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Feasibility Study for Biogas Generation from Household Digesters in Bangladesh: Evidence from a Household Level Survey

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ABSTRACT

Biogas could be an important alternative source of energy in order to meet its increasing demand in Bangladesh. To explore the feasibility of biogas generation in Bangladesh, a household level sample survey on the biogas digester adaptors and biogas digester non-adaptors were conducted. The study revealed that costs for cooking by using solid fuels are significantly higher compared to costs for cooking by using biogas. Biogas generation has become very urgent in Bangladesh because of absence of natural gas supply in rural households, collection of fuelwoods has become difficult because of increasing tremendous pressure on forest lands, and the cost of alternative cooking fuels like LP gas is unaffordable for rural people. As the substrates for biogas generation are readily available and people are highly interested to adapt biogas digester, a welcoming environment for biogas generation is prevailed in Bangladesh. Moreover, biogas digesters are easy to operate and easy to maintain and even women can operate and maintain biogas digesters. Biogas production is profitable, and almost all the biogas adopters are satisfied with the performance of biogas digesters. Logistic regression analysis identified some important factors that are significantly influenced for the adoption of biogas digesters and these are (i) education of household head, (ii) household income, (iii) costs for cooking fuels, (iv) number cattle available in the households, and (v) number of poultry available in the households. Results presented in this study indicate that Bangladesh is urgently needed to generate biogas and feasible environment for biogas generation prevails in Bangladesh. The only needs are the motivation, initiatives and necessary support from the top levels to install biogas digesters.

Keywords: Biogas, Solid Fuels, Anaerobic Digestion, Methane, Renewable Energy, Environment

JEL Classifications: Q4, P28

1. INTRODUCTION

In the era of urbanization, the demand of energy is rising with an unpredicted rate with each passing day. To meet the growing energy demand, developing countries have been depending on solid fuels for cooking. Worldwide, approximately 3 billion people are burning solid fuel, including biomass, agricultural residues and charcoal, for their daily cooking (Nigel, 2004; Eric et al., 2018). The overdependence on solid fuels as primary energy source has led to global climate change, environmental pollution and degradation, and thus leading to human health problems (Otun

et al., 2015). Global depletion of solid fuels has led to the search for alternative sources of energy.

In most developing countries, cooking is a dirty and time-consuming job that involves burning solid fuels to produce fire. Solid wood fuels used for cooking and heating, represent approximately 55% of global wood harvest and 9% of primary energy (UN FAO, 2013; REN21 Secretariat, 2013). About 50% of the wood fuel harvest is unsustainable (Bailis et al., 2015). Cooking over a 3-stone fire in a home is equivalent to burning 400 cigarettes in an hour that release toxic smoke and emissions which mostly

affect women and children (EFC, 2012). A study by Global Health revealed that inefficient cook stoves to be the largest environmental threat (GEC, 2012). Worldwide about 70,000 people die per year because of household air pollution (IHME, 2017). Thus, cooking by solid fuels is a challenge as inefficient systems of cooking have a major impact on health, environment and economy. Development of renewable and sustainable energy source is the best solution to the country's energy demand (Donald, 1998; Das et al., 2018). Biogas is an alternative promising substitute to solid fuel and capable of replacing current energy supply and can only be considered as the best for meeting the demand and insurance of future energy in a sustainable manner (Corro et al., 2013; Mel et al., 2015).

Biogas is assumed a green sustainable gas produced by the anaerobic digestion of organic agricultural waste, manure, municipal waste, digester materials, sewage, green waste or food waste. It can be produced from locally available raw materials and recycled waste and is agreed environmental friendly and neutralizing greenhouse effects and thus contributed climate change mitigation (Clements et al., 2006; McCarl, 2010; Zahariev et al., 2014; Das et al., 2018). This process produces gases which contains roughly 50-70% methane (CH_4), 30-40% carbon dioxide (CO_2), and trace amounts of other gases (USDA, 2014). The gases methane, hydrogen, and carbon monoxide can be combusted or oxidized with the presence of oxygen to provide heat, electricity or both (Babel and Pecharaply, 2009). Thus, stored biogas can provide a clean, renewable, and reliable source of baseload power in place of coal or natural gas. Using stored biogas limits the amount of methane released into the atmosphere and reduces dependence on fossil fuels. In addition to climate benefits, anaerobic digestion can lower costs associated with waste remediation as well as benefit local economies. It is a renewable energy source, like solar and wind energy. It does not have any geographical limitations or requires advanced technology for producing energy, nor is it complex or monopolistic.

