DETERMINANTS OF BIOGAS TECHNOLOGY ADOPTION IN SOUTH ETHIOPIA: THE CASE OF WONDO GENET WOREDA

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Abstract: *The major aim of this paper was to examine the determinants the biogas technology adoption in rural areas Wondo Genet Woreda, South Ethiopia. The study was based on the cross-sectional survey of a total of 211 households randomly selected using a multi-stage sampling technique where stratified random sampling techniques were applied for selecting 86 biogas technology adopters and 125 non adopters. Data were collected through individual interviews by using structural questionnaire. Logistic binary regression model was employed for examining the main determinants of the biogas adoption. Results show that socio-economic factors play an important role in the respondents' behaviors toward biogas adoption. The empirical results indeed highlighted that distance to access forest, cost of initial investment, cost of kerosene, credit access, cost of inorganic fertilizer, cost of health and distance household's home to urban center have significant influences on the decision of biogas technology adoption. Therefore, for future endeavours, it is essential to target the households residential location, reduction cost of initial investment through subsidy, enhance the use of slurry in place of inorganic fertilizer, and promote biogas technology as it reduces household's health cost that can help increase the adoption rate of biogas plants.*

Keywords: Alternative energy, Biogas, GHG, Technology Adoption, Environment sustainably.

1. Introduction and the research problem

Globally, it is acknowledged that energy is a core power of economic growth as it affects economy in general (Amigun et al, 2008). However, the sources and utilization of energy has become one of the most pressing problems at a global scale. According to Jan and Heegde (2010), over two billion people worldwide lack access to clean, safe and sustainable domestic energy services. Of these, about1.6 billion smallholders rely on forest resources for their domestic energy (J. Hemstock, 2006).

This poses a huge challenge to the energy sector requiring that alternative energy sources to be sought. Problems associated with non-sustainable use of fossil fuels have led to world-wide increased awareness and widespread research into the accessibility of new and renewable energy sources (Amigun and von Blottnitz, 2007). This awareness and concern about the environmental impacts of fossil fuels coupled with steep increases in oil prices have lent enormous weight to the argument for countries switching to renewable energy sources (Akinbami et al., 2001). In its assessment report, global energy institute (2009) noticed that unwise use of biomass as renewable sources of energy by itself could also cause energy crisis in which reliability of scarce resource are not sufficient to meet the demand in the one hand and severe natural resources degradation on the other hand which has a subsequent effect on ecology and livelihood of low income segment of the population.

It is estimated that approximately 2.5 billion people in developing countries rely on biomass fuels to meet their cooking needs. Whereas heavy reliance on biomass fuels (such as woody biomass and dung) contribute to deforestation, land degradation and health problems due to indoor air pollution (Bruce et al, 2000; Ezzati and Kammen, 2001).

In Ethiopia, the share of biomass energy which accounts over 92% of the total energy is almost entirely used for meeting household energy needs (Forum for Environment, 2010) that resulted in serious environmental, ecological and social consequences (Zebider, 2011). This biomass energy mainly comprises fuel wood, agricultural residues and dung cake used by rural community inside their homes though it has socio-economic and environment related adverse effects as many of which are disproportionately suffered by the women and the poor (MOWE, 2012), for which WGW is not an exception. The ever increasing needs for biomass fuels especially fuel wood has led to massive deforestation and soil erosion which now threaten agricultural productivity.

In response to these recycling problem pertained to deforestation, switching to alternative renewable energy sources has become not only an option to complement the traditional sources but also are sought as an elixir to mitigate the current energy shortage as well as to improve livelihood in Ethiopia. In this context, environment-friendly biogas production could be an interesting instrument with potentials of some portion of total energy. However, BT is misunderstood, overlooked and poorly utilized in WGW. In the study area, there was a scanty adoption and poor utilization of BT. Of the 57,282 households in the woreda; for instance, only 0.18% of households have adopted biogas technology (Woreda report, 2013). The report shows that biogas adoption is very dismal;

yet empirical results have been subjective on biogas technology adoption decision of farm households, while others have emphasized on the technology per se without looking at the linkages that may exist with livelihood improvement and environmental sustainability in the study area.

