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Adoption and perceptions of biogas: Empirical evidence from rural households of Melani Village in Raymond Mhlaba Municipality

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Abstract

Renewable energy which include biogas has been identified as a possible panacea to provide a cheaper energy, more accessible and environmentally sustainable. However, its adoption and use has been limited despite the important trade-offs it offers to rural households. Literature on agricultural innovations revealed that perceptions have an impact on decision making in respect of adoption of new technology and biogas is no exception. But there is paucity of systematic studies on the adoption and perception of biogas. This study was aimed at identifying the factors affecting adoption of biogas production, with emphasis on perceptions by means of a cross-sectional survey of 48 households. A binary logistic regression analysis revealed that age has a negative influence on biogas adoption, whilst employment status, land size and education have positive impacts on biogas adoption. Information on the economic benefits of low cost biogas should be made accessible to rural households.

***Keywords**: Agricultural innovations, biogas technology, economic benefit, technology adoption, rural development*

1. Introduction

Majority of African countries are energy insecure and there is a need to invest in renewable energy technology (Aliyu *et al*., 2017). The oil that most African countries import from other countries discourages economic growth and highlights the extent to which food security and energy security are interrelated. Since energy is needed for production and distribution of food, therefore, it is almost impossible to achieve food security without sufficient energy (Rasul & Sharma, 2016). In the face of the foregoing situation, researchers, including Maxwell (2014), have suggested that the adoption of biogas technology can be a sustainable approach in reducing energy insecurity at the local level. Smith, *et al.* (2014) added that the biogas digesters contributed towards reaching Millennium Development Goals (MDGs), and are no doubt crucial to the attainment of the successor Sustainable Development Goals (SDGs). Further, it is believed that this will encourage socio-economic development, create job opportunities and a growth path that is dual thus environmentally friendly and sustainable (DoE, 2015).

In the South African context, the Organisation for Economic Co-operation and Development— OECD (2015) revealed that electricity generation has not kept pace with growing demand, and power outages are the result of insufficient investment in expanding and maintaining electricity generation capacity. Despite the expenditure on energy by the rural communities, energy prices are still increasing (Department of Energy—DoE, 2012). The Department of Energy (2012) further explained that this energy price increase will cause a lot of stress to the rural communities. It is important for the government to consider potential energy substitutes in response to high energy prices (Arthur *et al.,* 2011).

The adoption of biogas is a vital tool to overcome energy deficits. It is further stated that biogas energy is found to be the most appropriate energy resource in addressing this challenge because it has been found useful by most rural communities of South Africa (Msibi & Kornelius, 2017). However the fact that this type of energy comes from waste matter creates special challenges. One is the obnoxious smell, which may repel some people and therefore lead to less than desirable response and adoption.

Technology adaptation is a complex process, and can both have uptake of technology and an existing technology. Traditionally, older farmers, who are experienced in their fields are risk averse (Meijer *et al*., 2015). Therefore, it is thought that perceptions, knowledge and

demographic factors have an effect on the adoption of renewable energy as argued by Sibisi and Green (2005). In addition, the decision of energy choices depends, to a great extent, on the household's level of income, size and awareness of the different energy sources available. For example DoE (2013) showed that low income households in South Africa heavy rely on fuel wood for cooking.

The emphasis given by the South African government and the promotion and the adoption of renewable energy was provided for in the 1996 Constitution, which has been translated in at least four policy documents thus 1998 White Paper on energy policy, 2003 White Paper on renewable energy and the 2011 climate change response white paper policy and the national development plan (DoE, 2015) as well as the Integrated Resource Plan, 2010 (RP2010).There is evidence that adoption of biogas technology is very low and little is known about factors that could be causing this poor adoption rate particularly amongst the rural households.

Therefore, the objective of this study was to identify the factors affecting adoption of biogas production, with emphasis on perceptions, in rural households by means of a cross-sectional survey of 48 households that included both producers and non-producers of biogas.

The rest of the article unfolds as follows: the next section provides a review of relevant literature before theoretical framework is presented. Afterwards, we describe the study methods and presents results with a discussion and conclude with some recommendations.