Bangladesh is one of the fastest growing economies in the Southern-Asia, with 64% of the total population are living in rural areas (Suntrace, 2018). It has been reported in WHO (2016) that 82% of the Bangladesh population primarily use wood, charcoal, coal, and kerosene for cooking. Bangladesh has a very limited energy reserve; small amount of oil, coal and countable natural gas reserves (Prati et al., 2013). Thus, in Bangladesh scenario, biogas can be a substitute for traditional fuels and can meet the rural energy demand and also provide a clean source of energy.

The primary concern of energy production in Bangladesh is the prolonged effects of energy demand. If the supply of energy is not proliferated accordingly there will be serious adverse implications for the nation's economic and social development as well as for the assurance of energy security for future generation. The energy development strategies are dependent on the sustaining relationship between energy consumption and economic growth, energy consumption and Human Development Index, biomass fuel consumption and economic growth and different energy sources

providing world energy demand. A long-term comprehensive and integrated energy policy along with appropriate strategies should be formulated to ensure security over short, medium and long terms for the country. The policy should ensure tapping of all possible sources of energy, adequate supply of energy to its various uses and equitable access of renewable energy to all segments of society. Due emphasis must be given on the usage of the renewable energy sources and extensive research and development programs should be conducted for the further development of renewable energy technologies.

Given the extensive use of firewood for cooking in developing countries, studies have been made on emissions from biomass-based stoves, including a detailed study of greenhouse gases from small-scale combustion with special reference to household stoves (Smith et al., 2000). All the studies identified that biomass-based stoves had adverse effects on health. In this context, the 7th Sustainable Development Goal includes the target of ensuring universal access to affordable, reliable and modern energy services by 2030 (UNDP, 2019). Another important challenge is the security of energy supply. To achieve these challenging goals, understanding the sources of affordable, reliable and clean energy that suit the economic and geographical conditions is needed. In this context, biogas from wastes, residues, and energy crops will play a vital role in future. Thus, this study aimed at evaluating feasibility and prospect of biogas generation in the rural areas of Bangladesh.

2. DATA COLLECTION AND METHODOLOGY

This study was based on cross-sectional data collected using four-stage cluster sampling. At the first stage, 20 districts from 64 districts of Bangladesh were selected randomly. At the second stage, one upazilla from each selected district were randomly selected. At the third stage, two unions from each selected upazilla were selected randomly yielding a total of 40 unions. As there is no sampling frame of biogas digester adaptors and the biogas digester adaptors are very limited in number, all the biogas digester adaptors of the selected unions were detected using snowball sampling technique and interviewed by a structured questionnaire.

A total of 498 biogas digester adaptors households and 500 biogas digester non-adaptors households neighboring the selected biogas digester adaptors households were selected and head of each selected household was interviewed by a structured questionnaire. Statistical software, SPSS was used to analyzed the data. Various statistical tools, such as summary measures and logistic regression analysis were used to meet the objectives of the study.

3. RESULTS AND DISCUSSION

3.1. Background Characteristics of the Respondents

Respondents' background characteristics are associated with the adaption of biogas digester in rural areas. Thus, this subsection summarizes background characteristics of the respondents and is presented in Table 1. Major disparities in some background

Table 1: Background characteristics of the respondents

	Adaptor	Non-adaptor
Religion		
Muslim	94.3	95.6
Hindu	5.7	4.4
Age		
<30	16.0	21.0
30-39	25.8	30.6
40-49	32.0	28.8
50-59	20.5	14.0
≥60	5.8	5.6
Family size		
≤4	23.8	34.4
5-6	52.5	43.0
7-8	19.3	14.0
>8	4.5	8.6
Education		
Primary	7.8	40.8
Secondary	49.8	29.8
Higher secondary	19.5	15
Graduate	18.5	8.4
Post-graduate	4.5	6.0
Occupation		
Agriculture	30.5	37.6
Service	19.8	22.8
Business	45.8	31.4
Foreign employment	1.8	4.0
Others	2.3	4.2
Total family income		
<5000	4.4	10.0
5000-9999	5.0	12.6
10,000-19,999	29.5	32.2
20,000-29,999	30.5	22.8
30,000-39,999	14.8	9.2
40,000-49,999	4.8	2.8
≥50,000	11.0	10.4
Total number of respondents	498	500