Investigating mechanisms to adopt BT is believed to help policy makers, development practitioners and researchers to make use of the information generated for intervention purpose or make informed decisions. Hence, systematic identification of constraints faced by biogas adoption and utilization is increasingly seen by agricultural research as important component of any strategy for reaching the millennium development goals (Giuliani and Padulosi, 2005) and ensuring the resilience of environment degradation to rapidly forest depletion in the study area is a key policy issue. Thus, an in-depth understanding of the determinants of BT adoption and utilization in the rural area of WGW remain important.

1.3 Objectives of the Study

The broad objective of the study is to examine the key socio-economic factors influencing biogas energy production and utilization from family sized digesters in South Ethiopia.

The specific objectives of the study are:

1. To identify potential entry barriers and opportunity of BT adoption.
2. To analyze the determinants of BT adoption in rural areas of Wondo Genet Woreda, South Eth

2.Review of Empirical Evidences

The variables often considered in biogas energy adoptions decision include age, educational status, income level, household size, gender of the household head, size of land owned by the household and the cost of alternative fuels (Somda et al., 2002). However, explanatory variables used in the adoption process have often lacked a firm theoretical basis, possibly due to the fact that households consider a variety of other issues beyond socio-economic incentives, including non-economic factors (Kebede et al., 1990). In this study, the selection of the prospective variables that could affect the house-holds' decision to adopt biogas plant was grounded in literature and field experiences. The considerable amount of literature on adoption behavior reports that social, physical, economical, human, natural resources and institutional factors are the core determinants of the adoption process (Walekhwa et al, 2009). Mendola (2007) asserts that the development and management of BT are far from a purely technical question and almost always involve natural, economic and social assets problems and human behavior characteristics.

Complementarily, a considerable amount of existing literatures on adoption behavior concurs that social, human, physical, economic and institutional factors are key determinants of the adoption process (Adesina and Baidu-Forson, 1995; Drake et al., 1999; Kassenga, 1997; Somda et al., 2002; Bekele and Drake, 2003). Some of the research findings that give an overview of the factors influencing BT adoption in developing countries include Akinbami et al. (2001); Amigun and von Blottnitz (2007); Karekezi (2002); Kebede et al. (1990); Mwakaje (2007); Ni and Nyns (1996); Pandey et al. (2007); Walekhwa et al. (2009). Also as reported in these studies, the income of the household, household size, land size holdings, educational status of the household head, cattle herd size and the price of alternative fuels generally influence biogas technology adoption decision positively. However, the importance and direction of influence of different variables will vary depending on the different socio-economic conditions and sites.

MATERIALS AND METHODS

3.1. Description of Study Area

Wondo Genet is found in Sidama Zone of Southern Nations Nationality and Peoples States (SNNPRS), 275 km away from the capital, Addis Ababa, at 7° 06′ N to 7° 11′ N, 38° 5′ E to 38° 07′ E, and altitude of 1700-2100 m (BOFED, 2011). The catchment area is located between the Lakes Basin and the Shebele Basin (Woldemariam, 1963). The forest of Wondo Genet Watershed is very fragmented forest that has been suffering from high pressure by ever growing rural population which depends heavily on forests for livelihood. There has been frequent periodic, allegedly human caused fire that has destroyed significant portion of the forest. Although apparently the forest belongs to the WGCF, there is no legally documented ownership. Hence, various claimants have caused unprecedented pressure on the management of the forest. Moreover, the watershed is found at the border of two regional governments, namely Oromia and SNNP, the residents of which frequently quarrel over resource use (Shawel,2006).

There is biogas program in 11 kebeles from the total of 16 kebeles. However, in some kebeles the biogas plants that were built at the outset of the program are come to exist without biogas.

3.4. Sample Size, Sampling Distribution and Methods of Data Collection

One of the important elements in any study is how samples are drawn from the study population. In this, due attentions is given to the representativeness of the sample to the total population for better generalization of the findings. The sample size estimation used this study was adopted from Cochran (1977) given by;

$$n = \frac{\frac{z^2 p(1-p)}{d^2}}{1 + \frac{1}{N}\left[\frac{z^2 p(1-p)}{d^2} - 1\right]}$$

Where n = sample size, z is the upper $\frac{\alpha}{2}$ points of standard distribution with α=0.05 significance level, which is z= 1.96, d is the degree of precisions (0.05), p is proportion of main event of biogas adoption which is taken from the other previous studies as 0.18 or 18%) .The level of precision is the range in which the true value of the population is estimated to be; it is expressed in percentage points (±5).The estimated sample size, using the above mentioned formula yields 211 households.

