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DETERMINATION OF DEMOGRAPHIC AND SOCIO-ECONOMIC FACTORS INFLUENCING CLEAN COOKING FUEL ADOPTION IN RURAL BANGLADESH

D. Shabnam[1] and L. Girling[2*]

[1]Smallholder Agricultural Competitiveness Project (SACP), Department of Agricultural Extension, Dhaka, Bangladesh.
[2] Graduate Institute of International Development, Agriculture and Economics University of Reading, UK

ABSTRACT

Biogas as a clean source of cooking fuel has enormous potential to meet Bangladesh's energy needs. The objective of this article is to identify the factors influence biogas adoption in rural households. The study aimed to look at the policy framework that needs to be put in place to promote biogas adoption as a cooking fuel in the study region. This study collected primary data by interviewing 118 respondents with a structured questionnaire (78 biogas users and 40 non-users) during July-August 2021. Respondents were women who cook for their families regularly. This paper based on a cross-sectional analysis of nine socio-economic and demographic parameters that may influence biogas uptake in Western Bangladesh. The dependent variable, biogas cooking fuel adoption status, was modeled as a dichotomous variable. To evaluate the relationship between independent variables with the dependent variable (biogas user and no-user), bivariate descriptive analysis (t-test for continuous data and chi-square test for categorical data) was performed. Then, a binary regression model was chosen to determine the adjusted effect of independent variables on biogas adoption decisions. The study found that the demographic factors such as income status of the women, education of household head, family size and total family income significantly and positively influence biogas adoption decisions. Contrary to the hypothesis, access to internet and total land area owned by the family show negative relation with biogas cooking fuel adoption status of the household. The outcome of this research added evidence to support energy policy with giving emphasis on subsidy, and adult education in rural areas.

Keywords: Biogas cooking fuel, Adoption decision, Socio-economic factors, Female responders

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[*] Corresponding author: dilrubashabnam29@gmail.com

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INTRODUCTION

Biogas is a renewable energy source created by anaerobic fermentation of organic material of animal or plant origin using organic waste sources to produce combustible methane gas ideal for cooking and lighting. Biogas technology was introduced in Bangladesh in 1972 (Haque, 2008). Biogas is one of the most promising household cooking fuels among the numerous clean biofuels, especially for rural farm families. Aberilla et al. (2020) evaluates the influence of cooking fuel on the environment, and found diesel is the worst option, while biogas from manure is the best, biomass fuels have a life cycle that is up to 47 times shorter than fossil fuels yet have 4-23% larger local environmental impacts A critical analysis conducted by the International Energy Agency revealed that the most cost-effective approach for ensuring universal access to clean cooking facilities in the developing world is compatible with global climate (IEA, 2019). Furthermore, it would directly benefit women, it could save billions of hours currently spent on cooking and gathering fuel wood (Bansal et.al. 2013). Along with the Sustainable Development Scenario (SDS), focus is being paid to what it would mean for the energy sector to achieve net-zero emissions by 2050 globally, termed as NZE 2050 in the World Energy Outlook (IEA, 2020). To accomplish the NZE 2050's pace and scale of emissions reductions, a wide range of interventions would be required.

Biogas has potentials of fulfilling about 10% of energy demand in Bangladesh (Rahman et al., 2018). According to Infrastructure Development Company Limited **(**IDCOL**)** database district wise distribution of biogas plant, biogas is the most rapidly expanding renewable energy source for cooking, but satisfactory biogas installation in rural Bangladesh is yet to be achieved (Islam et al., 2008). The reason behind the scenes is a matter of investigation. Berhe, (2017) found that despite biogas adoption, most households continue to depend on traditional biomass fuel; in fact, energy consumption increases with the availability of biogas. The researcher observes that gas production from each plant is below expectation; even though subsidies make small-scale biogas plants affordable, people can’t entirely rely on them. They use biogas only for simple food making, baking, or coffee preparation. Heavyweight cooking is not suitable for biogas. Different national and international non-government organizations like Grameen Shakti, LGED **(**Local Government Engineering Department**)**, IDCOL are working to disseminate biogas technology in rural areas. However, limited research is found on socio-economic and demographic factors that may positively or negatively influence the adoption behavior of rural households in Bangladesh (Hossain, 2012). This research hypothesis is that demographic and socio-economic factors may catalyze rural families' interest in small-scale biogas installation, which is still unopened. In different countries, determinants for biogas adoption and dissemination are investigated from various other aspects.