Table 2: Total monthly cost for cooking fuel

Monthly cost	Biogas	Solid fuels
<300	74.0	25.8
300-599	5.8	10.6
600-899	4.5	10.2
≥900	12.7	53.4
Total	498	500
Mean	420.3	1059.8
Standard deviation	971.6	1030.4
z-test for the difference of means between two costs	Z=10.10, P=0.0000	

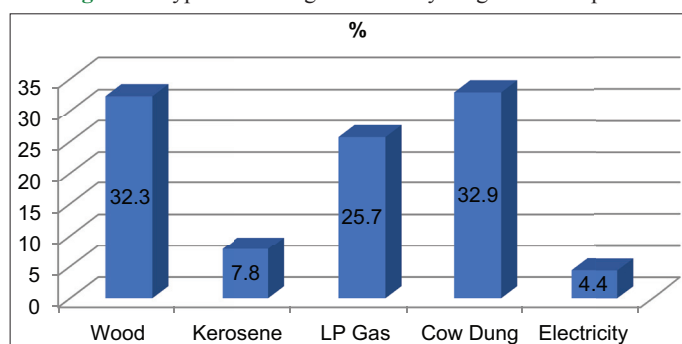
digester adaptors completed primary level education while about 41% of the respondents of biogas digester non-adaptors completed primary education. About 50% of the respondents of biogas digester adaptors completed secondary level education while only 30% of the respondents of biogas digester non-adaptors completed secondary level education. About 38% of the respondents of the biogas digester adaptors completed higher secondary or above level of education while about 29% of the respondents of biogas digester non-adaptors completed higher secondary or above level of education. It indicates that education of the household head is one of the catalysts for biogas digester adaption. Occupation is also an important factor for adaption of biogas digester. It is seen from Table 1 that highest proportion (about 46%) of biogas digester adaptors' occupation was business. About 31% of the biogas digester adaptors' occupation was agriculture. Family income is also one of the most important factors for influencing people to adapt biogas digester. Table 2 shows major disparities between family income of biogas digester adaptors and biogas digester non-adaptors. It is seen from the table that family income was higher for the biogas digester adaptors than biogas digester non-adaptors. About 61% of the biogas digester adaptors' households per month family income was Tk. 20,000 or more whereas about 45% of the biogas digester non-adaptor family's per month family income was Tk. 20000 or more.

characteristics of the respondents between the biogas digester adaptors and biogas digester non-adaptors are noticed.

The tabulation of respondents by religion indicates a majority of Muslim adherents (about 94% of the biogas digester adaptors and about 95% of the biogas digester non-adaptors) and the rest are Hindu adherents. Table 1 shows no major disparities in the age distribution of biogas digester adaptors and biogas digester non-adaptors. About 42% of the respondents of biogas digester adaptors belonged to aged below 40 years and 57% of the respondents of biogas digester non-adaptors were aged below 40 years. About 32% of the respondents of biogas digester adaptors were aged 40-49 years and about 29% of the respondents of biogas digester non-adaptors were aged 40-49 years. Family size is an important stimulus for the adaption of biogas digester because cost of cooking fuels for greater family size might be higher compared to smaller family size. It is seen from the table that family size of biogas digester adaptors' families was higher compared to biogas digester non-adaptors' families. About 76% of the respondents of biogas digester adaptors reported their family size as 5 or more while about 65% of the respondents of biogas digester non-adaptors reported their family size as 5 or more. Major disparities in education level between respondents of biogas digester adaptors and respondents of biogas digester non-adaptors were noticed. Only 8% of the respondents of biogas

