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RESEARCH PAPER

HOUSEHOLDS' WILLINGNESS TO ADOPT BIOGAS ENERGY IN THE BIRIM NORTH DISTRICT OF GHANA: INSIGHTS FOR LOCAL GOVERNMENTS FOR CLEAN ENERGY PROMOTION

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ABSTRACT
Rural Ghana has potential for widespread use of biogas energy by households, which would contribute to the achievement of UN's Sustainable Development Goal 7 (affordable and clean energy). However, knowledge of households' willingness to adopt it is still scanty. Therefore, this paper examines socio-economic factors that may influence the willingness of households in the Birim North District of Ghana to adopt biogas energy for cooking. Using survey data, the study analyses the effects of gender, age, education and occupation of household heads, household size, type of energy currently used for cooking, household expenditure on energy for cooking, income and prior awareness on willingness to adopt biogas. Data were collected from a random sample of 392 households, and analysed using chi-square and multiple binary logistic regression methods. With the exception of education, all the socio-economic variables stated above have significant effects on households' willingness to adopt biogas technology. However, the exact nature of the influence of these variables (i.e. whether negative or positive) does not necessarily conform to what pertains elsewhere. The findings provide local governments and other stakeholders with relevant insights to properly target households with appropriate educational and marketing strategies for biogas adoption.

Keywords: biogas technology; renewable energy options; socio-economic factors; Birim North District

INTRODUCTION

The UN's Sustainable Development Goal 7 (SDG7) seeks to "Ensure access to affordable, reliable, sustainable, and modern energy for all" (The World Bank, 2016, 14). However, billions of the world's population still depend on unprocessed, solid biomass fuel for cooking and heating (Ikonya, 2018; Karimu, 2016). This has exacerbated the problems of deforestation and greenhouse gas (GHG) emissions (Wachera, 2014) health hazards (Doghle, 2018), and environmental hazards associated with climate change (Panwar et al., 2011). In addition, fuelwood gathering, fire-making process and cleaning of soot-covered cooking utensils consume the labour time of women and the study time of children (Uhunamure et al., 2017)

Approximately 60% of Ghana's population relies on fuelwood for cooking, and biomass fuel consumption is twice as high as other energy sources (Armah et al., 2015; Doghle, 2018), contributing to the country's deforestation rate of about 2% per annum (Mensah et al., 2017). Meanwhile, the Metropolitan, Municipal and District Assemblies (MMDAs) are unable to effectively manage waste (Kyere et al., 2019) which includes 67% organic matter, of which 79% is food waste (Seshie et al., 2020) Therefore, biogas technology presents an opportunity for MMDAs to simultaneously promote clean energy and manage municipal waste more effectively (Doghle, 2018). The government's attempt to promote biogas began in the 1980s but this has been largely unsuccessful due to technological and dissemination challenges (Arthur et al., 2011; Bensah & Brew-Hammond, 2010) and limited involvement of MMDAs.

Although considerable research has been conducted on the prospects, successes, actual adoption, setbacks and other aspects of biogas technology (Arthur et al., 2011; Bensah & Brew-Hammond, 2010; Doghle, 2018), little is known about the willingness of rural households in Ghana to adopt it. Understanding households' willingness would help policymakers to design effective strategies to promote the technology. Therefore, the aim of this paper is to analyse households' willingness to switch from wood fuel to biogas, and whether this willingness is influenced by their socio-economic characteristics. The study site is the Birim North District, Eastern Region, where over 86% of households rely on firewood and charcoal for cooking (Ghana Statistical Service, 2014).

LITERATURE REVIEW

Understanding Biogas Technology and its Uses

Biogas is a colourless flammable gas produced through anaerobic breakdown of organic matter such as domestic waste, human and animal excreta, biomass, agricultural residue and food waste (Biswas et al., 2011; Sawyerr et al., 2019). It can be produced artificially in air-tight digesters designed to facilitate anaerobic digestion of organic matter (International Renewable Energy Agency (IRENA), 2015). The methane gas produced through this process can be combusted directly in conventional low-pressure gas burners for cooking and heating purposes (Gautam et al., 2009), or transported directly to a kitchen or stored in a floating drum storage, gas cylinder, gas bag or pressure tank.

Biogas is a cleaner, eco-friendlier and more sustainable source of energy than fuelwood. Its usage can reduce the rate of vegetation loss and GHG emission (Bensah & Brew-Hammond, 2010; Doghle, 2018)It is a means to address the waste management challenges that have bedevilled local governments in low-income countries and a source of organic fertilizer for farming (Rota et al., 2019; World Bioenergy Association, 2013). Moreover, the technology involved is said to be simpler (Ikonya, 2018) and cheaper (World Bank Group, 2014) than other energy sources like electricity and liquefied petroleum gas (LPG). It is also more time-saving, cleaner, healthier and renewable, compared to fuelwood and charcoal (Gautam et al., 2009). Despite these benefits, adoption of the technology in the developing world has been rather slow as most households prefer fuelwood (Surendra et al., 2011).

Although many developing countries have the potential to adopt and use biogas technology, most have either refused or are unable do so due to some of the barriers mentioned earlier (Bensah et al., 2015). Ghana is well endowed with a wide variety of organic material that can be used in anaerobic digesters as a feedstock for biogas production, which are categorised into *farm-based* and *biodegradable municipal* waste (Daniel et al., 2014). Farm-based waste includes crop residue, manure and other forms of animal waste while biodegradable municipal waste emanate from residential, industrial, commercial and institutional sources (see Figure 1).

