Determinant factors of Biogas Technology Adoption for Household Energy Use and its impact: evidence from Eastern zone of Tigray

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Abstract:

This paper analyzes the determinant factors influencing household's decision to adopt biogas energy technology and its impact in Eastern zone of Tigray. 248 households from three woredas of eastern region were surveyed and analyzed using logistic regression model. 96 biogas adopter households and 152 non adopters were used for the analysis. Number of cattle owned and land access per tsimad were affecting biogas technology adoption positively at one percent level of significance. Gender of the household head (being male) and being secondary education literacy as compared to illiterate households was found to be positive and significant at 5 percent while family size was found to be negative and significant at 10 percent. This paper also highlighted the problems related to the adoption of the technology like technicality problem, inadequate combustion, unaffordable price, demands water and animal dung, lack of enough knowledge of how to apply slurry and lack of spare materials. The researchers also found the technology has improved sanitation and family health, time saving from firewood collection, providing organic manure, smoke reduction and improves household's livelihood. The researchers conclude that efforts are needed to increase the widespread adoption of the technology, increasing benefits of the technology for baking enjera and awareness creation on technology adapting. Thus, policy makers need to focus on extensive training programs, building interface among the energy office and agriculture office at woreda level, creation of market for spare parts of the technology and introducing new benefits of the technology.

Keywords: Biogas, logistic regression, eastern zone of Tigray

Background and Justification:

Ethiopia is agrarian country where agriculture accounts for approximately 42% of the GDP, 80% of employment, and 70% of export earnings (MoFED, 2011).The country is striving to transform its agrarian based economy with the goal of becoming an industrialized middle-income country in the next decade (CRGE, 2011). However Ethiopia is facing immense energy challenges. Thus, Bio-based energy resources are expected to continue to dominate Ethiopia's energy mix into the foreseeable future due to high reliance on traditional biogas use and a slow rate of transition to modern forms of energy generation (Shanko, 2009).

Ethiopia is completely reliant on oil imports, which exposes it to the risk of petroleum product price increases. This reliance on different energy sources has resulted in the overexploitation and significant depletion of Ethiopia's forest resources, with annual forest cover loss estimated at 140,000-200,000 ha (Jargstorf, 2004; FAO, 2010a). This has resulted in fuelwood scarcity, especially in overpopulated highland areas.

Likewise, Ethiopia is a country with limited availability of electricity. Moreover, it has the lowest levels of electricity access and per capita consumption in the world, but has the potential to become a regional power hub. Consequently, renewable energy development is a core policy position of the federal government of Ethiopia, therefore better understanding of cost effective energy diversification investment is vital for making informed decisions for meeting these challenges.

Reliance on wood fuel is particularly high on energy consumption in rural households of Ethiopia. Households' studies show that wood remains the preferred form of domestic energy, largely because it doesn't require complex expensive equipment, it can be used in an open fire and can be procured often at no greater costs, than the labor of collecting it. Deforestation poses a serious threat to environmental sustainability and is jeopardizing progress towards poverty and hunger eradication (UNDP, 2013). Dependence on forests worsens energy scarcity, and increases opportunity costs due to the additional time spent collecting wood (UN 2010). This is especially true for women and children who spend many hours gathering wood fuel. These externalities arising from wood fuel dependence may hinder the achievement of millennium development goals (MDGs), of reducing child mortality, improving maternal health and achieving gender equality, as well as conserving the integrity of the environment.

Energy is the key to development. Biogas energy production and use has been illustrated to have the potential to reduce wood fuel consumption, mitigate against climate change and reduce indoor air pollution (Smith et al. 2012). Biogas technology uses biological process to convert organic wastes into biogas (combustible mixture of methane and carbon dioxide) and high quality fertilizer. The technology is carbon neutral, and therefore does not add or remove CO2 from the atmosphere.