Table 3.1 Sample Kebeles and sample size distributions

Kebele	Number of Household	Sample size
Woshana Soyama	2,935	52
Abaye	3,099	56
Eddo	2,639	48
Baje Fabirika	3,091	55
Total	11,764	211

Source: Own survey, 2014

The 211 sample households were selected through multi stage sampling techniques, which is commonly used probability sampling technique in a situation where the ultimate unit of selection requires certain series of stages in large scale studies of this kind.

Both quantitative and qualitative data collection methods were employed to collect from the primary and secondary sources of data. The bulk of the data was collected through household survey interview schedule. Prior to the surveys, reconnaissance visits to the study sites were conducted and focus group discussions (FGDs) were held with households and key informants to develop the interview guides for the survey and to ascertain the sampling frames obtained.

3.6. Data Analysis

3.6.1 Descriptive Statistics

Descriptive statistics was used to identify the general pattern of data such as percentage, mean and standard deviations. Chi^2 were also employed to measure the degree of association between dichotomous dependent and independent variables to screen variable for multiple regression. For continuous variables t-test was employed to measure the same.

Among other variables that may possibly influence the biogas adoption and utilization, the effects of household perceptions on adoption decisions was also conceptualized with models used on the basis of benefit maximization of the technology. Qualitative analysis was also used to complement quantitative ones under this section.

3.6.2 Econometric Analysis

Logistic regression model was employed to investigate determinants of biogas technology adoption It applies maximum likelihood estimation after transforming the dependent into a logit variable (Garson, 2008). It estimates the odds of a certain event occurring. The dependent variable with a logit, which is the natural log of the odds, will be stated as;

$$\ln\left[\frac{p}{1-p}\right] = a + bX \qquad P = \frac{e^{a+bx}}{1+e^{a+bx}}$$

Where, P is the probability of the event occurring, *X* are the independent variables, *e* is the base of the natural logarithm and *a* and *b* are the parameters of the model. The empirical form of the model used in the study is as follows:

$$PrY = \frac{1}{1+e^{-(a+bx)}}$$

Y is the logit for the dependent variable. The logistic prediction equation for the present study was:
Y = ln(odds(event)) = ln(prob(event)/[prob(nonevent)] = ln(prob(event/[1-prob(event)]). Therefore;
$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + ... \beta_n X_n$

Where b_0 is the constant with $X_1...X_n$ independent variables affecting the probability of choice of biogas technology and $b_1...b_n$ were the coefficients estimated. The dependent variable will be modeled as: Y= Adoption (utilization) of biogas technology = Pr Y; (1 = Household chooses to adopt biogas technology, 0 = otherwise). Similarly, affirmative responses [1] or disagreement [0] with the items related to technology adoption was summed to give a score from 0 to the extent it was set, with higher numbers indicating greater adoption of the technology. The association between the dependent variables and the predictors was also examined using Logit model.

RESULTS AND DISCUSSION

In table 4.4, the results of t test for continuous variables showed that many of predictors were identified to be significant at 10% or less. This implies that there is a sufficient evidence to conclude that the value of these predictors and biogas technology adoption statuses have a significant association. Obviously, these variables have sufficient evidences to conclude that they are able to predict the difference between adopters and non adopters of biogas technology (Table, 4.4). Therefore, it is a reasonable to assume that the predictors with sufficient evidence are valuable to determine the adoption status of the technology.

Table 4.4. Comparison of Selected Continuous Variables between Biogas Technology Adopters and Non-Adopters

	Biogas Adopters (n=86)		Non Adopters (n=125)		Total Sample (N= 211)		
Variable	**Mean**	**Std.Dev**	**Mean**	**Std.Dev**	**Mean**	**t value**	**p value**
AGEHHD	48.1163	11.3598	45.968	12.1999	46.84	1.29	0.091
FSIZE	2.60821	5.7907	6.368	3.03882	6.13	1.44	0.081
LSIZE	0.65168	1.19605	1.2324	0.75319	1.21	0.36	0.091
LIVESIZE	1.27788	2.22093	1.624	0.74773	1.86*	-4.27	0
DISFWT	0.57747	0.45977	1.1638	0.61336	0.87*	8.39	0
DISFWD	1.01395	2.09488	1.01596	0.62406	1.45*	-9.56	0
DISFSTAC	2.16395	1.245	1.30808	0.53204	1.66*	-6.84	0
COSTKER	3.83837	4.66418	13.0728	7.06663	9.3*	10.63	0
COSTHEL	535.53	395.447	1084.42	433.448	860.7*	9.36	0
COSTIFT	486.904	484.402	1557.1	663.888	1120.9*	12.78	0
INCOMHHD	12684.9	7520.2	6877.82	2738.33	9244.67*	-7.91	0
DISUCT	16.7384	9.01721	12.3059	8.06354	14.11*	-3.73	0.0002