2. Literature Review

2.1 Contribution of biogas production to rural households

In view of Msibi and Kornelius (2017) adoption of biogas technology by low income households in South Africa can reduce their expenses on fuel wood purchase and health hazards resulting from it, in that regard they will be saving their income while living a healthy life. Importantly, Chakrabarty *et al*. (2013) emphasized that the use of biogas digesters in farms regularly is consistent with enhanced farm income. This can be achieved by producing only electric energy or combined with carbon credits.

Further, biogas technology is also mostly appropriate for rural farming households. In this regard, according to the Statistics South Africa's general household survey (2016), there are 2.3 million households involved in farming and of those, 24% still uses fire wood for cooking. Of those found in the Eastern Cape, 33% own livestock, while the other percentage farm with crops and other forms of farming, therefore there is potential for biogas substrate

given that most rural households use pit toilets (GHS, 2016). Moreover, noting that up to 14% of the monthly income of the rural people is spent on energy purchases, which is said to be higher than the international benchmark of 10% for energy power, shows a great contribution that can be made by biogas to rural low income households in South Africa (DoE, 2012).

Chakrabarty *et al*. (2013) stated that biogas production contributes indirectly to rural household income. This is achieved by substituting of other energy sources with biogas. Chakrabarty *et al*. (2013) further stated that time saved from collecting and preparing previously used fuel material can be also used to generate income. Moreover, biogas production can directly contribute to increase crop yield as agued by Wargert (2009) when he mentioned that slurry that has been digested is a high grade fertilizer. In fact the processed substrates are a better fertilizer than before the procedure.

2.2 Constraints faced by biogas users in rural communities

While biogas have great and positive trade-offs to rural low income households, there are some challenges accompanying it. Such challenges include limits to biomass use, and specific technology needs such as waterless cooling systems owing to the scarcity of water, the main barriers are to be found in the South African energy innovation system and in the economics of renewable energy technologies (Southern African Biogas Industry Association- SABIA, 2016). In addition, Bormann and Gulati (2014) stated that water needed to generate electricity is expected to be more. This will be a challenge in water allocation trade-offs between energy and agriculture.

Further, Wargert (2009) found that in rural community's context, it is often cattle owning farmers who have profited from biogas. The deprived individuals who do not possess any cattle have not profited from biogas other than in a roundabout way. For them the advantages have originated from greater job opportunities that the biogas sector has given and from better availability of firewood.

Moreover, Sibisi and Green (2005) argued that rural electrification can be a key tool in addressing inadequate access to electricity in rural communities. However, provision of electricity is more focused in urban than in rural areas, hence rural communities depend on more expensive, less available, energy sources, thus wood, paraffin or LP gas. Sibisi and Green (2005) further explained that non-rural electrification is caused by high investment require for the installation from service providers. Long distances between main roads and

rural communities and this make it to be expensive for the supplier to connect few consumers along a particular length of line.

In addition, According to Bond and Templeton (2011), since 1970 there has been spread installation of biogas digesters in India, Nepal, German and China, respectively. These countries have been involved in development of biogas projects and programmes for some years. However in other less developed countries the digesters are not functioning. This is due to the lack of maintenance and repairing of existing facilities. However, the involvement in less developed nations has been limited to small scale application of anaerobic digestion in remote areas.

In light of the above, SABIA (2016) in the Southern African context, South Africa in particular, highlighted that lack of skilled man power and skilled local labour to develop energy sector often depend on expatriates from developed nations to ran some other operation. In addition, grid connected to large scale biogas programme are rare to find in developing nations. Further, farmers from remote areas face the lack of financial capabilities to invest in biogas plants (Wargert, 2009).

Wargert (2009) also mentioned that during rainy season biogas digesters that are installed underground get flooded and this leads to maintenance time and costs. In that regard, Terero (2015) added that rural electricity schemes are usually more expensive compared to urban, this is led by low income which contributes to unaffordability. Secondly, long distances result in great electricity losses on high cost customer support and equipment maintenance. With regards to the mentioned issue, it is thought that failure of municipalities in financial planning result in infrastructure not being planned for, in the financial period (Mannie & Bowers, 2014).