Biogas energy is considered a sustainable solution to local energy needs, and provides significant benefits to human and ecosystem health. Unlike firewood, biogas burns without smoke, improving indoor air quality, and thus saving women and children from respiratory distress and ailments. Biogas can be used to generate electricity, prolonging the active hours of the day and enabling the family to engage in social or self-improvement activities, or to earn extra income. Nonetheless, despite the huge potential for biogas, most households have persistently continued to use wood fuel, with the resultant negative effects.

Biogas technology has proved itself to be one of the most promising and sustainable sources of alternative energy in Tigray. Tigray being predominately an agricultural country, livestock plays an important role in Tigray's farming system. Biogas, the energy produced by biogas technology is used for household purposes such as cooking, heating and lighting. Availability of biogas for these purposes means reduction of use of fuel wood, which reduces pressure on the forest. Consequently it reduces deforestation that ultimately lessens soil erosion and maintains the land productivity. Over the years this high demand for wood fuel has put a lot of strain on the environment leading to destruction and disappearance of forests in the region, and by extension loss of carbon sinks and other ecosystem values and functions that emanate from trees. Besides, continued combustion of wood fuel in the area has contributed to indoor air pollution and increase in respiratory ailments among users, and this is attributed to excessive products of incomplete combustion (PICs) and smoke emissions in the poorly ventilated houses, common in the area. At the same time majority of area residents rear cattle, and hence huge quantities of dung are produced which emit massive fugitive methane gas into the atmosphere, exercabating global warming and climate change.

Many studies have investigated the determinants of household energy choice and how fuel wood scarcity affects energy substitution decisions and household welfare in other countries. However, such studies on energy use and its impact on household's welfare are missing in Ethiopia in general and Tigray in particular. In addition, though numerous efforts have done by several development organizations in Ethiopia, the federal government of Ethiopia and regional government of Tigray to introduce biogas technology in the area, to provide affordable, clean and sustainable domestic energy to the residents, biogas technology adoption and use have not been successful only a small proportion of the area residents have adopted the technology. Consequently, it is not clear what factors motivate some households in Tigray to adopt the technology while many others do not adopt. The question then that lingers is why is the adoption of this technology still low, and why are people not taking up the technology despite its enormous potential. Hence, the purpose of this study is to identify the factors that influence adoption of biogas technology in typical households in eastern zone of Tigray and the impact of biogas use on livelihood of the households.

Likewise, to the best of the researchers understanding there were not researches so far conducted systematically in this region where this study is proposed to be conducted. For this reason, the study is proposed to systematically analyze the determinant factors of biogas technology adoption for household energy consumption and its impact on livelihoods of the households'.

Objectives of the Study:

General Objective:

The general objective of the study is to analysis the impact of biogas technology adoption for household energy use and sustainable livelihoods in eastern zone of Tigray

Specific Objectives:

- ✓ To identify and analyze factors influencing biogas energy adoption and utilization in Eastern zone of Tigray; and
- ✓ To determine the role and potential of biogas energy technology in improving the livelihoods of the households

Research Design

This study employed a mixed approach with an emphasis given to quantitative household survey supplemented by the qualitative research method. The quantitative research approach was used to identify and analyze factors influencing biogas energy adoption and utilization in Eastern zone of Tigray and to determine the role and potential of biogas energy technology in improving the livelihoods of the households. In line with this, to capture some variables which are non-quantifiable (either methodologically or due to other reasons), qualitative methods of data analysis was also employed to describe the challenges and opportunities of using biogas technology.

Survey sampling procedure and sample size

In this study, therefore, a total of 252 households were selected from three tabias by using purposive stratified random sampling technique. Representative of biogas technology adopters and non-adopters was sampled from three woredas of the zone. Given the limited number of biogas users, purposive sampling was employed.

Secondary Data Collection

To enrich the primary data analysis and support it by some related theoretical concepts, the secondary data sources are, obviously, found to be important in every type of research. In line with this, the researcher looked at relevant literature from previously conducted research findings, reports, and relevant reviews of literature and documentary materials, some of which were gathered from Regional, zonal and woreda bureau of energy.