MATERIALS AND METHODS

Three districts of western Bangladesh were chosen for the study, namely Meherpur, Chuadanga, and Jhinaidah (Fig. 1). This area is preferred for study as this part of the country is out of National Grid of natural gas. Many rural households in this locality are already using biogas. Therefore, this area was suitable for conducting a comparative study between two groups of rural households (biogas user and biogas non-user). A structured questionnaire was developed/constructed to obtain the desired information from the study target population/sample respondent. The collected data with being categorized concerning demographic and socio-economic factors influence a household's decision for biogas adoption decision.

A questionnaire draft with some open-ended questions was first designed basis on research objectives and literature studies. The questionnaire was pretested by an informal conversation with rural biogas users. From the preliminary observations gained from the conversation, the questionnaire was updated, and thus the variables were chosen for primary data collection.

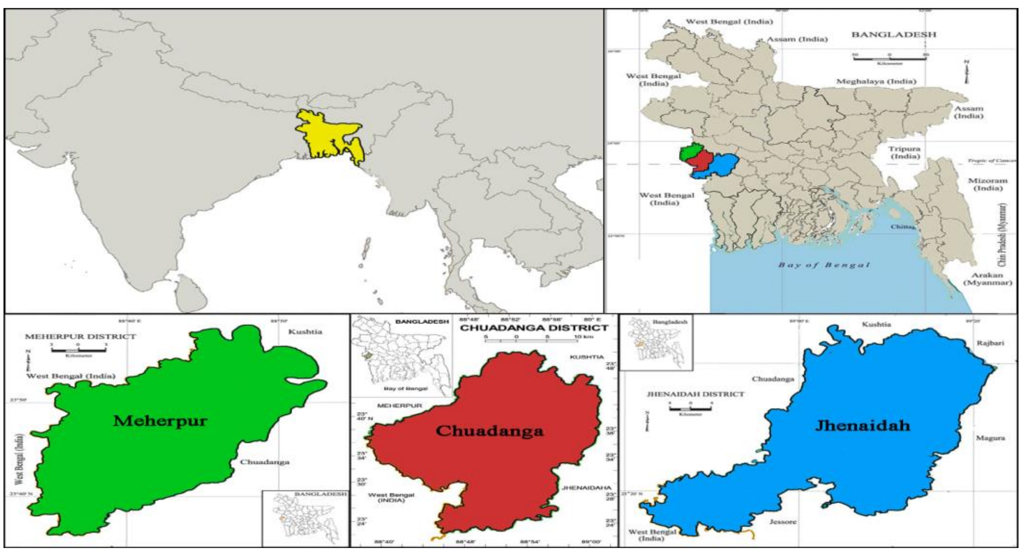

Figure 1. Map of study areas

The Statistical Package for Social Sciences (SPSS) was used for statistical analysis. Data is analyzed into both bivariate and multivariate setups. An independent sample t-test is performed to compare the mean value of continuous variables between two groups of dependent variables. For categorical variables, the chi-square test is considered. Thus, the unadjusted effect of the selected explanatory variables on biogas adoption status was evaluated. Since bivariate analysis fails to explain the adjusted impact of explanatory variables, a statistical model appropriate for a binary response is considered, namely a binary logistic regression model. Firstly, to evaluate the relationship between independent variables with the dependent variable (biogas user and no-user), bivariate descriptive analysis (t-test for continuous data and chi-square test for categorical data) is performed. Secondly, a binary regression model is chosen to determine the adjusted effect of independent variables on biogas adoption decisions.