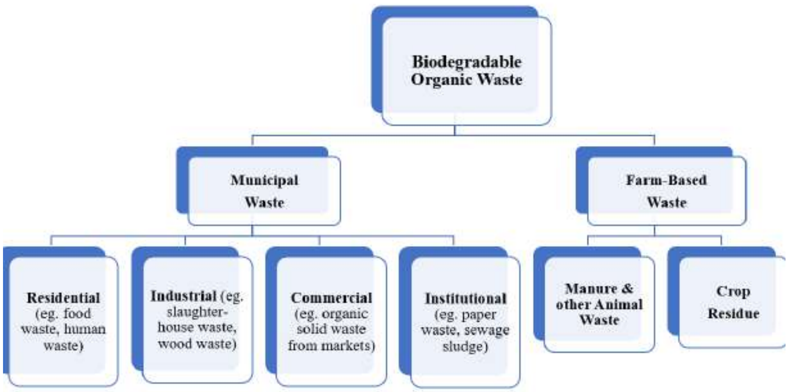

Figure 1: Categories/Sources of Biodegradable Organic Material

The Energy Ladder Model

The low level of clean energy usage and willingness of households to adopt biogas in Africa could be understood through the Energy Ladder Model. In this study, we adopt the model as a conceptual lens to explore the transitioning of rural households from traditional to modern energy sources and the factors that shape their willingness to adopt modern energy forms. The model likens household energy choices to the steps (rungs) of a ladder (Hosier, 2004; World Health Organization, 2006).

On the lowest rung of the ladder is the use of crop waste and animal dung in their raw state, from which households gradually move towards the use of firewood and charcoal, coal and kerosene, and, ultimately, technologically sophisticated energy forms such as LPG, natural gas and electricity on the upper rungs (Hosier, 2004) (see Figure 2).

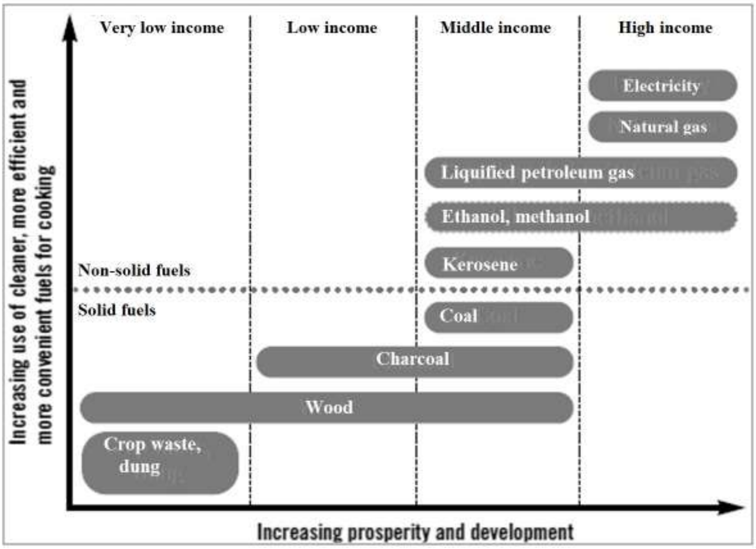

Figure 2: Illustration of the Energy Ladder Model (World Health Organization, 2006)

Generally, there is a positive correlation between the cleanliness, efficiency and cost of each fuel type, and its position on the ladder. Some scholars have divided the energy ladder climbing process into three phases: primitive, transition and advanced (van der Kroon et al., 2013). According to them, households rely on animal dung, agricultural waste and firewood at the primitive phase; charcoal, coal and kerosene at the transition phase; and LPG and electricity at the advanced phase. While households in developing countries are still in the process of making the transition, it is claimed that those in developed countries went through a similar transition as part of their industrialization process (Hosier, 2004). That is, the model does not only relate to 'levels' of household energy choices but also changes in levels of socio-economic development of nations and income status of households. Thus, as households earn higher incomes, they replace traditional, solid energy with modern non-solid sources to reflect their new status.

Although the energy ladder model is useful and central to explaining the energy choices of households, the reality of the energy transitioning process at the household level does not always follow a neatly linear progression as depicted by the model. For instance, do households necessarily have to step on all the rungs of the ladder? Is it not possible for some of them to leapfrog—e.g. from firewood to LPG without ever using charcoal, coal or kerosene for cooking? This can be done through aggressive government interventions. It is also possible for some households to descend the ladder for fuel types that are inferior to what they used before. For instance, in rural Ethiopia, Mengistu et al. (2016) report of a reverse energy transition in which households resort to cow dung, crop residues and other inferior fuels because of growing scarcity of fuelwood. It has also been established that the rungs in the household energy transitioning process sometimes overlap. Instead of substituting a lower type of fuel for a higher one entirely, households often embark on what Masera et al. refer to as "fuel stacking'' (Masera et al., 2000) In fuel stacking, households continue to use their old 'inferior' fuels (e.g. as backup) while adopting more advanced types. In other words, instead of making a total switch from one fuel to another, households create a portfolio of energy options that include fuels from both lower and upper rungs of the ladder (van der Kroon et al., 2013).

Local Governments and Renewable Energy Promotion

In Ghana, the promotion of biogas is currently centralised, with national level institutions such as the Ministry of Energy (MoE), Energy Commission (EC) and the Environmental Protection Agency (EPA) leading the effort. The legal framework establishing the conditions for the use of renewable energy has been enacted since December 2011—the Renewable Energy Act, 2011 (Act 832). In addition, the Ghana Renewable Energy Master Plan (REMP) has been prepared to, among other objectives, increase the share of renewable energy in the nation's total energy generation mix from 42.5 MW in 2015 to 1363.63 MW by 2030 (Energy Commission, 2019). However, realisation of this modest objective is daunting due to institutional, regulatory and economic challenges. A key setback discussed in the local literature has been the slow and/or limited involvement of the MMDAs.

Local governments are increasingly becoming pivotal in policy formulation and implementation due to the belief that decentralized authorities are closer to and understand the needs of citizens than central governments. Accordingly, Ghana's local governance reforms have been carried out on the premise that the MMDAs understand the needs of citizens better and can work with them to deliver responsive development (Ayee, 2004, 2008; Chikulo, 2007). According to the Local Governance Act, 2016 (Act 936), the MMDAs are responsible for the overall development of their respective jurisdictions, which includes natural resource management and renewable energy promotion (Republic of Ghana, 2016). In spite of their pivotal role in local development, MMDAs have been slow in working towards the adoption and/or promotion of biogas. For instance, Metropolitan Assemblies with large engineered landfills have shown little interest in landfill gas capture and energy recovery (Daniel et al., 2014).