Data Analysis

To attain the major objective of this study, the data collected from the study area are to be analyzed and interpreted. In the process of data analysis and interpretation, major attention was given to quantitative analysis although it is going to be supported by qualitative technique.

Method of Data Analysis

As part of quantitative research methods, primary data was collected by means of survey questionnaire. As part of quantitative data analysis, an econometric model was also used to analyze factors influencing biogas energy adoption and utilization in Eastern zone of Tigray and their impact in improving the livelihood of households.

Econometric Model specification

This research work has two specific objectives. In order to address the first objective, the researchers were employed binary logistic regression to identify and analyze factors influencing biogas energy adoption and utilization at household level. The dependent variable (dichotomous variable) assumes two values (biogas technology adopters recorded as 1 and 0 otherwise) and the independent variables assumed any value, both continuous and categorical variables. Hence, a binary dependent variable logistic model following Gujarati (1988) is specified as below and will be used.

$$P(Y_i = 1) = \frac{e^{\alpha + \beta X_i}}{1 + e^{\alpha + \beta X_i}}$$

Where: Yi is i[th] observation response who has two outcomes (biogas technology adopters recorded as 1 and 0 otherwise)

X_i = are factors that affect household's biogas technology adoption,

α = the constant term and β's are the coefficient of the variables (vector of parameters to be estimated).

The model used by this study was to determine factors affecting biogas technology adoption is given below:

$$\pi(X) = \frac{1}{1 + e^{-(\beta o + \beta i X i)}} \text{---[01]}$$

the above equation can be written as:

$$\pi(X) = \frac{1}{1 + e^{-Zi}} \text{---[02]}$$

Where Π(x) = the probability of household being biogas technology adopt

Zi = βo+β1X1 + β2X2 + ... + βnXn

βo = is an intercept

β1, β2 ... βn are slopes of the equation

Xi = explanatory variables it represents independent variables

The probability of biogas technology adoption is given by equation (02).

Similarly, the probability for biogas technology adoption is:

$$1 - \pi(X) = \frac{1}{1 + e^{Zi}} \text{---[03]}$$

Thus, it can be written the two equations ([02], & [03]) together as

$$\frac{\pi(X)}{1 - \pi(X)} = \frac{1 + e^{Zi}}{1 + e^{-Zi}} \text{---[04]}$$

$$= e^{Zi}$$

Then, $\frac{\pi(X)}{1-\pi(X)}$ is simply the odds ratio of biogas technology adoption

Finally, by taking the natural log of equation (04) it can be obtained:

$$Li = \ln \left(\frac{\pi(X)}{1+\pi(X)} \right) = Zi \text{--[05]}$$

Where, Zi = βo+β1X1 + β2X2 + ... + βnXn

If the disturbance term (Ui) is introduced, the logistic model becomes

Zi = βo+β1X1 + β2X2 + ... + βnXn + Ui-------------------- [06]

Where Li is the odds ratio, which is not only linear in Xi but also linear in parameters and Xi is the vector of explanatory variable.

Discussion and Analysis

As table 1 depicts, the mean age of biogas technology adopters is 56.22 while for those non adopters is 51.99. Moreover, the cattle ownership of biogas users is 4.6 on average which is higher than those non users which is 3.03. Looking at sample households on basis of their family size, the average family size of all sampled respondents is 5.64 with standard deviation 1.76 of which 5.81 is of the biogas technology users and 5.53 is of non-adopters. The family size ranges from one to ten.

Table 1: Age, family size and number of cattle of households

Biogas Adoption	Freq.	mean(hhage)	mean(ncattle)	mean(familysize)
adopters	96	56.2188	4.60417	5.8125
non-adopters	152	51.9868	3.03289	5.53289

Source: Survey data (2017/18)

From the total 248 respondents, 83 respondents were male headed households who adopt biogas technology while 102 were male headed households who did not adopt the technology. On the other hand, from the total 63 female headed sampled households 13 were biogas technology adopters while the remaining 59 were non adopters.