Table 1. Definition of dependent and explanatory variables

Variables	Description	Values
Dependent variable		
Biogas user group	Biogas adoption status	1= household adopted biogas. 0 = Otherwise
Explanatory Variables		
Res_income (X1)	If the respondence has her own income or not.	1= Respondents has income 0 = Otherwise
Res_HH (X2)	If the respondent is the head of the household or not	1=Respondent is the household head, 0=otherwise
HH_gender(X3)	Sex of household head	1= Male 0=Female
HH_age(X4)	Age of household head	Number of years
HH_edu(X5)	Education level of household head	1=No Formal education 2=Primary education 3=Secondary education 4=Tertiary education
Family size (X6)	How many people live in the residence	The number
Familyincome (X7)	The monthly average income of the family	In Taka
Internet access (X8)	If the family has their own device (mobile phone or computer) and has access to the internet	1=Yes 0=No
Land (X9)	Total land area owned by the family	In Acre

Independent sample t-test

Concerning each socio-economic variable, a contingency table was drawn up. The t-test statistic was used to analyze the contingency table data for continuous variables. It was employed in the analysis to test whether the mean value of explanatory variables were deferring between the biogas adopters and biogas non-adopters.

Chi-square test

As for categorical data, t-test is not suitable, chi-square test was performed for explanatory variables (Respondent's income status, respondent is the household head, gender of household head, education of household head, and internet access).

The regression analysis

The general (linear) regression model is:

$$Y = \beta 0(x) + \beta 1X1 + \beta 2X2 + \ldots\ldots\ldots\ldots + \beta pXp + \mu$$

But, whenever Y is dichotomous, then the linear regression model is not adequate for various reasons. For example, the Linear Probability Model (LPM) is simple to estimate and use but, its most important disadvantage is to provide outcomes of the fitted probabilities less than 0 or greater than 1, i.e., the predicted probabilities are out of range. These limitations of the LPM can be overcome by using a more sophisticated binary response model. Therefore, a binary logistic regression model was used to test the probability of a dichotomous outcome. A set of independent explanatory variables are hypothesized to test the demographic and socio-economic factors influencing biogas adoption. The logistic regression model determining biogas adoption was specified by using the following formula.

$$\frac{Pi}{1 - Pi} = \beta 0 + \beta 1X1i + \beta 2X2i + \ldots\ldots\ldots\ldots + \beta nXni + \mu$$

The subscript i signifies the observation in the i^{th} sample and P denotes the probability of the outcome. If β_1, β_2,…..β_n are the coefficients associated with each explanatory variable X_1,X_2….Xn. β_0 is the intercept. Individual explanatory variables' effects on the log of odds are reflected in the coefficients β_1, β_2,…..β_n . The log of odds increases in lockstep with the related independent variable when the coefficient is positive. Suppose the odds ln (P/1-P) log is positively (or negatively) associated with an independent variable. In that case, the outcome's odds ln (P/1-P) and P are also positively (or negatively) related to that variable. This relationship is linear for the log odds and nonlinear for the odds and probability of the outcomes. P 0.05 was used to declare all analyses significant. Wald statistics and odd ratios have been used to examine the significance of the variables in binary logistic regression. P-value was used to identify the significant level of the variables. Table 1 lists the independent variables used in the logistic regression model for adoption.

RESULTS AND DISCUSSION

Demographic and socio-economic factors are used to model the likelihood of a household's biogas cooking fuel adoption decision. In both uni-variate and bivariate arrangements.

Socio-demographic status of the samples

Table 2 shows a summary of descriptive statistics. The results of the descriptive analysis indicate that regarding respondents' demographics, 48% of total respondents (women) made financial contributions for their families. Only 14% of them are reported as head of the family. Eighty one percent of respondent households are male headed. For level of education of family head, it is revealed that 8 of 118 household heads have no formal education. Nearly half of the total household heads have secondary education. 47% responder of households reported that they have internet access. The mean of household heads' age is 47.51 years, with a standard deviation of 12 years. The mean income is observed to be monthly 12925 BDT with a standard deviation of 12663 BDT.

Fig. 2 shows that Among the 118 households, 44% families reported agriculture is their main income source (small and large-scale farming), for 24.5% households, main income comes from business (refers to earning from manufacturing or trading), 11% families live on day labor (they do not have any specific job, earn money providing daily labor), 20.34% households claimed that their main earning source is service (works under government or non-government organization). Among the respondents whose family income comes from daily labor, 92.3% of them didn't adopt biogas as cooking fuel. A significant proportion who has income sources from service (83.3%) and business (86.2%) are mostly intended to adopt biogas cooking fuel.