Study Hypotheses

Although the positive correlation between household income and their fuel choice implied by the Energy Ladder Model is empirically confirmed, the linkage is not always as strong as the model portrays (van der Kroon et al., 2013). Household income may not be the only determinant of the switch from one form of energy to another (Mengistu et al., 2016). In this study, we seek to ascertain whether there are other socio-economic factors that influence households' willingness to switch from wood fuel to biogas. Socio-economic variables considered include gender, age, education and occupation of household heads; household size; main source of energy for cooking; household income; household expenditure on energy for cooking; and household head's prior awareness about the technology. Several studies have found these factors do influence *actual adoption* of biogas and other environmentally-friendly goods in other parts of the world. For instance, compared to men, women are known to exhibit more environmentally-friendly attitude and behaviour (Fernandez-Manzanal et al., 2007; Liobikiene & Juknys, 2016) but are less likely to adopt biogas technology (Mbali et al., 2018; Walekhwa et al., 2009). Also, while Mbali et al. (2018) found a negative correlation between the age of household head and biogas adoption, Walekhwa et al. (2009) and Hafeez et al. (2017 found a positive correlation.

Other socio-economic variables that are found to influence actual adoption of biogas or other environmentally-beneficial goods include: educational level of household heads (Shallo et al., 2020) expenditure on traditional energy sources (Walekhwa et al., 2009); and prior awareness about those goods (Collart et al., 2010; Liebe et al., 2011). Thus, with regards to existing literature, this study has been conducted based on the following null ($\boldsymbol{H}_o$) and alternative ($\boldsymbol{H}_a$) hypotheses:

$\boldsymbol{H}_o$: Socio-economic characteristics of households do not influence their willingness to adopt biogas technology.

$\boldsymbol{H}_a$: Socio-economic characteristics of household influence their willingness to adopt biogas technology.

METHODS

Description of Study Area

Located between latitudes 6°11'43"N and 6°32'26"N and longitudes 0°49'7"W and 1°8'22"W, the Birim North District is one of the 33 districts in the Eastern Region of Ghana (see Figure 3). The district lies within the semi-equatorial climatic zone of Ghana with a mean temperature ranging between 26 °C and 27 °C and annual total rainfall ranging between 1,500 mm and 1,600 mm. The vegetation type is moist semi-deciduous forest (The Urban Associates Limited, 2019). The district is also endowed with a number of forest reserves that need to be protected from depletion through increased use of fuelwood because, among other functions, the forests help to protect several rivers and streams and maintain the natural ecological balance (see Figure 3).

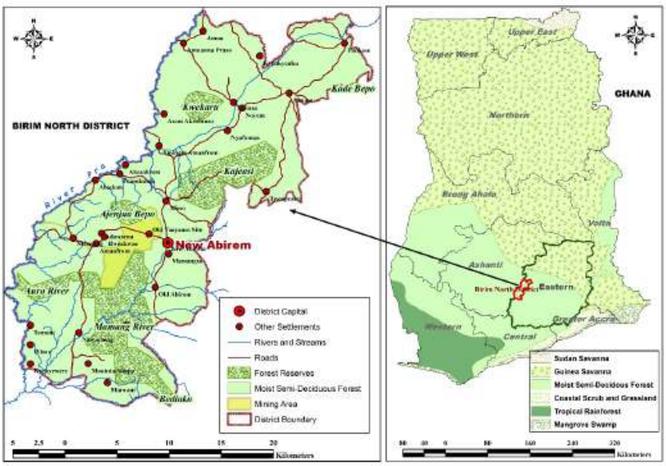

Figure 3: Map of Birim North District showing Settlements, Vegetation, Rivers and other features (Source: Drawn by Authors, July 2021)

According to available census data, the population of the district increased steadily from 27,096 in 1970 to 55,264 in 2000 and 78,907 in 2010, of which over 73% was rural. As of 2010, over 53% of its labour force was employed in the agricultural sector while the remaining 47% engaged in service and industrial activities (Ghana Statistical Service, 2014). Predominant agricultural activities include the cultivation of oil palm, cocoa, plantain, cocoyam, corn and cassava. The district is also home to a 1,990-hectare gold mine owned by Newmont Golden Ridge Ltd, the largest gold mining company in Ghana (The Urban Associates Limited, 2020). Since 2010, the company's mining operations have generated direct and indirect employment to both local residents and migrants. Oil palm processing, logging and illegal small-scale mining also thrive in the district.

Extensive use of firewood and charcoal for domestic cooking, together with crop farming, mining and logging, poses a major threat to the district's natural environment. In 2010, about 61% of households used firewood while another 25% used charcoal as their main sources of energy for cooking (Ghana Statistical Service, 2014). It is, therefore, imperative that the Birim North District Assembly and other stakeholders take measures to promote environmentally-friendly sources of energy like biogas.

Research design

The paper is based on a survey involving a random sample of 392 households. Since the main dependent variable of the study (i.e. willingness to adopt biogas) was categorical in nature, the central parameter of interest took the form of a *proportion*. Accordingly, the sample size was computed as 384 using the following formula, which is designed for making inferences about unknown population proportions (Agresti & Finlay, 2014):

$$\boldsymbol{n} = \boldsymbol{\pi}(\mathbf{1} - \boldsymbol{\pi})\left(\frac{\boldsymbol{Z}}{\boldsymbol{e}}\right)^{\mathbf{2}}$$

where

n = sample size;

Z = 1.96 = the standard normal variate (z-score) based on a 95% confidence level;

$\boldsymbol{\pi}$ = the unknown population proportion, which was taken as 0.5 in order to maximize $\boldsymbol{\pi}(1-\boldsymbol{\pi})$; and

e = 5% = margin of error.