3.2. Main Source of Cooking Fuels for Biogas Digester Non-adaptors

A large number of people in rural Bangladesh cook daily on traditional stoves and open fires with solid fuels like wood, which has far-reaching health, environmental, and socio-economic impacts. Much of the researches on solid cooking fuels have focused on energy efficiency and emissions in the kitchen (Salam and Alim, 2008; Salam and Alim, 2009; Bailis et al., 2015; Chagunda et al., 2017). Biomass fuels, such as wood, cow dung, and agricultural residues are collected mainly from the local environment and have become a traded commodity as cooking fuel as access to local biomass becomes ever more difficult. The supply of natural gas in rural areas are absent and new gas connection to household were suspended for an uncertain time. Figure 1 represents the sources cooking fuels in the study areas. It is seen from the table that most of the biogas digester non-adaptors used solid fuels such as fuelwood (about 32%) and cow dung (about 33%) for cooking. The solid fuel is used in traditional stoves which consist of a hole in the ground with a raised clay lip to rest the pot with a separate fuel entry hole. The traditional clay stoves are inefficient and generally poorly ventilated so that they produce fine particles, polycyclic aromatic hydrocarbons, carbon monoxide,

Figure 1: Type of cooking fuel used by biogas non-adaptors

dioxins and other carcinogens (Nigel et al., 2004). Housewives are exposed to high levels of these toxins between 3 and 7 h a day. Research revealed that this indoor air pollution occurs not only in the kitchen but slightly lower in the living area therewith affecting also other family members such as children (Nigel et al., 2004; Salam and Alim, 2009). The World Health Organization (WHO) estimated that there are 4.3 million premature deaths annually as a result of indoor air pollution exposure due to the lack of clean or modern energy services for cooking (World Health Organization, 2016). Further WHO attributes 1.3 million disability-adjusted life year to the use of solid fuels.

Indoor air pollution is the second biggest environmental contributor to illness worldwide after unsafe water and inadequate sanitation (WHO, 2007). Moreover, households cooking with traditional stoves and solid fuels use considerable parts of their incomes for either purchasing fuels for cooking, or using significant amount of their time for collecting firewood (World Bank, 2019). Even though cooking is not considered as the major cause of deforestation, where firewood is not collected sustainably both environmental and climate impacts are present. In the survey areas, 100% of the households where biogas was available used biogas instead of solid fuels indicating that rural people are highly interested to use biogas. Biogas mainly from animal and municipal wastes may be one of the promising renewable energy resources for Bangladesh. It is a potential source to harness basic biogas technology for cooking. As much biogas is viewed as a potential renewable energy source, most households have persistently utilized wood and cow dung with the resultant negative effects. It is therefore necessary to assess the factors influencing installation of biogas digester at the household level in rural areas of Bangladesh.

3.3. Cost for Cooking Fuels

When comparing fuel costs for cooking using biogas and solid fuel few dynamics can be noticed. The first interesting result is that adaption of biogas digester and access to biogas for cooking fuel can result in cost savings. Changing from solid fuels to biogas is the cheapest option (monthly cost of biogas is Tk. 420 compared to monthly cost of biomass fuel is Tk. 1060). In terms of direct cost for cooking with biomass fuels, it is significantly more expensive than cooking with biogas fuels. In terms of indirect cost, biomass fuel gathering can be dangerous as it leaves women exposed to threats of violence, and cooking on traditional stoves is time consuming, preventing women taking on income generating

activities and often making children do not attend school. It is important to note that fuel costs for cooking by using solid fuels and biogas vary, with less efficient solid fuels comprising a significantly higher costs than biogas.

3.4. Need for Adaption of Biogas Digester

Bangladesh is one of the fastest growing economies in the Southern-Asia, with 64% of the total population are living in rural areas (Suntrace, 2018). It has been reported in WHO (2016) that 82% of the Bangladesh population primarily use wood, charcoal, coal, and kerosene for cooking. Bangladesh has a very limited energy reserve; small amount of oil, coal and countable natural gas reserves (Prati et al., 2013). These have become a traded commodity as cooking fuel as access to local biomass becomes ever more difficult. The biomass fuels have been depleted due to tremendous pressure on these fuels. Only about 6% of the entire population has access to natural gas, primarily in urban areas, for cooking. Because of use of limited available gas in industrial production, government has suspended new gas connection for household consumption. Thus, in Bangladesh scenario, biogas can be a substitute for traditional fuels and can meet the rural energy demand and also it can provide a clean source of energy. It is seen from Table 3 that about 56% of the biogas digester adaptors and about 60% of the biogas digester non-adaptors thought that biogas was necessary because of absence of natural gas supply in their areas. About 69% of the biogas digester adaptors and about 71% of the biogas digester non-adaptors felt that biogas production was necessary because of difficulty of collection of fuelwoods. About 42% of the biogas digester adaptors and about 35% of the biogas digester non-adaptors were in favor of installation biogas digester because of excessive cost of fuelwood.