Table 2 as well shows that 38.71 percent of the respondents were technology adopters among which 83 respondents were male headed households (86.46 percent) and 13 were female headed households (13.54 percent) while 61.29 percent were non adopters. The chi^2 test indicates there is some relationship between gender of the household head and technology adoption.

Table 2: cross tabulation of gender and biogas technology adoption

Gender of the household head	Biogas technology		
	adopters	non-adopters	Total
male	83	102	185
row percentage	44.86	55.14	100
column percentage	86.46	67.11	74.60
female	13	50	63
row percentage	20.63	79.37	100
column percentage	13.54	32.89	25.40
Total	96	152	248
row percentage	38.71	61.29	100
column percentage	100	100	100
		Pearson chi2(1) = 11.6293	Pr = 0.001

Source: Survey data (2017/18)

In this study three sampled woredas were selected namely, Ganta Afeshum, Hawzen and Kilte awlaelo. 75, 81 and 92 respondents were selected from Ganta Afeshum, Hawzen and Kilte awlaelo respectively. The chi^2 test indicates there is no significant relationship in area of residence of the household head between adopters and non-adopter.

Table 3: woreda versus biogas adoption

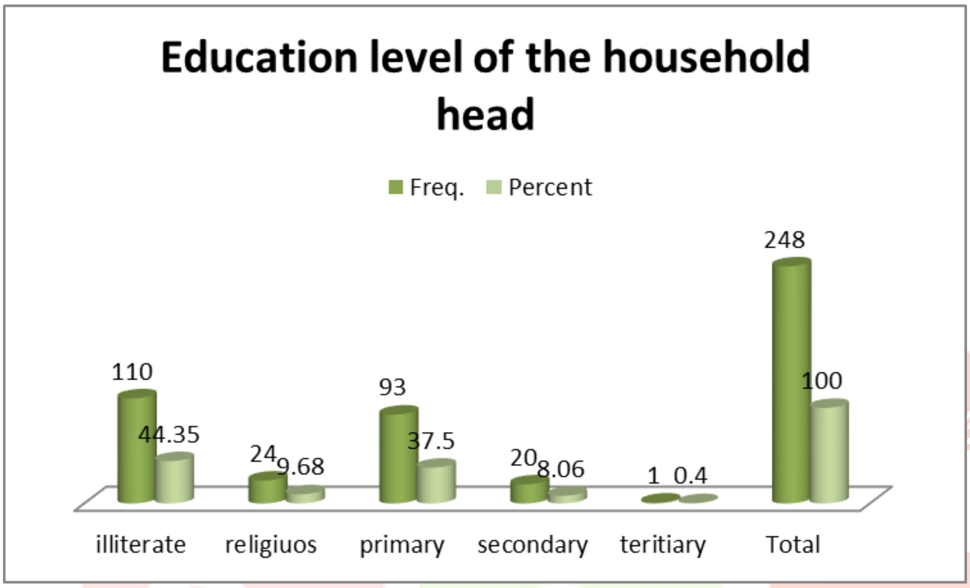
	Biogas technology		
woreda	adopters	non-adopters	Total
Ganta Afeshum	24	51	75
row percentage	32.00	68.00	100
column percentage	25.00	33.55	30.24
Hawzen	32	49	81

row percentage	39.51	60.49	100
column percentage	33.33	32.24	32.66
K/Awlaelo	40	52	92
row percentage	43.48	56.52	100
column percentage	41.67	34.21	37.1
Total	96	152	248
row percentage	38.71	61.29	100
column percentage	100	100	100
		Pearson chi2(2) = 2.3266	Pr = 0.312

Source: Survey data (2017/18)

As depicted in Figure 1, 110 household heads were illiterate, 93 household heads were primary educated, 24 were religious, 20 were secondary educated and 1 were from tertiary educated household.