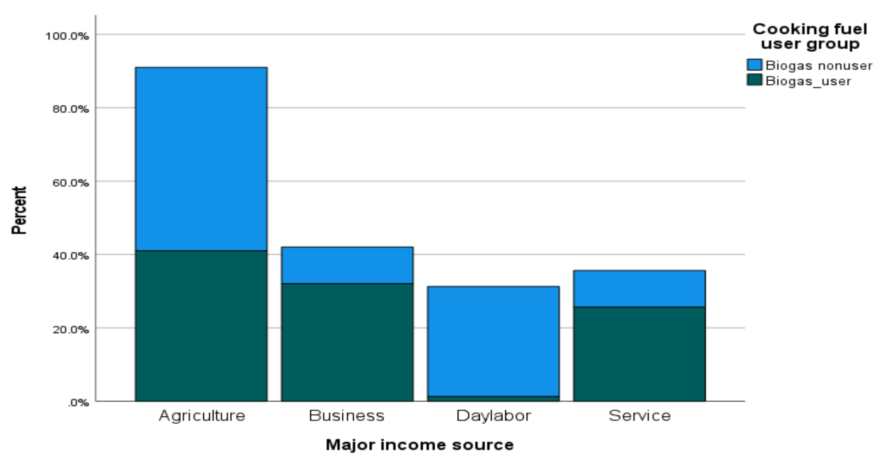

Figure 2. Major sources of income (biogas user and non-user households)

Table 2 presented comparative statistics of households who adopted biogas cooking fuel and households who did not adopt biogas. For continuous variables (age of HH, family size, family income, and land owned by the household) independent sample t-test is performed to compare the mean score of the variables between the two groups. As the independent t-test is not suitable for categorical variables, the chi-square test is chosen for variables like Respondents' income status; the respondent is the HH, gender of HH, education of HH, and internet access. P-value of the independent sample t-test show statistically significant variation for the age of the household head and Family income between the two groups (Table 2). Chi-square test report indicates that Respondents' income status, the respondent is the head of family, gender of HH, access to the internet, and education categories, no education, primary and tertiary level of education for household head show significant influence on the biogas adoption status of the sample households (Table 2).

Table 2. Comparative demographic and socio-economic characteristics of biogas users and non-user households.

Categorical variables	Response category	Biogas Non-user n=40		Biogas user n=78		Chi square test
		Frequency	Percentage	Frequency	Percentage	P-value
Respondent's income	No	29	72.5	32	41	
	Yes	11	27.5	46	59	0.001
Respondent is Household Head	No	39	97	63	81	0.012
	Yes	1	3	15	19	
Gender of Household Head	Female	5	12.5	17	21.8	0.221
	Male	35	87.5	61	78.2	
Education of Household Head	No education	6	15	2	2.6	<0.011
	Primary	16	40	10	12.8	<0.001
	Secondary	18	45	40	51.3	<0.518
	Tertiary	0	0	26	33.3	<0.001
Internet access	No	31	77.5	31	39.7	0.0001
	Yes	9	22.5	47	60.3	
Continuous variables		Biogas non-user, n=40		Biogas user, n=78		T test
		Mean	SD	Mean	SD	P value
Age of Household head		51.90	15.023	44.94	9.69	0.000
Family size		4.83	1.152	4.93	1.085	0.901
Family income (TK)		12925	3924.85	26461.54	10101.68	0.000
Land (acre)		2.16	1.34	2.59	1.16	0.417

The mean value of the age of household head (51.90 years) for biogas non-user is higher than that of the biogas user group (44.94 years). The mean value of Family income for group biogas non-user is estimated as less than half of the mean value of family income for the biogas user group. The magnitude of difference in mean differences for those variables was highly significant with a P< 0.001. The significant variables were respondent's income and education status, family income, age of household head and internet access. Whereas family size and land owned by the household and education level of Household Head secondary show the non-significant difference between the two groups, biogas non-user and user. Descriptive statistics show a significant variation in demographics and socio-economic characteristics between two groups of respondents. However, inferring causality as the result of uncontrollable external factors is challenging (Kinyili et al., 2020). As a result, an econometric study based on a logistic regression model is implied to identify factors influencing the adoption of biogas as a cooking fuel while adjusting for unobserved variables.