Source: Computed from own survey data, 2014

4.4.1 Determinants of Biogas Technology Adoption in Wondo Genet Woreda

Table 4.17. Logistic Regression Estimates of Factors Affecting Biogas Energy Adoption

BIGASS	Odds Ratio	Robust Std. Err.	Z	P>|z|	[95% Conf. Interval]	
AGEHHD	1.025154	0.0351109	0.73	0.468	0.9585965	1.096332
SEXHHD	1.332205	1.110177	0.34	0.731	0.2601551	6.821969
FSIZE	0.9914578	0.1156747	-0.07	0.941	0.7887937	1.246192
EDUCHHD	0.9804743	0.768353	-0.03	0.98	0.2110515	4.554954
LSIZE	0.5351343	0.3269757	-1.02	0.306	0.1615716	1.772396
LIVESIZE	1.044665	0.3972998	0.11	0.909	0.4957396	2.201406
DISFWT	0.3942216	0.2366806	-1.55	0.121*	0.1215349	1.278734
DISFWD	3.692348	2.920883	1.65	0.099*	0.7833355	17.40433
DISFSTAC	3.25795	1.140225	3.37	0.001***	1.640738	6.469189
COSTKER	0.7905447	0.0549105	3.38	0.001***	0.6899264	0.9058371
INFOBT	3.319036	15.3127	0.26	0.795	0.0003926	28061.75
COSTII1	3.004849	1.555306	-2.13	0.034**	1.089537	8.287116
COSTIFT	0.998625	0.0005914	2.32	0.02**	0.9974665	0.9997849
CREDAC	5.358605	3.913918	2.3	0.022**	1.280369	22.42685
BIOSUS	1.539834	1.685158	0.39	0.693	0.1802763	13.15252
INCOMHHD	1.000022	0.0000586	0.38	0.706	0.9999073	1.000137
COSTHEL	0.9985596	0.0007697	-1.87	0.061**	0.9970522	1.000069
DISUCT	1.087605	0.0478402	1.91	0.056**	0.9977676	1.18553
Cons	0.0198817	0.1105205	-0.7	0.481	3.69	1072.002

*** (* *) * denotes significant difference at P<0.01, 0.05 and 0.1, respectively

Number of obs = 211
Prob > chi² = 0.0000
Wald chi2(18) = 53.88
Pseudo R^2 = 0.7837
Log pseudolikelihood = -30.84949
% of correct prediction for biogas adopters = 95.24% (80 households out of 84)

% of correct prediction for biogas non adopter = 95.28% (121 households out of 127)

% of total correct prediction = 95% (201 households out of 211)

Source: Own computation, 2014

For the logistic model (Table 4.18), the estimated values fitted the observed data reasonably well. Measures of goodness-of-fit of the model results indicated that the independent variables were simultaneously related to the log odds of adoption. The choice of independent variables correctly predicted households' biogas adoption conditions for 95.24% of the total observations. Pseudo R^2, an analogous measure of goodness-of-fit, was 78.37% . This is more than adequate for cross-sectional data. This indicates that the model fitted the data to an acceptable level.

Credit Access (CREDAC): In the study area, biogas plant construction was perceived as costly by those who are in need of adopting the technology. Under such circumstances, credit plays a significant role in enhancing the technology promotion. As anticipated, credit affects biogas technology positively and significantly at P<0.05 (p=.02). The odds ratio, other factors held constant, in favor of adopting biogas technology increased by a factor of 5.36 for adopters who had received credit. The result reveals that the availability of credit and receiving enhances smallholders adoption decision on biogas technology. The result is supported by Lelisa (1998) who studied determinants of fertilizer adoption, intensity and probability of its use that revealed access to credit is one determinant of fertilizer adoption and intensity of its use. Doss *et al*. (2003), Feder *et al*. (1985), and Cramb (2003) also reached the same conclusion that credit correlated with the use of improved inputs. However, the result of the study does not confirm the other side of the hypothesis which speculates access to credit causes dependency syndrome that in turn results in the problem of technology utilization being defaulter to pay it back in a due time.