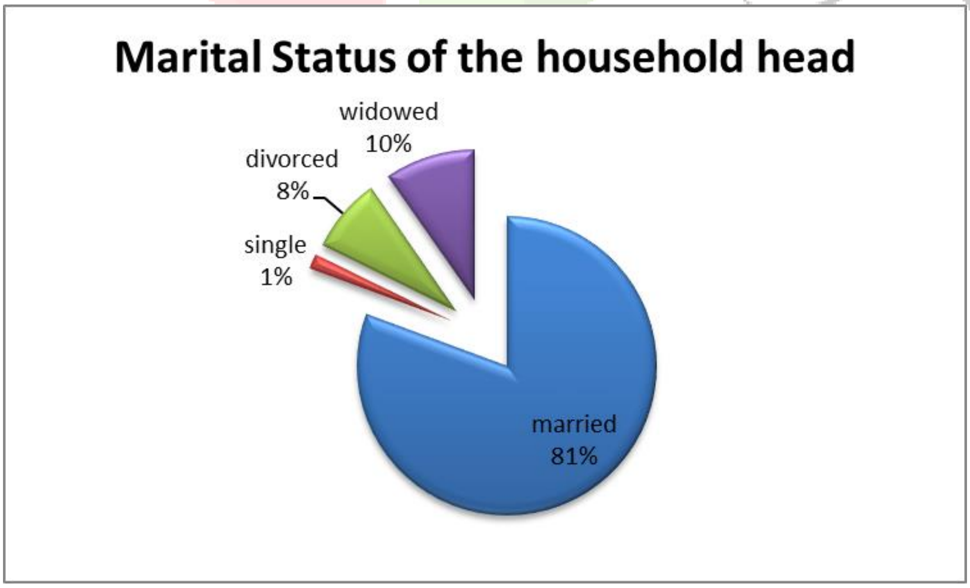
Figure 1: education level of household head



Source: Survey data (2017/18)

Looking to the marital status of the households, as the pie chart reveals among the total respondents 81 percent were married, followed by widowed 10 percent, divorced 8 percent and single 1 percent.

Figure 2: Marital status of households



Source: Survey data (2017/18)

Sources of income for households

Based on the nature of their livelihoods, the accessibility of various economic opportunities and the particular interests, preference and capabilities of people in the pastoral and agro-pastoral communities, households depend on different sources of income. We found that households participate in a range of types of employment or activities to generate income and maintain themselves. Households' choices of supplementary activities depend largely on their way of life, pastoral or agro-pastoral, with livestock keeping as the mainstay for many. Thus, households in the study area undertake pastoral activities (43.62%) as their main activity, followed by agricultural work (29.24%), domestic activities (8.76%), employment of different forms (7.71%), daily labor (3.22%) and various retail or trade activities (2.61%).

As shown in Table 4 below, 71.37 percent of the households do not have supplementary jobs to improve their monthly or yearly income. They depend on their main activity as the principal source of their households' income, agriculture. Only 28.63 percent of households participated in other alternative income generating activities.

Table 4: main source of income of households

income	Freq.	Percent	Cum.
Agriculture	177	71.37	71.37
Agriculture and trade	6	2.42	73.79
Agriculture, trade and other	1	0.4	74.19
Agriculture and employed	1	0.4	74.6
Agricultural and daily labor	23	9.27	83.87
Agricultural, daily labor and other	3	1.21	85.08
Agriculture and other	7	2.82	87.9
employed	10	3.23	91.94
Employed and daily labor	2	0.8	91.94
Employed and other	1	0.4	92.34
Daily labor	14	5.65	97.98
Daily labor and other	1	0.8	98.79
other	2	1.21	100
Total	248	100	

Source: Survey data (2017/18)

From the total respondents 90 households had access to electricity while 158 respondents do not have access. Moreover, the chi^2 test reveals that there is no significant relationship between electricity beneficiary households and technology adoption. Likewise, 40 households use both electricity and biogas technology and 102 households do not use both electricity and biogas technology.