Regression analysis

To get the adjusted effect of selected variables for biogas adoption, binary logistic regression model is considered. The result of the binary logistic regression showing the relationship between nine demographic and socio-economic factors on adoption of biogas cooking fuel are shown in Table 3. The variables in the equation were described using B = 0.668, SE = 0.194, Wald = 11.792, P = 0.001 and Exp (1.95).

Table 3. Binary logistic regression showing the relationship between nine socio-economic factors on adoption of biogas cooking fuel.

Variables	Coefficients	SE	Wald	Odd ratio	P value
Respondent's income	4.773	1.547	9.520	118.2	0.002**
Respondent is Household Head	4.602	2.588	3.163	99.67	0.075
Gender of Household Head	2.519	1.974	1.629	12.419	0.202
Age of Household Head	-0.090	0.059	2.326	0.914	0.127
Education of Household Head_	3.139	1.117	7.899	23.076	0.005*
Familysize	1.390	0.718	3.752	4.017	0.05*
Family income	0.001	0.000	13.49	1.001	<0.001***
Internet access	-1.253	1.300	.930	0.286	0.335
Land	-0.631	0.491	1,650	0.532	0.199
Constant	-24.425	7.295	11.487	0.000	<0.001

Number of observations 118
-2 Log likelihood value =32.416
Hosmer and Lemeshow Test chi^2 = .389
Prob. > chi2 (>0.05) Cox and Snell R^2 =0.634

*Indicate significant at 10% level
**Indicate significant at 5% level
***Indicate significant at 1% level
Nagelkerke R^2=0.878

For the logistic regression model, the estimated value for measuring the fitness is found to be good. Measures of goodness of fit of result suggested that the explanatory variables were simultaneously related to the log odds of adoption status. The Cox and Snell R^2 value is 63%, Nagelkerke R_2=88%. The Hosmer and Lemeshow Chi test report suggest that this model is more fit than the traditional Chi-square test, mainly as several continuous variables are considered for the study.

Table 3 presents the results of binary regression analysis, show that respondents' income status, education of Household Head, family size, and family income are statistically significant factors for biogas adoption. The level of significance for these variables are at 5%, 10%, 10%, and 1%, respectively. Respondents' income status was positively related to biogas adoption status of the household. That means if the woman, who works in the kitchen regularly, has her own income, it increases the probability of biogas cooking fuel adoption by 9.52 times compared to the households where the respondents are out of self-income. Respondents' income status has a two-way influence; firstly, as an additional income source, strengthens the household's financial ability to invest in biogas. Secondly, respondents' income is supposed to support her opinion in decision-making for more comfortable cooking fuel. Women are the primary victims of long-term health effects for this arduous activity and smoke in the kitchen because of using harmful fuel sources. If all other circumstances remain constant, women are more interested than males to participate in the biogas plant adoption process (Ghimire, 2005). Therefore, male household head was expected negative effect on biogas adoption status. However, the finding of this study doesn't prove the significant influence of male household head on biogas adoption in the study area. In contrast to this study, Walekhwa et al. (2009) in Uganda, Kelebe, et al. (2017) in Ethiopia, Kabir et al. (2013) in Bangladesh, found that the female-headed households are found to be more likely to use biogas in that study. On the other hand, study by Mwirigi et al. (2014) in Kenya and Mengistu et al. (2016) in Ethiopia, male-headed households were more likely to embrace biogas technology than female-headed households. In conclusion, the impact of gender on biogas adoption status is not consistent, and further research is needed in this area. Education of the HH is a statistically significant factor for biogas adoption decisions. A higher level of education increases the likelihood of biogas cooking fuel adoption by a factor of 23.076. The household head is 1 level higher educated means 7.9 times more likely to adopt biogas cooking fuel. This could be because household heads with no formal education are more likely to be slow to accept new technology. Low literacy levels obstruct the effective flow of information needed to make decisions about new technology (Kelebe et al., 2017). In line of this study several studies highlighted the positive association between education and the adoption of new technology (Kabir et al., 2013). Contrary to them (Walekhwa et al., 2014) reported that the formal education of household heads is negatively related to biogas adoption in Uganda, possible reasons for such result was explained by the researcher. Education system in Uganda is lack of emphasis on hands-on practical training Biogas is seen as a technology for the less educated and those who live in rural areas. Higher educated people are mainly live-in urban regions. Overall studies suggest that only study on education level is not enough to figure out the relation between education and biogas adoption behavior of households, rather it is important to consider education system and social perspectives of study location for that. Data on family size revealed that the average number of family members in the research area is reported to be five. Household size positively influences biogas adoption decision, one person increase in a family member is 3.75 times more likely to adopt. A larger family means more support for cattle and biogas plant maintenance. This criterion is also supported by Walekhwa et al. (2009), who found that bigger household sizes were linked to a higher likelihood of biogas adoption. However, Kabir et al. (2013) found a non-significance relationship between household size and biogas adoption. Family Income is found to have a highly significant ($P<0.001$) positive relation with biogas adoption with the factor of 1.001. Income of the household influences biogas adoption likelihood with a factor of 13.49. As a household's income rises, the likelihood of the household adopting technology is projected to rise because of increased financial capability. Study by Walekhwa, et al. (2014) discovered a consistent income outcome for biogas adoption in Uganda. However, Kelebe et al. (2017) reported that household income does not affect the rate of biogas adoption in Ethiopia. Such result could be due to the existing government subsidies for domestic biogas digester installations. Gwavuya et al. (2012) reported that he government of Ethiopia, SNV2, and other organizations provide subsidy up to 40% of the total construction cost of a biogas digester to increase biogas adoption. Study in Bangladesh revealed that biogas clients would be burdened by investment costs, while subsidies and credit played a critical part in making the decision to adopt a biogas plant (Kabir et al., 2012).