Taele *et al*. (2006) have noted that in rural areas animals are kept in different areas seasonally. This prevents collecting enough animal waste needed to feed the biogas digesters and disrupts steady generation capacity. Wargert (2009) added that it is difficult to collect animal dung in an extensive farming system.

2.3 Factors affecting adoption of biogas production in rural households

According to Vera and Langlois (2007), energy is vital for eradicating poverty, enhancing human welfare and raising standards of living. However, most current patterns of energy supply and use are unsustainable. In that regard, Kaygusuz (2011) emphasized that

circumstance in rural communities is considerably more critical as local demand interest for energy exceeds accessibility and most of rural communities rely on upon non-commercial energy supplies. Several researchers including Pollet *et al*. (2015) and Msibi and Kornelius (2017) view biogas technology adoption as the key tool in addressing energy insecurity and environment problems in South Africa.

Psychologically adoption requires the use of individual's capabilities to be well informed about their environment in an intelligent manner. In that regard, a person and their environment have an effect on adoption process. The initiation of adoption process is when a person becomes aware and well informed. Rejection may follow or the adoption decision making may proceed. The adoption process occurs amongst particular contextual factors, be it social and cultural context, climate, geography and economic conditions (Botha and Atkins, 2005).

Local communities need to be knowledgeable about the technology to ensure long term competence in monitoring biogas digesters. The motive behind this initiative is for government to implement pilot biogas projects in agricultural areas to identify the importance of biogas technology (Wargert, 2009). Therefore, it is important to consider that knowledge a person have towards technology reflects perceptions and attitudes the person have towards the technology (Meijer *et al*., 2015).

3. Conceptual framework of the study

The conceptual framework demonstrates the interrelationships in the study area, the key variables and how they are involved and how they affect the uptake of biogas energy.