Table 5: electricity users versus biogas adoption

Biogas adoption	Electricity users		
	yes	no	Total
adopters	40	56	96
non-adopters	50	102	152
Total	90	158	248
Pearson chi2(1) =	1.9582	Pr = 0.162	

Source: Survey data (2017/18)

The table above reveals that from the total 96 biogas users 82 households have connected their toilet to the system while the remaining 14 do not. On the other hand, 23.96 percent of the beneficiaries their biogas is not functional while 76.04 beneficiaries are getting benefit from the adoption of the technology.

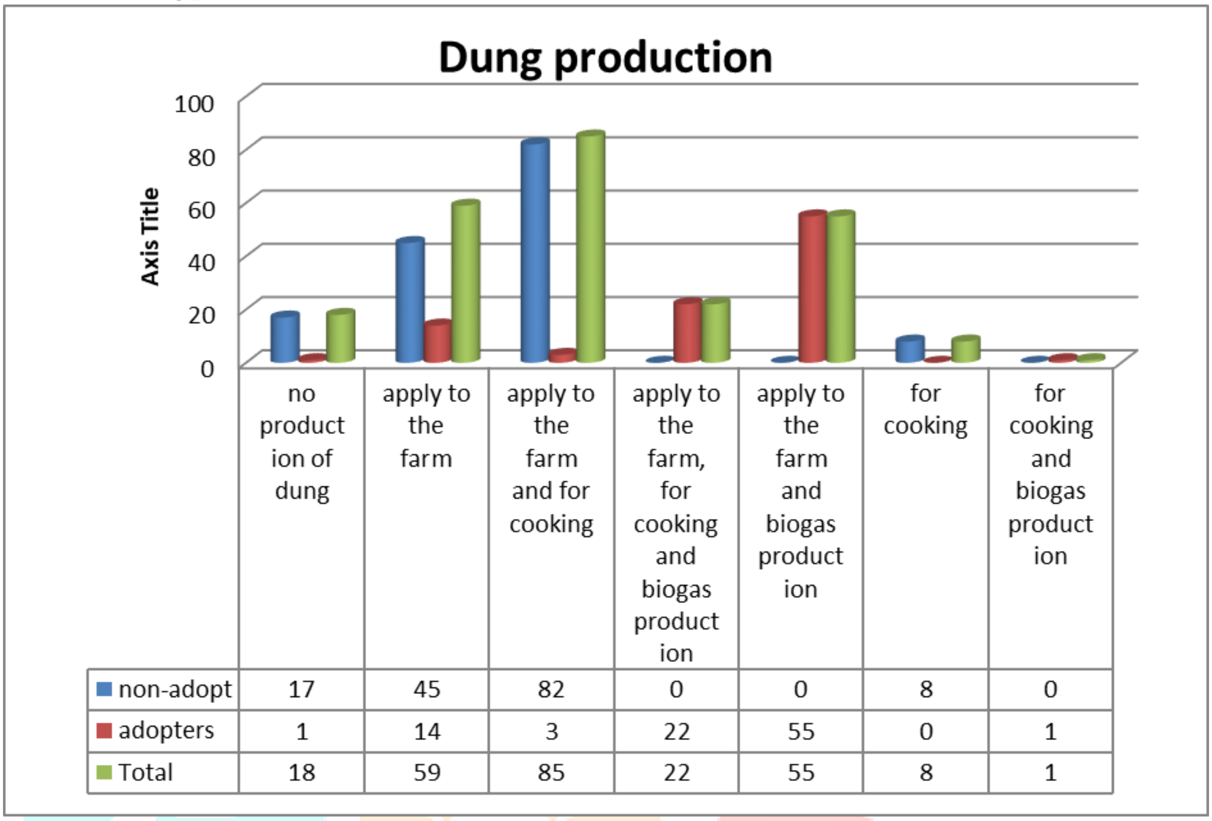
Table 6: connect toilet to the digester

toilet	Freq.	Percent	Functional	Freq.	Percent
yes	82	85.42	yes	73	76.04
no	14	14.58	no	23	23.96
Total	96	100	Total	96	100

Source: Survey data (2017/18)

Figure 3 shows households use of dung for adopters and non-adopters. 85 households use apply it for farm and cooking, 59 households apply it only for farm, 55 households apply it for farm and biogas generation, , 22 households apply it for farm, cooking and biogas, 18 households do not apply for anything, 8 households apply it for cooking only and the remaining 1 households apply it for cooking and biogas generation.