Age of household head, internet access, and land area showed the non-significant effect on biogas adoption in the overall model. Contrary to the hypothesis, this study shows those with no internet access were more likely to be biogas user. It may be due to the internet users are basically the young members of households, who are not responsible for taking decision about cooking fuel. At the same time, a recent study conducted by Rahman et al. (2021) reported that internet access significantly positively affects biogas adoption in Bangladesh. The difference in finding may be due to for different location or pattern of data used in the study.

Though the regression analysis finds age of the household head as a non-significant variable, the mean difference of age between the two groups studied (for biogas user 45years and for non-user 52 years), indicates that household heads of the biogas user group are younger than the non-user group. Whereas Kebele et al. (2017) showed a substantial and positive link between household head age and biogas technology adoption, implying that older household heads are more likely to adopt biogas technology than their younger counterparts. Furthermore, Baiyegunhi and Hassan (2014) in Nigeria, Walekhwa, et al. (2009) in Uganda and Tadesse (2009) in Ethiopia found that they choose clean and safe energy sources as people get older. These discrepancies regarding the correlation of age of household head and biogas adoption behavior, suggests the need for more research.

A biogas plant is an integrated plant unit, cattle shade, kitchen, slurry compost pit; they all need to be close together. That indicated that more extensive landholding would positively influence biogas adoption, but contrary to the hypothesis, this factor found to be non-significant factor for biogas adoption. It may be because the residence plot size is important factor for biogas installation. Therefore, total land area is a less critical factor for biogas adoption behavior in the study area.

CONCLUSION

In Bangladesh the pace of adoption dissemination rate of biogas cooking fuel is low overall. According to the literature, the adoption rate of biogas depends on different factors such as socio-economic, institutional, and policy implementation. In summary, the current study's findings show that that the socio-economic characteristics of the population are significant factors that contribute to the adoption of biogas in the area and finances remain the most significant perceived obstacle. Nevertheless, it is not the sole barrier; instead, it dictates whether or not one can adopt biogas. Therefore, Bangladesh government should integrate biogas program with other rural development and poverty alleviation programs. To penetrate more into poorer section of the society, a massive awareness campaign, a stable subsidy policy as well as group loans without collateral should be one of the strategies for implementation of massive biogas cooking fuel dissemination program.