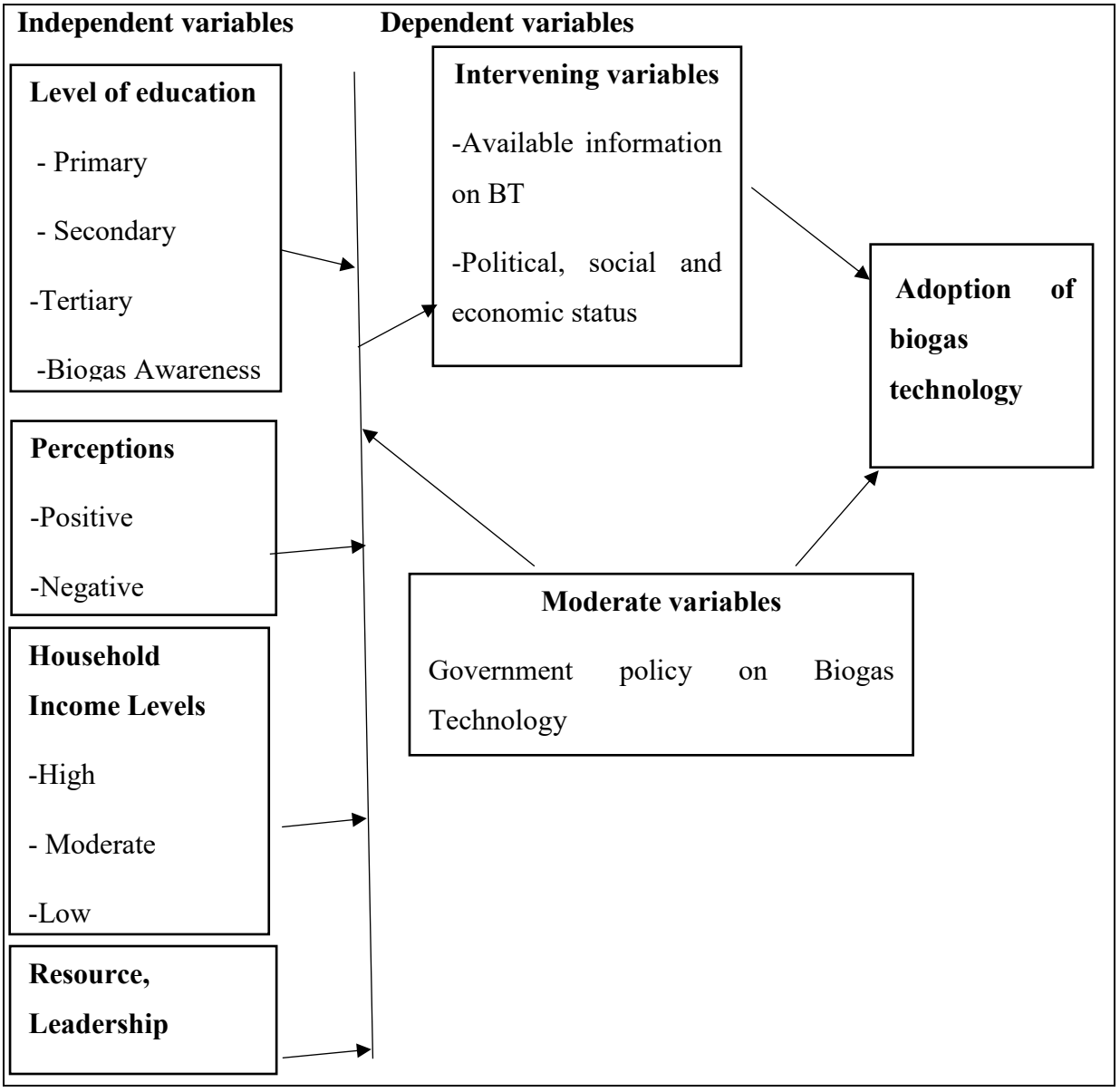

Figure 1: conceptual framework of biogas technology adoption by households.
Source: Adapted from Gakuu *et al*., (2013)

Figure 1 illustrate the conceptual framework of biogas technology adoption by households. This study was steered by the conceptual framework which has the following independent variables: level of education, perceptions of households, household income levels as well as resource and leadership. Other intervening variables included government policy on energy and investments in biogas technology.

The conceptual framework indicates that level of education of the respondents is bound to affect their adoption of biogas technology as those with formal education have access to information, knowledge and are, therefore, more likely to invest in biogas unlike those respondents without formal education. Knowledge about the technology and maintenance of

the biogas plants could affect adoption. Perceptions are also important in adoption of biogas technology.

Gakuu *et al*. (2013) reported that how people react when presented with biogas technology solely depends on their attitudes or perceptions regarding its use and cost, among other factors. Perceptions may either be positive prominent to their investing in the technology or negative which may mean their deteriorating to invest. Household incomes plays a crucial role in determining the decision to either invest or not based on the amount of disposable income available in the household and priorities that require allocation of scarce resources within the household. There more the household have high household income, there more the household invest in biogas while low income will make households decline the investment in biogas technology.

Noting the important trade-offs between biogas and low income rural households needs as discussed in the above sections, it make sense to think that factors such as resources owned by households in terms of size of land, number of cattle and size of household could influence the decision to adopt biogas technology. Further, Level of education plays an important role in Biogas adoption through the knowledge acquired from school. Leadership role is important and it play a role of being the gate keepers and innovators in the community which is an important aspect in technology adoption as their decision to take up or not an innovation influences the other community members positively. The study was carried in an at least consistent environment where the political leadership, economic status and social status are the same for all the people involved in the study area

4. Methodology

The study was carried out in Melani village of the Raymond Mhlaba Local Municipality. The Raymond Mhlaba municipality is described as a countryside municipality that sits on the foot of mountain range of the Winterberg (Nkonkobe Intergrated Development Plans, 2010/11). It covers 3 725 km^2 and makes up the R63 road of the surface areas of the Amatole District Municipality. The study employed information in the literature review and suggested that the research site should be in the Raymond Mhlaba Municipality, specifically in Melani village which is located in Alice town. Melani was chosen because it is the only village in the Municipality where biogas plants are in operation. The study was conducted from all biogas users and selected non-biogas users.

4.1 Data

The variables examined in the study are presented in Table 1. Previous studies have shown that household biogas production is strongly influenced by such factors as the physical conditions of the nature of production, access to production.