Figure 3: use of dung production



	no production of dung	apply to the farm	apply to the farm and for cooking	apply to the farm, for cooking and biogas production	apply to the farm and biogas production	for cooking	for cooking and biogas production
non-adopt	17	45	82	0	0	8	0
adopters	1	14	3	22	55	0	1
Total	18	59	85	22	55	8	1

Source: Survey data (2017/18)

Determinants of Biogas Technology Adoption

Male headed households tend to adopt biogas technology as compared to their female counterparts and the result was found positive and significant. He reason behind this might be male headed households have better position in decision making in the household and are also believed to be household asset keepers.

Being secondary educated head of household head has positive and significant impact to biogas technology adoption as compared to illiterate household heads. This is due to the fact that, relatively higher education provides households better awareness of the emerging technology, less conservative, more exposed to sources of information, and therefore more informed, knowledgeable, and environmentally aware about the harmful effects of firewood use on family health, and environment.

Contrary, to the expectations, family size has negative and significant impact to biogas technology adoption. This might be increase in family size leads to households having alternatives source of energy such as biomass.

As expected, number of cattle has positive and significant impact to the technology adoption. This might be due to the technology requires higher number of cattle ownership to adopt the technology.

Size of land influences adoption of biogas technology positively due to the fact that land is used for growing crops and the slurry will automatically used for agricultural productivity.

Table 7: determinants of biogas technology adoption

Iteration 0: log pseudo likelihood = -165.52306
Iteration 1: log pseudo likelihood = -133.14895
Iteration 2: log pseudo likelihood = -129.59585
Iteration 3: log pseudo likelihood = -129.5544
Iteration 4: log pseudo likelihood = -129.55437
Iteration 5: log pseudo likelihood = -129.55437

Logistic regression Number of obs= 248
Wald chi2(11)= 63.75
Prob > chi2= 0.0000
Log pseudo likelihood = -129.55437 Pseudo R2= 0.2173

Biogas	Coef.	Robust Std. Err.	Z	P>z	[95% Conf.	Interval]
gender (1= Male)	0.98848	0.44675	2.21	0.027	0.11287	1.86409
age	0.21371	0.13023	1.64	0.101	-0.0415	0.46896
age2	-0.0017	0.00117	-1.46	0.143	-0.004	0.00058
marital (1= married)	0.3348	0.54288	0.62	0.537	-0.7292	1.39881
religious	-0.2254	0.54515	-0.41	0.679	-1.2939	0.84304

primary	0.49939	0.35539	1.41	0.16	-0.1972	1.19594
secondary	1.41539	0.68984	2.05	0.04	0.06333	2.76745
Family size	-0.174	0.10066	-1.73	0.084	-0.3713	0.0233
Land timad	0.72323	0.1492	4.85	0.000	0.43082	1.01565
Electricity (1=yes)	0.09852	0.3364	0.29	0.77	-0.5608	0.75786
no of cattle	0.49472	0.11916	4.15	0.000	0.26117	0.72827
_cons	-10.126	3.43203	-2.95	0.003	-16.853	-3.3996

Source: Survey data (2017/18)

Conclusion and Recommendation

The adoption of biogas has immense great importance to small holder farmers as it provides renewable energy in addition to the existing biomass energy that can be used for various uses such as lighting and cooking. In addition, biogas conserves the environment and puts wastes i.e. human and animal waste into good use.

The study analysed determinant factors for biogas adoption. The study found out that gender of the household head, being secondary education completed, family size, access to land and number of cattle owned was the great determinants of the biogas adoption. Accordingly, the following key policy implications were recommended.