Distance from home to fetch water (*DISFWT****):*** As stated in the hypothesis, the proximity to water point has a significant influence on biogas technology adoption by speeding up a decision to adopt it. Other factors remain constant, the odds ratio in disfavor of biogas technology adoption decreased by a factor of 0.39 when the distance of from home to fetch water increases by one kilometer to reach where the water point is located. Moreover, there was statistically significant means difference of water point distance level between users and non-users groups of biogas technology. Indeed, the extent of distance to fetch water by biogas users and non-users were 0.577 and 1.16 kilometers, respectively (Table 4.19). Beyond other basic determinants, some researchers emphasize on the accessibility and availability of infrastructure considering it as essential physical capital for biogas technology adoption (Leach, 1992). However, a study in South Africa found that infrastructure has been of little importance (Davis, 1998).

Distance from home to collect fuel wood (DISCW): The increase of distance from rural household to arrive at the availability of fuel wood has a positive effect on the probability of household to adopt biogas technology and to abandon the use of biomass at $p<0.1$ ($p=0.099$). The odd ratio, other factors held constant, in favor of adopting biogas technology increases by a factor of 3.69 for adopters whose home distance increase by 1 km from the availability of fuel wood. A number of studies proved that the rural community, who live in hilly and mountainous side covered with forest, tend not to abandon the use of biomass because they are positioned to have access to both forest sources and agricultural residues, making biomass more accessible than those who live elsewhere. On the other hand, the resident who are located at the far distance from the availability of fuel wood abandon deforestation which could contribute to switch from biomass degradation to alternative energy like biogas technology. Wuyuan Pen (2010), on the basis of empirical analysis, vindicated that innovative alternative technology release the rural community from the problem of fuelwood shortage because of its accessibility and with the special concern to conserve natural resources. The author further had explained that inducing biogas technology help not only to reduce biomass use as a source of fuel but also it help to save time which would have been spent for fuel wood collection.

Distance to the nearest urban center to sale fuel wood (DISUCT): As anticipated, distance to the nearest urban center to sale fuel wood affects biogas technology adoption positively and significantly at $P<0.1$ ($p=.056$). The odds ratio, other factors held constant, in favor of adopting biogas technology increased by a factor of 1.09 as distance of households home location to the urban center increased by one kilometer. Among other physical capitals, household home location proved to be one of key factors in biogas technology adoption. Most biogas users were located in rural areas, where there is limited access to sell fuel wood at urban center, and there were fewer biogas digesters located nearer to urban areas because of easier access to sell fuel food at urban center and to use other energy sources. This shows that the more the distance from household home location to urban center, the lesser of the chance to cut forest plant to make it possible fuel wood for urban community at the expense of environment. Other studies also tend to agree with this study as household home location found to have limited access to urban center is a key determinant of both for those who switch to new energy sources and who retain in using the traditional biomass as a source of energy (Jiang and O'Neill, 2004). Therefore, the households those who have limited access to town were more likely to adopt and utilize biogas than those who were located at the proximity of urban center.

Distance for Forest Access (DISFSTAC): Accessibility of abundant forest resources in the vicinity of household influences his or her decision to adopt and utilize biogas. The distance of forest accessibility to household home found to have positive influence on biogas technology adoption which confirmed hypothesis. The households those do not have abundant forest resources nearby their home were more likely to adopt biogas technology and statistically significance at the probability level of 1% ($p=0.001$). The likely odds ratios, other factors held constant, increases by a factor of 3.26 when the distance of forest access increases by one km. The results further show that abundant forest inaccessibility at the proximity of the smallholders home increases the propensity of adopting biogas technology. It creates certainty on the part of farmers and open up opportunity to undertake investment measures such as construction of biogas plant and/or long-term forest management strategies. This result is in line with the results of other empirical studies of other energy related technologies in rural areas of Ethiopia (Demeke and Hunde, 2004; Ayalew *et al*., 2005).