Table 1: Variable measurement and priori expectations

Variable	Description and unit of measurement	Expected Sign
Employment status	Amount of income generated by a household	+
Age	Age of household head in years	+/-
Level of education	Number of years spent in school by household head	+
Marital status	The farmers maybe single, married or widow	+/-
Household size	Number of family members	+
Technology adoption	Level of understanding of biogas production	+
Cattle ownership	Number of cattle owned by household	+/-
Water availability	Availability of water in the study area	+/-
Biogas equipment	Availability of biogas equipment in the study area	+
Biogas digesters monitoring	The safety and monitoring of the functioning of biogas digesters	+

Source: Field Survey, 2016

Education level (standard obtained): High levels of education could probable make it easier for them to understand many things regarding new techniques of production and information workshop trainings, especially new technology adoption. People who are illiterate have difficulties in understanding and so they need extra care.

Employment status: This variable is expressed as the head that brings income to a family. This determines the state of income the family has to survive, and consequently the time the family devotes to own production, If they are employed they will devote less time to mown production and vice versa.

Age: Older people are less energetic, illiterate and unease to comprehend technological advances.

Household size: The number of people living together in one house influences the activities occurring in the house. Having a large household means more hand available to perform household duties including more people available for farm

Marital Status: This variable determines the level of support one has from his partner has compared

Technology adoption: Training and education of householders is needed in relation to the maintenance of digesters, feedstock suitability and the environmental and potential livelihood benefits of digesters.

Cattle ownership: Households who owns cattle are likely more to have access to biogas compared to households who do not have the herd.

Water availability: Biogas operations consist of a fixed dome plant that uses biodigesters to produce biogas from waste material and water. So, the availability of water will matter as this will create a competition between drinking water and irrigation water.

Income: Income generating activities, both agricultural and non-agricultural,

4.2 Sampling technique and sample size

According to Ranjit and Kumar (2005), sampling is the process of selecting a few (a sample) from a population of interest so that by studying the sample we may fairly generalize our results back to the population from which they were chosen. The sample consist of 48 respondents who are biogas users and non-biogas users. Convenience or availability sampling was used which is a non-probability sampling method, respondents were interviewed with questionnaires until the desired sample size of (48) was reached. Sample size of 48 was used because the research focused only in the Nkonkobe municipality, which is with many numbers of farmers.

A sample of 48 households will be selected to participate in the research survey. The households will be selected to represent the population under the study. According to Bless *et al.* (2013), a sample of at least 48 units will capture the characteristics of the population. Choice of sampling size depends on budget for travelling costs, and time availability.

4.3 Data collection

Before data collection, the researcher conducted a survey with Fort Hare Institute of Technology officials to familiarize with the study area. Communal areas were visited in order to explore the income levels, biogas production projects, agricultural status, water availability and water sources and resource conservation techniques practiced. After identifying the

resources in the area, the researcher planned activities of the field study. Later on the planning of the field study, interviews were held in communal areas on matters relating to biogas production programs, income levels and agricultural activities in the study area.

Data were collected through administering close-ended questionnaires. The questionnaires were administered by researcher in order to reduce the problem of misrepresentation, or misunderstanding of some words or questions. It therefore, ensured that all the questions will be considered without respondents omitting the seemingly difficult ones. During interviews, questions were translated to the Xhosa language in order to enhance respondents' understanding and comfort in responding to questions. A qualitative approach was used, whereby both primary and secondary data shall be utilised.

Furthermore, interviews were conducted at household level to get individual farmer's opinions.

4.4 Analytical Framework

The study adopted binary regression analysis

$\sum \quad f = f1 + f2 + f3 + \cdots \ldots \ldots \ldots \ldots \ldots . fn$ ....(1)

Where:

$\sum \quad f =$ Sum of the frequency of the biogas users and non-biogas users

n is the number of biogas users and non-biogas users distinct values taken by the variable f

$f1 + f2 + f + \cdots \ldots . fn$ are the frequencies of the biogas users and non-biogas users?

To describe the average distribution and standard deviation of the households by age of household head, gender, farming experience, number of years in school and farm size, the mathematical symbol for mean and standard deviation were estimated by this expression:

$\mu = \frac{1}{n}\sum_{i=1}^{n} \quad x_i$..(2)

$\sigma = \frac{1}{n}\sqrt{\sum_{i=1}^{n} \quad (x_i - \mu)^2}$.. (3)

Where

μ is the population mean of the biogas users and non-biogas users, and it is calculated by adding up the values for each household and dividing by the total number of households.