REFERENCE

Aberilla, J.M., Gallego-schmid, A., Stamford, L. and Azapagic, A. (2020). Environmental Sustainability of cooking fuels in remote communities: Life cycle and local impacts. *Science of the Total Environment,* 713:136445.

Bansal, M., Saini, R.P. and Khatod, D.K. (2013). Development of cooking sector in rural areas in India-A review. *Renewable and Sustainable Energy Reviews,* 17: 44-53.

Berhe, M., Hoag, D., Tesfay, G. and Keske, C. (2017). Factors influencing the adoption of biogas digesters in rural Ethiopia. *Energy, Sustainability and Society,* 7(1), pp.1-11.

Ghimire, P.C. (2005). Final report on technical study of biogas plants installed in Bangladesh. National Program on Domestic Biogas in Bangladesh.

Guta, D.D. (2018). Determinants of household adoption of solar energy technology in rural Ethiopia. *Journal of Cleaner Production,* 204:193-204.

Gwavuya, S.G., Abele, S., Barfuss, I., Zeller, M. and Muller, J. (2012). Household energy Economics in rural Ethiopia: A cost-benefit analysis of biogas energy. *Renewable Energy,* 48: 202-209.

Hossain, M.S., Rahman, M.W., Aziz, A. and Mohammedy, F.M. (2012). Prospect of biogas & Biomass as potential sources of renewable energy in Bangladesh. *International Conference on Informatics, Electronics & Vision (ICIEV)* 1101-1106.

IEA. (2020). World Energy Outlook 2020, IEA, Paris.

IEA. (2019). World Energy Outlook 2019, IEA, Paris

Islam, M.R. and Beg, M.R.A. (2008). Renewable energy resources and technologies practice in Bangladesh. *Renewable and Sustainable Energy Reviews*, 12(2):299-343.

Kabir, H., Yegbemey, R.N. and Bauer, S. (2013). Factors determinant of biogas adoption in Bangladesh. *Renewable and Sustainable Energy Reviews*, 28:881-889.

Kabir, H., Palash, M.S. and Bauer, S. (2012). Appraisal of domestic biogas plants in Bangladesh. *Bangladesh Journal of Agricultural Economics*, 35(454-2016-36351):71-89.

Kelebe, H.E., Ayimut, K.M., Berhe, G.H. and Hintsa, K. (2017). Determinants for adoption decision of small-scale biogas technology by rural households in Tigray, Ethiopia. *Energy Economics*, 66: 272-278.

Kinyili, B.M., Ndunda, E. and Kitur, E. (2020). Socio-economic and institutional factors influencing adoption of agroforestry in Arid and Semi-Arid (ASALs) areas of sub-Saharan Africa.

Mengistu, M.G., Simane, B., Eshete, G. and Workneh, T.S. (2016). Factors affecting households' decisions in biogas technology adoption, the case of Ofla and Mecha Districts, northern Ethiopia. *Renewable Energy*, 93: 215-227.

Mwirigi, J., Balana, B.B., Mugisha, J., Walekhwa, P., Melamu, R., Nakami, S. and Makenzi, P. (2014). Socio-economic hurdles to widespread adoption of small-scale biogas digesters in Sub-Saharan Africa: A review. *Biomass and Bioenergy*, 70: 17-25.

Rahman, M.S., Majumder, M.K. and Sujan, M.H.K. (2021). Adoption determinants of biogas and its impact on poverty in Bangladesh. *Energy Reports*, 5026-5033.

Rahman, K.M., Harder, M.K. and Woodard, R. (2018). Energy yield potentials from the anaerobic digestion of common animal manure in Bangladesh. *Energy and Environment*, 29(8): 1338-1353

Tadesse, T. (2009). Environmental concern and its implication to household waste separation and disposal: Evidence from Mekelle, Ethiopia. *Resources, Conservation and Recycling*, 53(4): 183-191.

Walekhwa, P.N., Lars, D. and Mugisha, J. (2014). 'Economic viability of biogas energy production from family-sized digesters in Uganda', Biomass and Bioenergy, 70: 26-39.

Walekhwa, P.N., Mugisha, J. and Drake, L. (2009). Biogas energy from family-sized digesters in Uganda: Critical factors and policy implications. *Energy policy*, 37(7): 2754-2762.