Household Health expenditure reduction (COSTHELT): Sanitation and hygienic related health cost reduction is the other important factors significantly determining the likelihood of adoption of biogas technology at 10%. The odds ratio, other factors remained constant, shows that the probability of households to practice biogas technology increases by a factor of 0.998 as the household sanitation and hygienic related cost reduction decrease by one birr. Moreover, there was statistically significant mean difference of the level of health cost between users and non-users groups of biogas technology (Table 18). Indeed, the extent of costs reduction of hygienic and sanitation related health problems of biogas users and non-users were negatively related to biogas adoption. The negative sign for household health cost can be explained by the fact that the reduction of household health cost help smallholders invest on environment friendly and soot free technology to have health labor thereby it improves farm productivity.

As previously explained, non-biogas users are more exposed to the dangers of cooking with firewood and smoke in the kitchen than biogas-users. Non-biogas users complain about the indoor air pollution and particles from smoke. Exposure to indoor pollution can have very serious health consequences most predominantly a higher risk of respiratory illnesses such as bronchitis and pneumonia. These all sanitation related diseases cause fatal death otherwise demand high cost to recover from them. The cost that spent on household health related problems would have been invested in other income generating activities provided that the cost had reduced with switching from the use of biomass as a source of energy to environment friendly new alternative technology. This result is in line with the study of BS, Taylor (1992) which also reported a negative correlation between health cost in birr and probability of biogas technology adoption.

Cost of Kerosene (COSTKER): Since biogas technology significantly reduce the cost of kerosene, it was included in the model and was found to be positively correlated and statistically significant at 1% (P=0.001). The odds ratio, other factors held constant, the likelihood of biogas technology adoption increases by a factor of 0.79 when kerosene cost increases by one birr. This implies that household heads who spend more to purchase kerosene (more than the sample mean cost of kerosene) are 0.79 time as likely to adopt biogas technology than those spend less to purchase kerosene (less than the sample mean cost of kerosene).

Biogas technology adoption took worth attention as it has the efficiency and effectiveness to reduce kerosene cost. Wuyuan Pen (2010) asserts that the availability and nature of a new technology are critical factors in influencing the decision of a household to adopt it as a substitute technology. A household must be convinced that the new technology is unquestionably better than the existing technologies. The development and acceptance of biogas will, therefore, largely depend on the exploitation of its technological advantages over the existing costly technologies.

In WGW, fuelwood and kerosene are the primary energy sources for cooking and lighting for the majority of the rural population though it is inconvenient in the one hand and costly energy source on the other hand (FGD). This study is directly allied to the policy analysis report of Ministry of Water and Energy of Ethiopia which indicates that fuel wood and kerosene are the major source of energy in rural community of Ethiopia (MoWE, 2002).

Evidence from other similar adoption studies indicates that biogas technology is more attractive when the local equivalent energy price is high and when the digester is highly efficient and easy to manage (Brush and Taylor, 1992). When the price of the replaced energy is high, this positively motivates the biogas producer and user to turn to cheaper biogas energy. Similar results were reported by Ji-Quin and Nyns (1996) who concluded that for the biogas consumer, the motivation usually depends on the economic benefits obtained by replacement of traditional fuels with biogas and the modernization and convenience of daily life. They further observed that biogas is a type of high grade fuel that offers several advantages over traditional fuels. As deforestation increases in Wondo Genet, the cost of fuelwood has been skyrocketing, while the price of other alternative energy sources for cooking has also increased. This increases the likelihood of households accepting biogas as a cheaper alternative energy source. For lighting purposes, the price of kerosene is relatively high. Moreover, discussant asserted that biogas energy is regarded a more efficient, clean and convenient energy source. The chances of households adopting biogas energy on the basis of lighting cost are higher than on fuelwood cost for cooking.

Cost of inorganic Fertilizer (COSTIFT): The mean difference between cost of inorganic fertilizer that used by non adopter (= 663.88, p=0.000) and adopter of biogas (=484.40, p=0.000) was strongly and positively related with adoption of biogas technology adoption as it was expected, which implies that as inorganic increase by birr 663.88, biogas plant increases by one unit (Table 4.4).