σ is the standard deviation of the, biogas users and non-biogas users and it is a measure that is used to quantify the amount of variation of the data collected. A low standard deviation indicates that the sample tend to be close to the mean, while a high standard deviation indicates that the sample are spread out over a wider range of values.

n is the number of biogas users and non-biogas users distinct values taken by the value of x

5. Results and Discussion

The demographic characteristics such as gender, age, household size, income, education level and occupation are very important determinants of household decisions in terms of the technologies they employ in their farming operations, the way they allocate resources, and how much they want to produce as well as decision as to what to eat and what to sell. Table 2 represents demographic characteristics in the study area.

Table 2: Demographic characteristics of respondents (n= 48)

Variable	Biogas user		Non-biogas user	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Gender				
Female	7	53.8	25	71.4
Male	6	46	10	28.6
Total	13	100.00	35	100.00
Age of respondents				
20 – 40	6	46.2	6	17.1
41 – 60	5	38.5	14	40
61 – 80	2	15.4	12	34.3
>61	0	0	3	8.6
Total	13	100.00	35	
Marital status				
Married	4	30.8	13	37.1
Single	7	53.8	13	37.1
Widowed	2	15.4	7	20
Divorced	0	0	2	5.8
Total	13	100.00	35	100.00
Educational level				
No formal education	0	0	9	25.7
Primary education	4	30.8	18	51.4
Secondary education	9	69.2	8	22.9
Total	13	100.00	35	100.00
Household size				
1 – 4	7	53.8	20	57.1
5 – 8	5	38.5	14	40
9 – 12	1	7.7	1	2.9
Total	13	100.00	35	100.00
Employment status				
Unemployed	8	61.5	29	82.9

Formally employed	1	7.7	2	5.7
Self employed	3	23.1	4	11.4
Part time farmer	1	7.7	0	0
Total	13	100.00	35	100.00
Source of income				
Agricultural activities	0	0	1	2.9
Salaried employment	3	23.1	3	8.6
Trading/business	2	15.4	2	5.7
Social grants	8	61.5	29	82.9
Total	13	100.00	35	100.00

Source: Based on SPSS processing of field data, 2017

Descriptive analysis revealed that number of factors has influence on the biogas adoption. Low levels of education and knowledge on operation of biogas digesters seemed to hinder the adoption of the biogas technology in the study area. The results revealed that biogas adoption is influenced by age, education, and source of income. Moreover, results showed that the older the people are less active in biogas project in Melani village. This could be triggered low levels of education and average household income as the findings have shown.

5.1 Distribution of biogas adoption in relation to lack of awareness

Informing rural communities about biogas and its positive effect is vital. In that case people will be knowledgeable about the technology might trigger their decision making. The results are shown in Table 3.

Table 3: Lack of awareness of biogas technology

	Biogas user		**Non biogas users**	
Response	**Frequency**	**Percentage**	**Frequency**	**Percentage**
No	6	46.2	15	42.9
Yes	7	53.8	20	57.1
Total	**13**	**100.00**	**35**	**100.00**

Source: Based on SPSS processing of field data, 2017

Table 3 indicated that lack of awareness of biogas technology was the important factor in biogas adoption as most respondents both users (53.8%) and non-biogas users (46.2%) agreed that lack of awareness was the major constraint that influence the adoption of biogas technology in the study area.

5.2 Distribution of biogas adoption in relation to lack of knowledge about operation of biogas digesters

From view of progressive communal innovation programme, knowledge counts as one of most vital variable in the analysis. In that regard, Wargert (2009) emphasized that biogas project are sustainable if people are well knowledgeable about the technology. Interestingly, if this is maintained no technical errors will be incurred. The situation with respect to knowledge and influence on adoption were examined. It is vital to spread the knowledge locally about biogas technology to ensure the sustainability in construction and maintenance of biogas digesters (Wargert, 2009), the results are presented in Table 4.