To account for the possibility of non-response and missing data, the computed sample size of 384 was inflated by 5% to 404 households, which represented 2.2% of the district-wide target population of 18,511 households. The adjusted sample size was then distributed proportionally among 21 randomly selected communities. Considering that the mean number of households per house in the district was about 1.1 (Ghana Statistical Service, 2014), the maximum number of households selected per house was one. In each of the sampled communities, the systematic random sampling technique was used to select houses. In situations where a house had two or more households, those households were assigned numbers and one of them was selected using the simple random sampling technique. The survey, which took place in February 2020, was conducted using a questionnaire designed to collect data on demographic characteristics of households and household heads, household income and expenditure patterns, sources of energy for cooking, awareness about the environmental, health and economic benefits of biogas, and willingness to adopt biogas as an alternative source of energy for cooking. In the end, 392 household heads responded to the survey, which represented 102% of the computed sample size.

Variable description

The outcome variable in this study was willingness to adopt biogas technology, which was assumed to be influenced by nine explanatory variables as previously hypothesised. The name, description, type and measurement of each variable are presented in Table 1.

Table 1: Description of Variables

Variable Name	Variable Description	Variable Type/Measurement
Outcome Variable:		
willingness	Is household head willing to adopt biogas as alternative source of energy for cooking?	Dichotomous (Yes = 1, No = 0)
Explanatory Variables:		
female	Is household head a female?	Dichotomous (Yes = 1, No = 0)
age	Age of household head	Continuous (measured in years)
education	Did household head complete at least Junior High School?	Dichotomous (Yes = 1, No = 0)
farmer	Is household head a farmer?	Dichotomous (Yes = 1, No = 0)
household	Household size	Continuous (measured as number of people in household)
firewood	Is firewood the main source of energy for cooking	Dichotomous (Yes = 1, No = 0)
income	Monthly household income	Continuous (measured in GHS '000)
expenditure	Monthly household expenditure on energy for cooking	Continuous (measured in GHS '000)
awareness	Did household head have prior awareness about biogas technology at the time of the survey?	Dichotomous (Yes = 1, No = 0)

(Source: Authors' Construct, February, 2020)

Analysis

Correlations between the outcome variable and the explanatory variables were analysed using Chi-Square and binary logistic regression methods. The Chi-Square tests were conducted to ascertain the statistical significance of observed associations between the outcome variable and each of the explanatory variables based on an alpha (significance) level of 0.05. Binary logistic regression was used to determine the nature and significance of the effect of each explanatory variable on the outcome variable while controlling for the other explanatory variables. The logit (logistic regression) model, which estimates the log-odds of the outcome variable at given values of the explanatory variables, is of the form:

$$\ln\left[\frac{p}{1-p}\right] = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_k X_k \text{ ...... (1)}$$

where

p = the '*success*' probability *P(willingness = 1)* at a given value of predictor X_i

α = the intercept

β_i represent coefficients of explanatory variable X_i, i=1,2,3,…,*k*

The above model also implies that the probability of a given respondent having the willingness to adopt biogas technology can be computed by taking the antilog of both sides of equation (1) and solving for $\boldsymbol{p}$ as shown in equation (2):

$$p = \frac{e^{\alpha+\beta_1 X_1+\beta_2 X_2+\beta_3 X_3+\cdots+\beta_k X_k}}{1+e^{\alpha+\beta_1 X_1+\beta_2 X_2+\beta_3 X_3+\cdots+\beta_k X_k}} \quad \ldots\ldots. (2)$$

All significance tests in the regression analysis were based on an alpha level of 0.05 as stated previously. STATA, SPSS and MS Excel were the main software used in the analysis.

RESULTS

Characteristics of Respondents

As Table 2 shows, most (63.0%) of the household heads who were surveyed in this study were males. This is consistent with the general situation in the study district, and for that matter Ghana, where most households are headed by men (The Urban Associates Limited, 2019). It is also a reflection of the patriarchal nature of the social structure of African traditional societies where decision-making power is concentrated in the hands of men (Geleta, 2018; Munemo, 2017)**.** The mean age of household heads was 52.1 years for males and 54.0 years for females. Also, most household heads were farmers (60.7%) with low levels of education—only 42% of them had attained middle/junior high school education or higher. Mean monthly household income was GHS 577.40 out of which GHS 11.46 was spent on energy for cooking.

Table 2: Descriptive Statistics

Variable	Proportion/Mean
Gender/Age of Household Head, Household Size (n = 392):	
Males	63.0%
Females	37.0%
Mean age	52.9 years
Mean household size	6.3
Level of Education (n = 392):	
No formal education	30.1%
Primary School	27.8%
Middle/Junior High School or higher	42.1%
Main Occupation and Income (n = 392):	
Farming	60.7%
Trading	18.9%
Other	15.1%
Retired	5.3%
Mean monthly household income	GHS 577.40
Mean monthly expenditure on energy for cooking	GHS 11.46
Main Source of Energy for Cooking (n = 392):	

Firewood	53.1%
Charcoal	30.4%
Liquified petroleum gas (LPG)	10.2%
Electricity	6.4%
Prior Awareness about Biogas Technology (n = 392):	
Yes	65.3%
No	34.7%
Willingness to adopt Biogas as Alternative Energy Source (n = 392):	
Yes	44.6%
No	55.4%

(Source: Authors' field survey, February, 2020)

Determinants of Willingness to Adopt Biogas

The data show that majority of households depended on firewood (53.1%) and charcoal (30.4%) as their main sources of energy for cooking, with the remaining 16.5% depending on either LPG or electricity. Although 65.3% of the respondents had prior awareness of the existence and benefits of biogas, only 44.6% of them indicated that they were willing to adopt the technology (see Table 2). This was consistent with the fact that over 75% of them were satisfied with their current sources of energy. But, could their willingness to adopt biogas be influenced by their socio-economic characteristics and awareness about the technology? To ascertain this, chi-square and multiple binary logistic regression analyses were conducted.