3.5. Feasibility for the Adaption of Biogas Digester

Factors affecting the fermentation process of organic substrates under anaerobic conditions are: (i) pH, (ii) temperature, (iii) loading rate, (iv) agitation, etc. According to different temperature ranges the anaerobic digestion can be classified as psychrophilic (12-30°C), mesophilic (30-45°C), and thermophilic (45-65°C) with anaerobes performing best in mesophilic and thermophilic temperatures (Song et al., 2004; Nges and Liu, 2010; Meena et al., 2011; Gashaw, 2014). Based on the literature reviews mesophilic temperature is most suitable for biogas production in anaerobic digesters systems (Parawira et al., 2008; Phetyim et al., 2015). The methanogenic bacteria, which facilitate the formation of biogas, are very sensitive to temperature changes and the optimum temperature for the bacteria to operate is between 33° and 38°C (Gashaw, 2014). Temperatures below this slow down the biogas production process, while a higher temperature than necessary kills the biogas producing bacteria (Gashaw, 2014). The temperature in which maximum biogas produced is from cow dung is 27.7°C (Otun et al., 2015). Temperature in Bangladesh remains at mesophilic (30-45°C) stage in most of the days of the year except in short duration of winter (December to February). Thus, temperature in Bangladesh is ideal for the anaerobic digestion. It is seen from Table 4 that almost 80% of the respondents believe that the temperature in Bangladesh is suitable for biogas generation.

Construction of biogas digester completely depends on the availability of substrates used for biogas generation. About 85%

Table 3: Need for adaption of biogas digester

Need for adoption biogas digester	Adaptors	Non-adaptors
Insufficient supply of electricity	17.9	26.9
No supply of gas	56.3	60.3
LP gas cylinder is not available	38.9	28.4
Collection of fuelwoods is difficult	69.2	70.6
Fuelwood is very expensive	41.7	35.4
Use of bio-slurry as fertilizer	67.8	32.2
Reduce deforestation	34.2	12.3
Reduce pressure on natural gas	29.7	10.2
Total number of respondents	498	500

Table 4: Feasibility indicators for adoption of biogas digesters

Scope of constructing biogas digesters	Percent
The temperature of Bangladesh is suitable for biogas digesters	80.5
The feedstock for biogas digesters are available from own farm	85.4
Need very small piece of land for biogas digester construction	54.6
Women can maintain biogas digesters	60.0
Feedstocks for biogas digester	
Cow dung	90.8
Poultry droppings	8.9
Others	0.3
Sources of feedstocks	
Own households	98.1
Purchase	1.9
Whether profitable	
Profitable	85.3
Loss project	14.7
Total number of respondents	
Cost of construction of biogas digester (in Tk.)	
<20,000	16.7
20,000-40,000	48.6
40,000-60,000	25.9
More than 60,000	8.9
Average	Tk. 35,111
Impression about installation cost	
Cost is reasonable	60.0
Cost is moderately reasonable	21.0
Cheap	17.0
Very expensive	2.0