Similarly, the regression result also reveals that cost of inorganic fertilizer has a significant and positive relation (β=2.32, p=0.02) on the level of decision to adopt biogas technology. The odds ratio, other factors held constant, the likelihood of biogas technology adoption increase by a factor of 0.998 as cost of inorganic fertilizer increases by one birr. This implies that household heads who spend more to purchase chemical fertilizer (more than the sample mean cost of chemical fertilizer) are one time as likely to adopt biogas technology than those spend less to purchase chemical fertilizer (less than the sample mean cost of chemical fertilizer). This is so because of the use of a byproduct of biogas could replace inorganic fertilizer to produce possibly higher for the crop products. The present study supports the study that undertook by Andre Croppenstedt and Mulat Demeke(1996) indicating new agricultural input technology adoption and the cost of inorganic fertilizer were found to have likely positive relationship. The author further explains that smallholders farmers are price sensitive to consume fertilizer and they want likely to shift other inputs or technology that would replace inorganic fertilizer. The justification for this could be that the cost of inorganic fertilizer has becoming un affordable for many of smallholders in the one hand and unavailable at the required amount and time on the other hand(FGD).

Initial Investment Cost (COSTII): Biogas digester system construction and installation require households financial ability, which might discourage an adoption of the technology. As hypothesized, Initial investment cost influences adoption of biogas technology negatively and significantly at P<5%. The odds ratio, other factors held constant, the likelihood of biogas technology adoption decreases by a factor of 3 as initial investment cost increases by one birr. This implies that a household head is three time less likely opt to adopt biogas technology as the cost of initial investment come to be more than the sample mean cost. The result is also supported by earlier studies of Mwakaje (2008) and Akinbami (2001) in explaining initial cost of investment is the most important constraint hindering biogas technology in the developing countries. Walekhwa et al., (2009) asserts that the most probable effect of income of household on adoption of biogas energy is the financial ability to install a digester system, which is often cited as the single most important factor determining whether a household adopts biogas or not.

5.1. Conclusion

The principal objective of the study was to investigate the socio-economic and environmental contribution of BT. The findings of this study reveal that biogas technology is one among other alternative energy that offers multiple socio-economic benefits and contribute to environmental conservation. Despite its importance, BT was not widespread in the study area. The finding of this study reveals that the adoption of this technology depends on socio-economic, environmental as well as demographic factors among the smallholders populace. Specifically, the study shows that the probability of a household adopting biogas technology increases with decreasing distance to access water, increasing distance to access fuelwood, increasing distance to access forest, increasing cost of kerosene, increasing cost of initial investment, increasing cost of inorganic fertilizer, increasing credit access, decreasing health cost reduction, and increasing distance to access urban center. Therefore, dealing with these factors could be of a great help to enhance biogas technology adoption in the study area.

5.2 Recommendations

The study shows that despite the multiple benefits to many people, adoption and utilization of BT has challenges. In this regard, policy makers and practitioners need to address the challenges that particularly the rural people are facing. Therefore, the following recommendations are forwarded based on the findings of the study to address the issues in point.

- Initial investment cost was found be discouraging a numbers of smallholders in the study area. In response to this, the existing subsidy and flat credit system should be considered because initial investment costs cannot be easily affordable for many rural households.
- Concerned stakeholders should cooperate at the different level and should devise non-ill mannered system to provide credit to adopters in order to share timely economic burden of the investment with the household. This can be implemented with the help of government institutions such as microfinance institutions (MFIs), Savings and Credit Cooperative Organizations (SACCOs), NGOs, and rural community development agencies.
- The study indicated that the households' proximity to the forest and fuelwood access had a negative effect on the attitude of farmers towards technology adoption and utilization processes even after installation of biogas plant. The implication is that proper targeting of household setting and awareness raising efforts should aim at reducing the attitude of dependency on biomass.
- Cost of inorganic fertilizer found to be another key factor that let rural people adopt biogas technology with the aim to utilize bio-slurry after biogas plant installation. At present, bio-slurry has become a living promotional tool by which smallholders' agricultural productivity increased by far better than that inorganic fertilizer does. Agriculture development office, Mines and Energy Agency, and other relevant stakeholders should be integrated to use model farmers whose livelihood is improved through the use of bio-slurry to scale up BT adoption and utilization.
- Fuelwood consumption is the main source of GHG emissions in Ethiopia. The wood is mainly used for residential baking and cooking purposes. As most of the households, particularly in rural areas, use highly energy-inefficient technologies (e.g., open fire or three-stone technology), the improvement potential here is huge. The dissemination of technologies leading to a reduction in fuelwood consumption, either by making more efficient use of it or by shifting to other, less carbon intense fuels, can be a major lever for GHG abatement. Therefore, biogas technology should be considered for its GHG abatement potential to ensure green economy.

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