Chi-Square analysis

The results show an association between the gender of household heads and their willingness to adopt biogas for domestic cooking. The proportion of male respondents (about 54.1%) who were willing to adopt the technology was much higher than that of female respondents (28.8%) and the association had a Pearson Chi-Square of 23.7 with a p-value of 0.000 (below the alpha level of 0.05). That is, willingness to adopt biogas is higher among men than women despite the fact that women bear a greater burden of the drudgery and health hazards associated with the use of firewood and charcoal for cooking.

The analysis shows further that, generally, younger household heads were more willing than older ones to adopt biogas as an alternative source of energy for cooking. For instance, among household heads who were aged 45 years or younger, about 61% were willing while the remaining 39% were unwilling to adopt biogas. This contrasts sharply with those aged above 70 years of whom less than 23% were willing and 77% were unwilling to adopt biogas (see Figure 4). The association between age and willingness had a Pearson Chi-square of 26.8 and a p-value of 0.000 (less than the alpha level of 0.05). It can therefore be inferred that, within the study population, a negative correlation exists between age and willingness to adopt biogas technology.

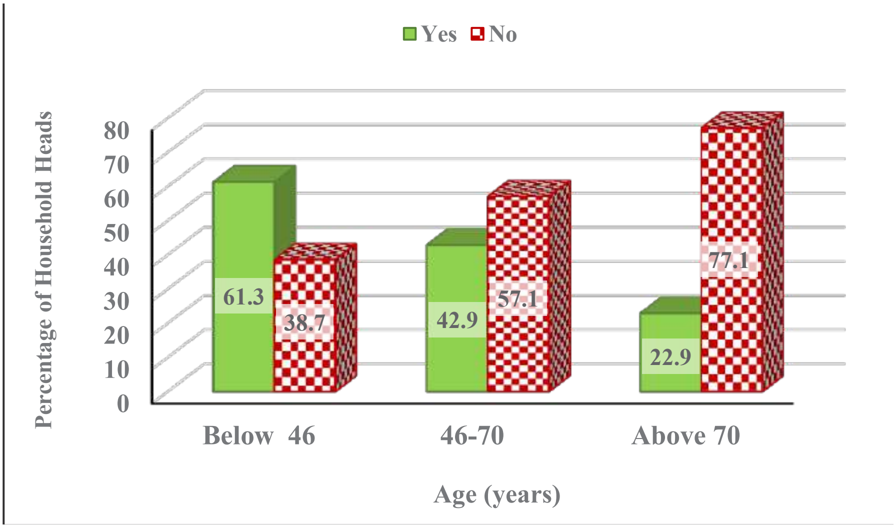

Figure 4: Willingness to adopt Biogas by Age (Source: Authors' field survey, February, 2021)

The level of education of household heads positively and significantly correlates with their willingness to adopt biogas with a Pearson Chi-Square of 38.4 and p-value of 0.000. For instance, only 25% of household heads who had never had formal education were willing to adopt biogas while the corresponding percentages for those with Middle/Junior High School and Secondary/Senior High School education were 56% and 71%, respectively (see Figure 5).

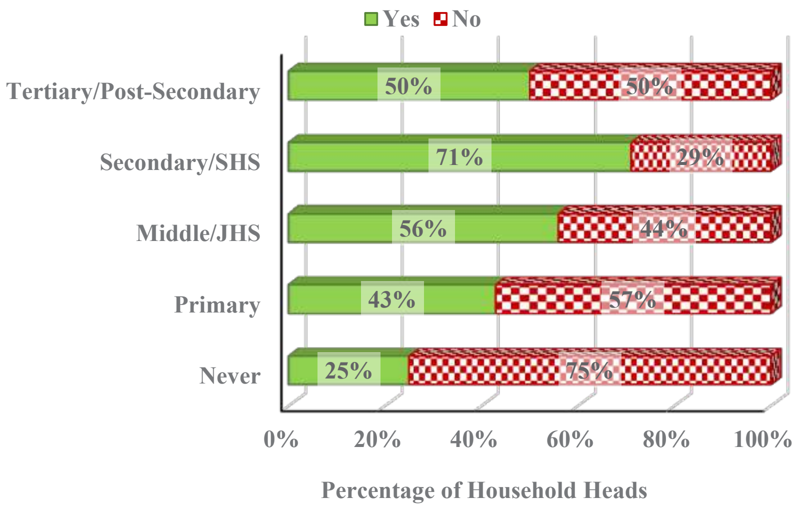

Figure 5: Willingness to adopt Biogas by Level of Education
(Source: Authors' field survey, February, 2020)

The data also show a significant association between occupation and willingness to adopt biogas with a Pearson Chi-Square of 6.5 and a p-value of 0.011. For instance, the proportion of farmers willing to adopt the technology was only 40%, compared to 53% of non-farmers. It is also worth noting that an overwhelming majority (92%) of households that depended on firewood were farm households. Since, in the study district, firewood is usually fetched from the farm or forest for free, it was found to be the cheapest source of cooking fuel available to farm households. In contrast, about 90% of non-farm households used improved fuels such as charcoal and LPG, instead of firewood. It is, therefore, inferred that non-farm households in the district have a higher propensity to shift to improved energy technologies than farm households.

There is also a positive correlation between household size and willingness to adopt biogas as the heads of smaller households were more likely to be willing to adopt the technology than those with larger households (see Figure 6). The Pearson Chi-Square statistic for this association was 24.5 with a p-value of 0.000. It was found that small households were nuclear families, renting or living in detached or semi-detached houses with exclusive use of kitchen facilities, where the use of biogas technology would be relatively easier. However, larger households (with 7–12 members), mostly had extended family members (nephews; nieces, aunties etc.) who lived in compound houses, where most spaces were shared with other households. In such environments, installation of biogas technologies may be difficult.