Table 5: Attitude of biogas digester adapters towards biogas

Attitudes	Percent
Reasons for the adaption of biogas digester	
Feedstocks are available in own household	47.4
Beneficial for the environment	38.2
Less costly	42.9
Motivation from government and NGOs	11.9
Scarcity of other fuel sources	11.4
Encouraged by other biogas digester adapters	5.9
Others	7.1
Total number of respondents	498
Whether satisfied with the performance of biogas digester	
Satisfied	88.1
Dissatisfied	11.9
Reasons for satisfaction with the biogas digesters	
A profitable investment	16.7
Easy to get benefits	15.5
Easy to maintain biogas digester	44.8
Cheap to cook	72.6
Solid residuals of fermentation can be used as fertilizer	72.6
Beneficial for health	35.6
Upgrade social value	19.9
Benefits for the environment	50.5
Others	7.3
Whether want to advice others to install biogas digesters	
Yes	97.8
No	2.2

in Bangladesh can use co-digestion system. Amount of biogas generation depends on the quantity of new feedstocks added to the digester daily. Almost 98% of the biogas digester adapters collect feedstocks for digester from their own household. Thus, about 85% of the biogas digester adapters believe that feedstocks for biogas generation was available in their own households. Availability and easy access to feedstocks for biogas generation is one of important catalysts for sustainable generation of biogas.

Costs for the setup of biogas digester is another important factor for the adaption of biogas digester. If the cost for setup of biogas digester would not be affordable for the farmers, they would not be interested to adapt the biogas digester. About 17% of biogas digester adapter spent less than Tk. 20000 and about 49% of the biogas digester adapter spent Tk. 20,000 to Tk. 40,000 for setup of a biogas digester. Average cost for setup of a biogas digester was Tk. 35111. The cost for setup of biogas digester is reasonable and farmers can easily afford this amount for construction biogas digester indicating that adaption of biogas digester is feasible in terms of cost. According to 98% of the biogas digester adapters' installation cost of biogas digester in Bangladesh is reasonable or cheap.

3.6. Attitudes of Rural People towards Biogas Digester Adaption

Successful implementation of any innovation is primarily determined by the end users' attitude. The generation of biogas through anaerobic digestion offers significant advantages over other forms of energy production. It has been evaluated as one of the most energy-efficient and environmentally beneficial technology for energy production (Weiland, 2010). It can drastically reduce greenhouse gases emissions compared to fossil fuels by utilizing locally available resources. In spite of its versatile

of the biogas digester adapters believe that feedstocks for biogas diester were available in their own households (Table 4). In about 91% of the biogas digesters used cow dung as substrates for biogas generation and in about 9% of the biogas digesters used poultry droppings as substrate for biogas generation. Cow dung and poultry droppings are available in their own households. Sagagi et al. (2009) utilized fruit and vegetable wastes and cattle manure individually to study their biogas production potential and found that highest wly production rate was in cow dung (1554 cm³ biogas) > other wastes (<1000 cm³ biogas). Organic kitchen wastes co-digested with cattle manure improves the biogas production potential as compared to cattle manure alone (Otun et al., 2015; Abebe, 2017). Consequently, the costs for biogas generation by using cow dung or poultry dropping alone are not favorable due to their relatively low biogas yield in comparison with co-digestion with more biodegradable wastes such as kitchen wastes (Moller et al., 2004; Aragaw et al., 2013). Thus, biogas digester adapters

Table 6: Factors influencing installation of biogas digesters: logistic regression analysis

Variable	Coefficient	Standard error	Wald	P-value	Odds ratio
Age	0.155	0.078	3.924	0.048	1.168
Family size	0.080	0.104	0.587	0.444	1.083
Religion	-0.194	0.387	0.250	0.617	0.824
Education	0.283	0.069	16.596	0.000	1.327
Monthly income	0.158	0.059	7.224	0.007	1.171
Fuel cost	-0.429	0.042	104.716	0.000	0.651
Number of cattle	0.971	0.105	86.191	0.000	2.641
Number of poultry	1.121	0.292	14.732	0.000	3.069
Constant	-4.169	0.700	35.465	0.000	0.015
Chi-square			43.155		
P-value			0.000		
Correctly predicted user			76.4%		
Correctly predicted non-user			84.6%		
Overall percentage predicted			81.1%		

benefits, adaption of biogas digester and use of biogas depend on the attitude of the end users towards biogas. The study results show that biogas digester adapters were interested to setup biogas digester because of easy availability of feedstocks (about 47%), because it is environmentally beneficial (about 38%), and less costly (about 43%). About 88% of the biogas digester adapters were satisfied with the performance of the biogas digester. The reasons for satisfaction were low cooking cost (according to about 73% of the respondents), solid residuals of fermentation might be used as fertilizers (according to about 73% of the respondents), easy to maintain biogas digesters (according to about 45% of the respondents) and benefit for the environment (according to about 51% of the respondents). About 98% of the biogas digester adapters would like to advice others to setup biogas digester (Table 5). All these results indicate that Bangladesh is an ideal place for adaption of biogas digester.

