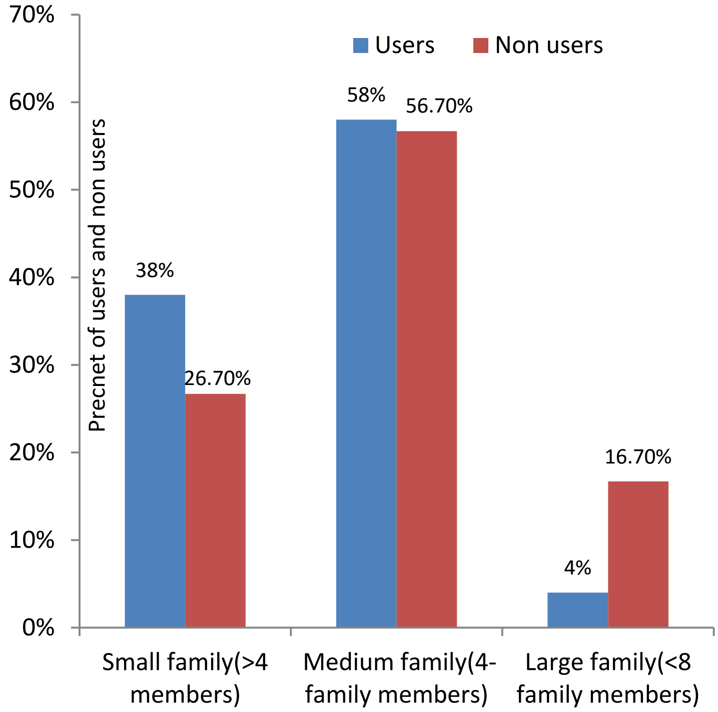

Figure 1 Family Composition of users and non-users

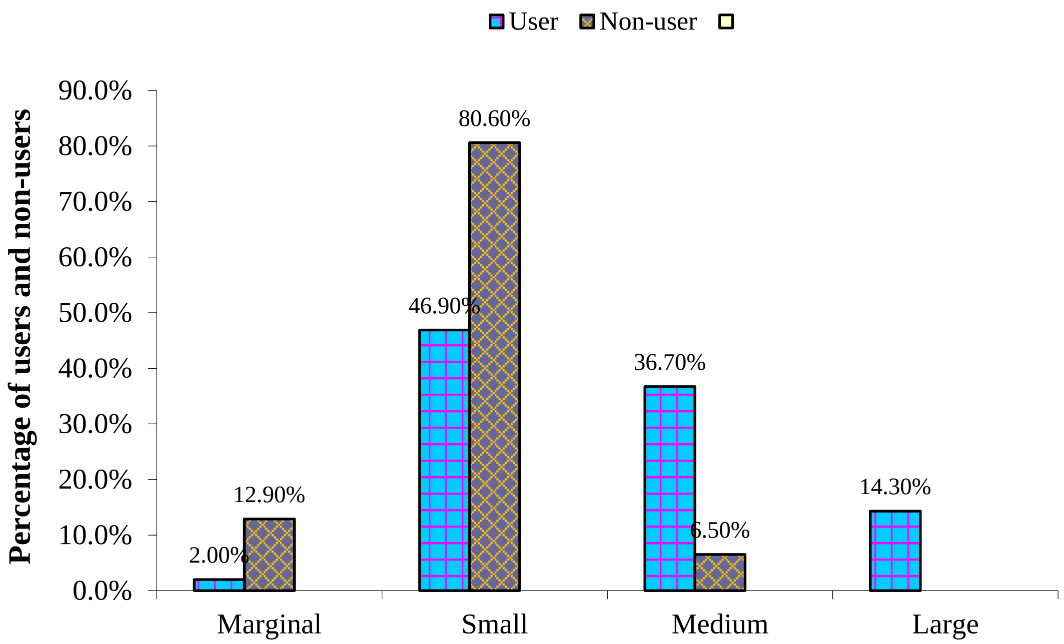

Figure 2 Farm size of biogas users and non-users

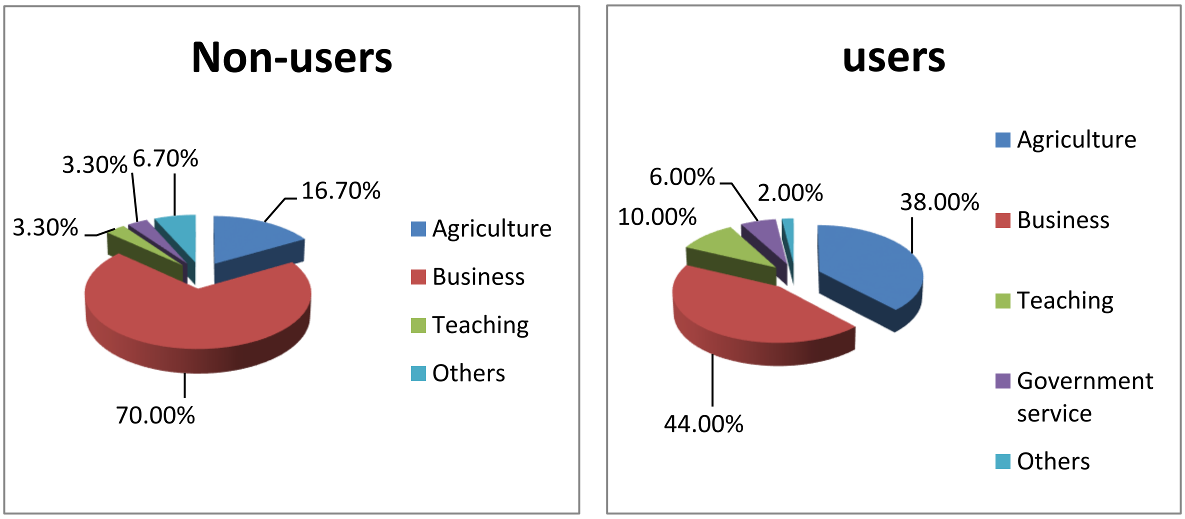

Figure 3 Occupation of the biogas users and non-users

In this case, biogas can play a crucial role as an alternative source of aid to traditional energy problems in rural areas.

Biogas is one option in Bangladesh. As an agro-based country being endowed with plentiful biomass. Moreover, the technology is considered by many experts to be an effective tool for improving life, livelihoods, and public health in the developing world. Biogas energy is considered a sustainable solution to local energy needs, and provides significant benefits to human and ecosystem health. Unlike firewood, biogas burns without smoke, improving indoor air quality, and thus saving women and children from respiratory distress and ailments. Biogas can be used to generate electricity, prolonging the active hours of the day and enabling the family to engage in social or self-improvement activities and to earn extra income.