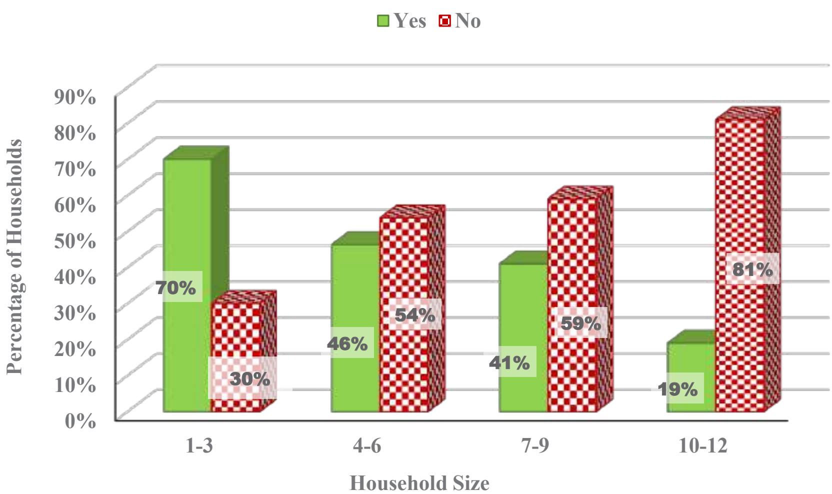

Figure 6: Willingness to adopt Biogas by Household Size
(Source: Authors' field survey, February, 2020)

Respondents' current source of energy for cooking were found to significantly relate with their willingness to adopt biogas, with a Pearson Chi-Square of 8.0 and a p-value of 0.005. As expected, those who used firewood as their main energy source for cooking were less willing to adopt the technology than those who used other sources. This could be attributed to the slow processes rural households go through in accepting new technologies. They questioned their ability to adopt and use the technology; as well as the cost of maintaining its use. Households that had been able to shift from traditional energy sources were therefore more open to better technologies, when it was well-explained to them. For instance, the proportion of respondents who said they were willing to adopt biogas technology was only 38% among firewood users and 52% among non-firewood users.

The data show a marginally significant positive correlation between household income and willingness to adopt biogas, with a Pearson Chi-Square of 5.8 and a p-value of 0.053. That is, higher income earners were more likely to adopt biogas than lower income earners. This was expected as higher income households have been associated with improved socio-economic status on the Energy Ladder Model (van der Kroon et al., 2013). Lower income households are seen as being at the "primitive phase" on the energy ladder, and are yet to move to the "transition phase" (Hosier, 2004). In addition, there is a significant positive correlation between willingness to adopt biogas and the percentage of household income spent on energy for cooking. For instance, only 13% of those who did not spend money on energy for cooking were willing to adopt biogas while 35%–92% of those who spent money on energy for cooking were willing to do so (Figure 7). A test on the relationship yielded a Pearson Chi-Square of 65.2 with a p-value 0.000. This finding points to the cost of adopting new energy sources as a factor for households' willingness to shift up the energy ladder. Thus, households within the "transition phase", who have started spending on improved energy sources are likely to move faster up the energy ladder, as shown in Figure 6, where the higher the proportion of household income spent on energy, the more willing it is to adopt biogas technology.

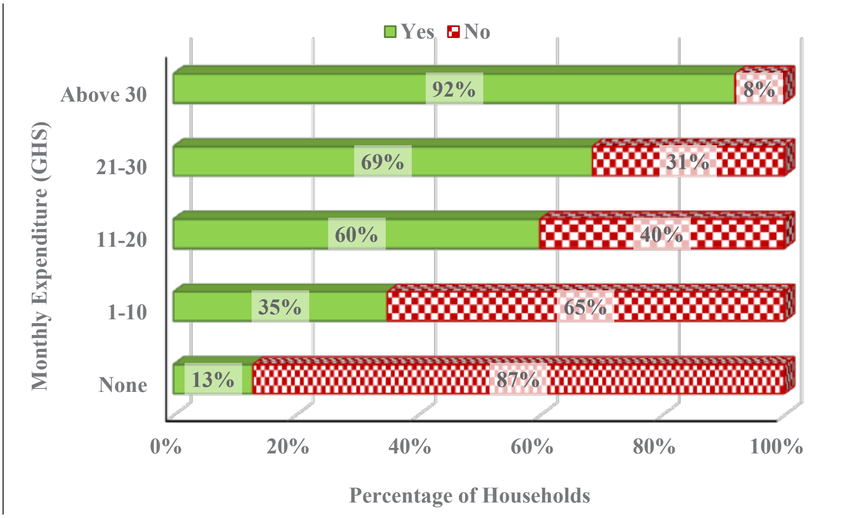

Figure 7: Willingness to adopt Biogas by Monthly Expenditure on Energy for Cooking (Source: Authors' field survey, February, 2020)

As expected, the data show that awareness about biogas is highly correlated with willingness to adopt it. Those who had prior awareness about the existence and/or benefits of the technology were more willing to adopt it than those who were unaware at the time of the survey. For instance, 63% of those who were aware were willing while only 11% of those who were unaware were willing to adopt the technology. The strong association between awareness and willingness is evidenced by a high Pearson Chi-Square value of about 95.2 with a p-value of 0.000.

Logistic Regression

The preceding bivariate analysis suggests that household heads' willingness to adopt biogas as an alternative source of energy for cooking is significantly associated with all the nine (9) predictor variables (*gender, age, education, farmer, household size, firewood, expenditure, income* and *awareness*). But, does the relationship between each of these predictors and the outcome variable (willingness) remain individually significant when the other variables are controlled for? This question is addressed by conducting a multiple binary logistic regression analysis. Table 3 shows two logistic models, Model 1 and Model 2. Model 1 includes the full list of nine (9) predictors stated above. Diagnostic tests for linearity using the STATA software's "*boxtid logit*" command revealed that the continuous variable *income* is not linearly related to the *log odds* of the outcome variable. This assumption violation was corrected by transforming the said predictor into a new variable named *income_2*, which is defined as the inverse of the square of the original variable—i.e. $income\_2 = income^{-2}$. In addition, diagnosis tests for variance inflation factor (VIF) shows no serious problem with multicollinearity among the predictors, which have individual VIFs ranging between 1.03 and 2.20. These are below the recommended threshold of 2.5 for logistic regression (Senaviratna & Cooray, 2019).