Table 4 : Lack of knowledge about operation of biogas digesters

	Biogas user		**Non biogas users**	
Response	**Frequency**	**Percentage**	**Percentage**	**Frequency**
No	6	46.2	17	48.6
Yes	7	53.8	18	51.4
Total	**13**	**100.00**	**35**	**100.00**

Source: Based on SPSS processing of field data, 2017

According to Table 4, majority of respondents both biogas users and non-biogas users agreed that lack of knowledge about operation of biogas digesters influence the adoption of biogas by 53.8% and 51%, respectively. The reason could be that biogas users did not get proper training. These results are rationale with Momanyi *et al.* (2014) who indicated that lack of knowledge in relation to technical services are the major constraint in biogas adoption.

5.3 Factors influencing perceptions held

Results attained from the logistic regression model and these results are based on factors influencing biogas adoption. Number of factors influencing the biogas adopter was tested using the Binary regression Logistic Model. Measures of the significance were at 1% and 5%. Variables were selected based on previous studies. Factors influencing biogas adoption included age, source of income, land size and education. The results are presented in Table 2.

Table 5: Factors influencing perceptions held

Variable	**β**	**S.E**	**Sig.**
Constant	-5.139	3.291	0.118
Age	-0.082	0.042	0.052**
Source of income	-0.837	0.356	0.019***
Land size	1.301	0.617	0.35**
Education	-0.315	0.537	0.001***
Likelihood	45.577		

Pseudo R2	0.325
R^2	0.440
N = 48	

*** and ** represent significance levels at 1% and 5%

Source: Field survey, 2017

The variables that included age, source of income, land size and education were identified as significant from the study results. On one hand, age and land size variables were significant at 5% on other hand source of income and education variables were significant at 1%.

Age: The variable was statically significant at 5% level, in reference with results presented in descriptive statistics. The coefficient was negative and was in commensurate with expected priori. The coefficient was negative indicating that biogas adoption decreases as the age increases. This reason for such is that older people are pensioners and they do not have time to spend on community projects, they are only focusing on their health, however young household heads are active and willing to work. These results are in line with descriptive statistics that indicated that majority of households were unemployed biogas user and non-biogas constituting, 66.5% and 82.9 respectively.

Source of income: The variable was statistically significant at 1 percent level. The empirical results from binary model indicate that source of income has an influence in biogas adoption. As shown in descriptive statistics majority of households in Melani village depend on social grants, this indicates that they are not able to stand with the ever increasing energy prices (Phogole, 2011). So, biogas is cheaper and affordable hence most of them will choose to save and opt for biogas adoption. Moreover, the time that they spend to fetch wood will be redirected to other income generating activities. Lastly the money that they spend on electricity will be reduce therefore they can use it to other household needs.

Land size: The logistic regression suggested that a unit increase in household land size is likely to increase the chances of biogas technology adoption. The variable was statistically significant at 5 percent level. This means that households with larger land size have enough space to build a biogas digester in their homestead. Moreover, household with larger gardens are in advantage to use slurry in their gardens as fertilizer consequently they will be increasing crop yield as the fertiliser is more fertile. This will also encourage the multiple cropping especially that the fertiliser will be suitable and yield will be increased (Warget, 2009).This implied that households with large gardens were more adaptive to biogas technology compared to the ones with small gardens.

Education: The variable was strongly statistically significant at 1 percent level. However the coefficient was negative it is clear that younger people are more knowledgeable about biogas technology than the elderly people. The main reason for variation in adoption is led by literacy amongst age groups. Number of older non-biogas adopters without formal education is much higher compared to younger non-biogas adopters.

6. Conclusion

While biogas technology has many advantages and can potentially improve rural livelihoods of the residents of Melani village, its adoption has not increased since the inception of the project. Majority of households have primary education and some of them had no formal education. Education, source of income and land size were found to have an influence on technology adoption. It was exactly clear that perceptions played any significant role in the limited adoption of the biogas technology by households in the study area. In the absence of such evidence, it is reasonable to assume that a stronger marketing strategy would be necessary to create awareness of the benefits of the technology and encourage rural dwellers to adopt the technology for both domestic and productive activities.

Recommendations

Households, especially in rural areas, need to be made aware of new technological advancement that can be of help to them. This can be attained through awareness campaigns by government in collaboration with the private sector. Government should employ more facilitators to train the communities about technical errors of the technology.

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