- To overcome the barrier of high up-front costs, affordable financing is an important factor.
- Intensive awareness creation to households on the benefits of cooking with cleaner fuels.
- Intensive awareness creation to non beneficiary households on health impacts of cooking with traditional biomass could help accelerate the shift towards modern cooking methods
- Work on empowering women on reducing their burden from biomass energy use and subject to the health impacts from burning it.
- Policy makers should also conduct research to develop and enhance the benefits of the biogas to include oven stove.

References:

- Brouwer, D., Hoorweg-Marti, C., and van Liere, J., 1997. When Households Run Out of Fuel: Responses of Rural Households to Decreasing Fuel Wood Availability. Ntcheu District, Malawi. World Development, 25: 255-266.
- Climate Resilient Green Economy (CRGE), 2011. Ethiopia's Climate Resilient Green Economy: Green Economy Strategy. Addis Ababa, Ethiopia.
- Deutsche GesellschaftfürTechnischeZusammenarbeit (GTZ), 2006. The Significance of Biomass Energy Strategies (BEST) for Sub-Saharan Africa. Background Paper for 1st Regional Workshop on Biomass Energy Strategy (BEST) Development held in DareSalaam, Tanzania, 12-14 September 2006.
- Food and Agriculture Organization of the United Nations (FAO), 2010. Global forest resource assessment, country report Ethiopia. Forest Resources Assessment, FRA2010/065, Rome.
- Kruyt, B., vanVuuren, D., deVries, H., and Groenenberg, H., 2009. Indicators for energy security. Energy Policy, 37: 2166-2181.
- Jargstorf, B., 2004. Renewable Energy & Development, Deutsche GesellschaftfürTechnischeZusammenarbeit and Ethiopian Rural Energy Development and Promotion Centre: Addis Ababa, Ethiopia.
- Lim, L., Vos, T., Flaxman, D., Danaei. G., Shibuya, K., and Adair-Rohani, H., 2012. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet, 380 (9859): 2224-2260.
- Ministry of Finance and Economic Development (MoFED), 2011. National accounting data base of Ministry of Finance and economic development, Addis Ababa, Ethiopia.
- Rasul, G., 2014. Food, water, and energy security in South Asia: A nexus perspective from the Hindu Kush Himalayan region. Environmental Science and Policy, 39: 35-48.
- Rehfuess, E.A., Briggs, D. J., Joffe, M., and Best, N., 2010. Bayesian modelling of household solid fuel use: Insights towards designing effective interventions to promote fuel switching in Africa. Environmental Research, 110 (7): 725-732.
- Smith, K.R., 2012. Household Air Pollution Findings from the Global Burden of Disease 2010 Study. Global Alliance For Clean Cook stoves Sector News.
- Thurber, M., Phadke, H., Nagavarapu, S., Shrimali, G., and Zerriffi, H., 2014. 'Oorja' in India: Assessing a large-scale commercial distribution of advanced biomass stoves to households. Energy for Sustainable Development, (Available at: http://dx.doi.org/10.1016/j.esd.2014.01.002, accessed on 05/01/2014).
- UNDP (2013). The Energy Access in Situation in Developing Countries: A Review Focusing on the Least Developed Countries and Sub-Saharan Africa. UNDP, New York, NY
- United Nations (2010, September) Secretary-General, at summit high-level event, describes energy poverty as obstacle to Millennium Development Goals. www.un.org/News/Press/docs/2010/sgsm13124.doc.htm

- Venkataraman, C., Habib, G., Eiguren-Fernandez, A., Miguel, A., and Friedlander, S., 2005. Residential biofuels in South Asia: carbonaceous aerosol emissions and climate impacts. Science, 307: 1454-1456.
- Wang, Q., 2009. Prevention of Tibetan eco-environmental degradation caused by traditional use of biomass. Renewable and Sustainable Energy Reviews, 13: 2562-2570.
- World Health Organization (WHO), 2006. Fuel for life: household energy and health. World Health Organization, Geneva.
- Rosenbaum, P.R., and Rubin, D.B. (1983). The Central Role of the Propensity Score in Observational Studies for Causal Effects. Biometrika, 70 (1), 41-55.