Table 3: Logistic Regression Models to Establish the Association between the Nine Predictors and Households' Willingness to Adopt Biogas.

Predictors	Model 1			Model 2		
	Coefficient	Wald Statistic	Odds Ratio	Coefficient	Wald Statistic	Odds Ratio
constant	1.358* (0.776)	3.067	3.890	1.205* (0.747)	2.600	3.336
female	-1.290*** (0.349)	13.657	0.275	-1.167*** (0.307)	14.403	0.311
age	-0.044*** (0.012)	13.064	0.957	-0.044*** (0.012)	13.208	0.957
education	-0.257 (0.336)	0.583	0.774	--	--	--
farmer	-0.943** (0.415)	5.161	0.390	-0.941** (0.416)	5.116	0.390
household	-0.308*** (0.060)	26.456	0.735	-0.304*** (0.060)	25.988	0.738
firewood	0.793** (0.410)	3.735	2.209	0.835** (0.407)	4.204	2.305
expenditure	0.114*** (0.021)	28.481	1.121	0.114*** (0.021)	28.647	1.121
income_2	0.011*** (0.004)	6.776	1.011	0.011*** (0.004)	6.577	1.011

awareness	2.613*** (0.357)	53.558	13.634	2.540*** (0.342)	55.065	12.674
Log likelihood	-161.2953	--	--	-161.5901	--	--
Likelihood Ratio Chi-Square	216.33***	--	--	215.74***	--	--
Pseudo R-Square	0.4014	--	--	0.4003	--	--
n	392	--	--	392	--	--

* p≤0.10; ** p≤0.05; *** p≤0.01; Standard Errors are in parentheses

Model 2 excludes the predictor *education*, which has an insignificant coefficient in Model 1. The predictive power of this variable, and therefore its significance in the logistic model, was assessed further based on the test statistic *2[(log-likelihood of Model 1) – (log-likelihood of Model 2)]* (Chatterjee & Hadi, 2012). The statistic, which measures the difference in log-likelihood between Model 1 and Model 2, has a Chi-square distribution with 1 degree of freedom (i.e. the number of predictors being assessed). The computed test statistic is 0.59, which is far less than the critical value of 3.84 based on an alpha level of 0.05 in the Chi-square distribution. This confirms that the variable *education* does not significantly improve the predictive power of the logistic model. This conclusion is also confirmed by results of AIC and BIC tests.

The appropriateness of the eight (8) remaining predictors in specifying Model 2 was confirmed using STATA's "*linktest*" command to diagnose a possible specification error. The test regresses log odds of the outcome variable on predicted values of the log odds and the predicted values squared. An insignificant coefficient of predicted values squared means that generated predictor has no explanatory power and, therefore, the model is correctly specified. Thus, Model 2 becomes the final model represented by equation (3):

$$\boldsymbol{ln\left[\frac{p}{1-p}\right] = 1.21 - 1.17X_1 - 0.04X_2 - 0.94X_3 - 0.30X_4 + 0.84X_5 + 0.11X_6 + 0.01X_7^{-2} + 2.54X_8} \quad \ldots\ldots(3)$$

where:

$\boldsymbol{X_1}$ = *female*

$\boldsymbol{X_2}$ = *age*

$\boldsymbol{X_3}$ = *farmer*

$\boldsymbol{X_4}$ = *household*

$\boldsymbol{X_5}$ = *firewood*

$\boldsymbol{X_6}$ = *expenditure*

$\boldsymbol{X_7}$ = *income*

$\boldsymbol{X_8}$ = *awareness*

The model shows that the variables *female, age, farmer* and *household* have negative associations while *firewood, expenditure, income_2* and *awareness* have positive associations with the log-odds of the dependent variable. These findings are largely consistent with results of the bivariate analysis, except for *firewood*. For instance, willingness to adopt biogas is higher among men than women, which is contrary to our alternative hypothesis. That is, the odds of a female household head being willing to adopt biogas is only 0.311 when the other predictors are controlled for. Similarly, *age* is negatively correlated with the log-odds and its odds ratio of 0.957 implies that one year increase in age reduces the odds of the dependent variable by 4.3%. According to the Chi-Square tests, respondents whose households currently use firewood as their main energy source for cooking are less likely to be willing to adopt the technology than those who use other sources. However, the logistic regression shows that the reverse is the case when the effects of the other predictors are controlled for.

DISCUSSIONS

The purpose of the study was to analyse the effects of socio-economic characteristics of households on their willingness to adopt biogas technology as an alternative to fuelwood. The results show that most household heads are satisfied with their current sources of energy and are, therefore, unwilling to adopt the technology. Also, with the exception of education, all the explanatory variables considered in this study have significant effects on respondents' willingness to adopt the technology. However, while the data confirm some of the findings from previous studies, they do contradict others. Conclusions and policy implications based on key findings from this study, and how they compare with the larger body of literature on biogas technology adoption, are discussed below.

Effects of Gender, Age, Education and Occupation of Household Heads

In terms of gender, the data from Birim North show that female household heads are less likely than their male counterparts to be willing to adopt biogas. This finding is contrary to the claim that women are more concerned about the environment and, therefore, tend to be more willing to adopt environmentally-friendly practices (Casey & Scott, 2006; Fernandez-Manzanal et al., 2007; Liobikiene & Juknys, 2016). It is also contrary to the fact that women stand to benefit the most from biogas adoption since they are the ones who bear most of the burden and hazards associated with the collection and use of fuelwood for cooking. However, the finding is consistent with a few other studies on actual adoption of biogas technology, which have found male household heads to be more likely to adopt biogas (Mbali et al., 2018; Walekhwa et al., 2009).