3.7. Factors Influencing Farmers to Adapt Biogas Digesters

Adapting a new technology depends on numerous factors which influence target user to adapt or reject including perceived usefulness, availability of feedstocks, and socioeconomic conditions of the biogas digester adapters. These factors can make a positive or a negative contribution towards new technology adaption. In order to identify the influencing factors for the setup of biogas digesters, binary logistic regression model was employed. The dependent variable was status of biogas digester adaption: $Y=1$ if respondent is a biogas digester adapter and $Y=0$ if respondent is not a biogas digester adapter. A coefficient indicates the impact of each independent variable on the outcome (dependent) variable adjusting for all other independent variables. The Wald statistic is used to assess the contribution of individual predictors or the significance of individual coefficients in a given model. The results of the study presented in Table 6 show that socioeconomic factors such as age, education, monthly family income, and per month cooking fuel cost were significantly contributed to the adaption of biogas digester. Socioeconomic factors determine individual's capacity to obtain information, know-how and perception towards the biogas technology benefits which in flip have an impact on one's decision to adapt biogas digesters. Facilitating factors such as number cattle owned, and number of poultry owned were also significantly associated with the adaption of biogas digester.

The model can help describe the relative contribution of each independent variable to the dependent variable, controlling for influence of the other independent variables. The odds ratio (OR) is a comparative measure of two odds relative to different events. It is a measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure compared to the odds of the outcome occurring in the absence of the exposure. The OR can also be used to determine whether a particular exposure is a risk factor for a particular outcome, and to compare the magnitude of various risk factors for that outcome. $OR = 1$ indicates exposure does not affect odds of outcome, $OR > 1$ indicates exposure associated with higher odds of outcome. $OR < 1$ indicates exposure with lower odds of outcome. The overall fit of the model can be assessed by Chi-square statistic. The value of Chi-square is significant indicating that at least one of the predictors was significantly related with the installation of biogas digester. The high value of sensitivity (76.4%) and specificity (84.6%) indicate a better fit of the model.

4. CONCLUSION

Anaerobic digestion is a renewable energy source which can comfortably replace fossil fuel as an environment friendly process. The increasing demand for renewable energy compels the exploration of the increasing installation biogas digester especially in developing countries like Bangladesh. Biogas production addresses both waste reduction and energy production. The production of biogas is influenced by many factors and prominent among the factors are pH of feedstock, temperature, flow rate of feed and retention time. Temperature suitable for high production biogas is persist in Bangladesh. High potential feedstock for biogas production, cow dung and poultry droppings, are readily available in own households in rural areas of Bangladesh. It is feasible to produce biogas from animal manure with simple equipment and a straight forward procedure. Even women family members can maintain the biogas digesters in Bangladesh. Biogas digester adapters are satisfied with their biogas digester and would like to advice others to adapt biogas digester. The cost for cooking by using biogas is significantly lower than the cost for cooking by using solid fuels. Moreover, the process of biogas production is not merely source of energy, but also used as source of organic fertilizer.

It is observed from the results of the study that Bangladesh is an ideal place to produce biogas. Generation of biogas will meet the increasing demand of energy mainly for cooking and lighting. Biogas production from various wastes through anaerobic digestion technology is growing worldwide and is considered ideal in many ways due to its economic and environmental benefits. In Bangladesh, the use of cow dung and poultry droppings for biogas generation is well established. However, the costs of only cow dung or poultry dropping digesters are not favorable due to their relatively low biogas yield in comparison with co-digestion with kitchen wastes.

Energy policy makers in Bangladesh should encourage farmers to adapt new biogas digesters and to use co-digesting technology. Successful implementation of anaerobic digestion as a method of waste treatment has the potential to change the concept waste into that of a valuable resource which will lead to total utilization of renewable energy resources reducing energy requirement, creating more jobs and income, reducing costs, making it readily available and minimize environmental pollution.

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