With regard to age, this study has revealed that younger household heads in Birim North are more willing to switch from fuelwood to biogas, compared to older household heads. The finding is consistent with the fact that younger people are considered to be more receptive of environmentally-friendly initiatives than older people. This is because younger people are more exposed to environmental information (Gan et al., 2021) and less integrated into a conservative social order that views environmental solutions as a threat to human freedom (Casey & Scott, 2006; van Liere & Dunlap, 1980). The finding also confirms other studies that show a negative correlation between age and adoption of biogas (Walekhwa et al., 2009; Yasmin & Grundmann, 2019) while contradicting others that have found a positive correlation (Kelebe et al., 2017; Mbali et al., 2018).

According to conventional wisdom, educated people are more exposed and receptive to scientific information, and are therefore more likely to accept new technologies (Kelebe et al., 2017; Putra et al., 2017; Shallo et al., 2020). Therefore, household heads who are more educated are expected to be more likely to adopt biogas technology than less educated ones. However, surprisingly, the binary logistic regression analysis reveals that education has no significant effect on household heads' willingness to adopt biogas in the Birim North District. Similar findings have been made by Mbali et al. (2018) and Yasmin and Grundmann (2019).

The current study also shows that household heads whose primary occupation is farming are less likely to be willing to adopt biogas than non-farmers. This is likely so because most farmers in Birim North, and for that matter rural Ghana, harvest firewood from their farms at little or no financial cost. As a result, they have little motivation to switch to biogas energy, which would involve financial cost. On the other hand, non-farmers may have a greater motivation to make the switch because they are more likely to be paying for firewood, charcoal or other cooking fuel already.

Effects of Household Size and Reliance on Firewood

In addition to the demographics of the household head, socio-economic attributes of the household—such as household size, main source of energy for cooking, household income and expenditure on energy for cooking—are found to influence willingness to adopt biogas. For instance, larger households have more of the labour required to operate biogas technology (Mengistu et al., 2016). As a result, a number of studies have found household size to positively influence biogas adoption decisions of households (Kelebe et al., 2017; Mengistu et al., 2016; Putra et al., 2017). However, the data from Birim North show the opposite—the likelihood of a household adopting biogas decreases with household size. Similar findings were made by Walekhwa et al. (2009) and Hafeez et al. (2017).

Another finding from this study is that households that rely on firewood as their main source of energy for cooking are more willing to adopt biogas once the element of financial cost and other factors are controlled for. This is possibly due to the fact that the use of firewood is much more burdensome, injurious to human health and time-consuming than other sources. For instance, the use of firewood is associated with the emission of harmful smoke and staining of homes and cooking utensils, which require substantial amounts of labour to clean. This is also in line with a similar finding made by Yasmin and Grundmann (2019).

Household Income and Expenditure on Energy for Cooking

This study has shown that households' willingness to adopt biogas technology is positively influenced by their income level. This is expected because consumers' willingness to acquire an environmentally beneficial good, and for that matter any traded good, is influenced by the monetary sacrifices they can make out of their disposable income in exchange for the said good (Le Gall-Ely, 2009; Liebe et al., 2011). The finding from Birim North also confirms studies conducted elsewhere. For instance, in Ofla and Mecha Districts, Ethiopia, Mengistu et al. (2016) found that income positively influenced biogas adoption decisions by households.

Similarly, the likelihood that a household in Birim North would be willing to adopt the technology is found to increase with how much it is already paying for traditional energy sources such as firewood, charcoal and LPG. This supports other studies that show that households that have actually adopted biogas technology tend to have a higher level of income than non-adopters (Das et al., 2017; Mbali et al., 2018; Shallo et al., 2020; Walekhwa et al., 2009).

Effect of Prior Awareness

The results show that household heads with prior awareness about the health and environmental benefits of biogas technology are much more likely to be willing to adopt it than those without prior awareness. This is so because the benefits that potential consumers expect to derive from a good influence their willingness to acquire it (Liebe et al., 2011). This is consistent with findings from other studies that suggest that knowledge or awareness of environmentally beneficial goods increases people's willingness to acquire such goods (Collart et al., 2010; Gil & Soler, 2006). For instance, a study on the effectiveness of a campaign to increase young people's awareness about the importance of preserving the Lenggong Valley World Heritage Site in Malaysia revealed that the campaign significantly improved respondents' awareness of the value of the site, which in turn increased their willingness to participate in efforts to conserve it (Jaafar et al., 2015). Moreover, environmental awareness has been found to have a positive effect on consumers' willingness to pay a higher premium for renewable energy (Karaoğlan & Durukan, 2016).

CONCLUSION

This paper has sought to contribute to the discourse on biogas adoption by analysing households' willingness to switch from fuelwood to biogas, and whether this willingness is influenced by their socio-economic characteristics. It has revealed that socio-economic variables such as gender, age, formal education, occupation, household size, current energy source, income level and expenditure on energy have significant influence on households' willingness to adopt biogas. However, in terms of how the magnitude and direction of influence of these predictors compare with what has been found in other studies, the findings of this study are rather mixed. In other words, as far as Birim North District is concerned, the influence of socio-economic variables on households' willingness to adopt biogas energy does not necessarily conform to what pertains elsewhere. Therefore, the paper emphasises the need for local governments to pay particular attention to context-specific socio-economic variables in their efforts to shift from the current centralised approach to localised approaches in the promotion of renewable and clean energy technologies. This will enable the local governments and other stakeholders to properly target households with appropriate educational and marketing strategies for biogas adoption. For instance, the fact that household heads with prior awareness of the health and environmental benefits of biogas technology are much more likely to be willing to adopt it is an indication that increased education and awareness campaign would be necessary. Such efforts will help to effectively manage household waste, improve upon environmental quality, protect forest resources, save women and children from the drudgery involved in fuelwood usage and, ultimately, contribute to the achievement of SDG7 (affordable and clean energy) at the global level.

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