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Livestock Farmers' Perception on Generation of Cattle Waste-based Biogas Methane: the Case of Embu West District, Kenya

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Abstract

Perception of livestock farmers on the generation of cattle waste-based biogas methane was evaluated in this study. The study was carried out in Embu West district in Kenya. A random sampling technique was used to gather information related to farmers' perception and the data collected with the help of self designed questionnaires and face to face interviews. In the study, 92.9% of the one hundred and fifty six (156) livestock farmers practiced zero-grazing and only fourteen (9%) of them had installed biogas digesters in their farms. Chi square tests yielded a value of $\chi = 0.591$, $p > 0.05$ which indicated that there was no significant relationship between uptake of cattle waste-based biogas and farmer's perception. The hypothesis that low uptake of cattle waste-based biogas technology was due to negative perception of the farmers was found not to hold. Further Chi square tests indicated significant relationship ($\chi=23.56$, $p< 0.05$) between farmers' perception and knowledge of cattle waste-based biogas methane. Thus livestock farmers in Embu district had a very positive perception and were quite knowledgeable about biogas technology despite the minimal installation of the cattle waste-based biogas digesters. The research findings indicated that other factors like installation cost contribute to the low uptake of biogas technology. These research findings should assist government and industry understand the reason behind public 'reservations' in the adoption of biogas technology as well as develop strategies for enhanced promotion of renewable energy technologies.

Keywords: Biogas methane, perception, renewable energy, Embu west

1. Introduction

Biogas methane is produced by the anaerobic (oxygen free) digestion or fermentation of organic materials such as cow dung, sewage, green waste, plant materials and crops. This natural process is exploited in a digester, where organic material is put in an airtight container or digestion chamber. The products are biogas and an organic residue (bio-manure). Biogas comprises of 55-66% methane (CH_4), 40-45% carbon dioxide (CO_2), and small amounts of hydrogen (H_2) and hydrogen sulfide (H_2S) gas depending on the conditions during production (KVIC, 1993). Methane is a constituent of natural gas and therefore biogas methane is primarily used as a fuel when combusted with oxygen. The main fuel for cooking and lighting, in many homesteads practicing small scale farming commonly found in geographical areas like Embu West district, is biomass –mostly wood fuel (68%), followed by fossil fuels-petroleum (22%), electricity (9%) and renewable energy sources at about less than 1% (SNV, 2012). The concerns arising from the use of fossil fuels include the possible depletion of these mineral resources, their ever-increasing cost and the environmental pollution from their combustion. The use of biogas as a fuel is set to increase in the future due to its potential to counteract health and environmental impacts connected with traditional biomass energy and fossil fuels. This is because biogas methane has higher content of hydrogen relative to carbon (Svensson, 2005). The combustion of biogas methane produces more water (H_2O) and less carbon dioxide (CO_2) compared to more complex hydrocarbons such as coal, oil and solid fuels.

Biogas is a renewable energy source and has many advantages. Although methane is a potent green house gas, its contribution (20%) to green house effect is much lower than the contribution (60%) of carbon dioxide produced by human activities such as combustion of fossil fuels (Svenssons, 2005). Combustion of biogas methane helps minimize amounts of methane in atmosphere originating from increase in livestock waste, landfills and leakages during drilling of fossil fuels. Biogas methane is an energy source widely used as a fuel substitute for firewood, dung, agricultural residues, and kerosene (Lichtman, 1983). It is a clean and particulate free source of energy which reduces the likelihood of respiratory diseases that are associated with the indoor combustion of bio-mass and fossil fuels (Banerjee, 1996). Biogas energy frees up time for rural women, since a regular supply of energy piped to homes reduces daily task of gathering firewood (Lewanhak, 1989). Biogas technology contributes to healthier lifestyles because anaerobic digesters function as waste disposal systems, reduce odor, and prevent spread of pathogens (Lichtman, 1983). The residue organic waste (bio-manure) from biogas digesters has superior nutrients over usual organic fertilizers because all nutrients (e.g. Nitrogen and phosphorous) in original substrate are retained in soluble and plant-available forms in the residue (Held *et al.,* 2008). Use of residue (bio-manure) leads to increase in agricultural productivity (Sasse *et al.,* 1991). Biogas, a clean fuel and raw material is in demand for many industrial manufacturing processes (Held *et al.,* 2008). Although Biogas can be generated from a variety of organic materials, animal manure (cow dung) is the most suited for most of the domestic installations in Africa (Felix and Kai, 2007).

Large-scale installations of renewable energy sources have faced widespread opposition in Europe (Toke, 2005; Upreti, 2004; Upham & Shackley 2007; and Warren *et al.,* 2005). In particular, some people in many of European countries consider biogas technology as dirty and rather old-fashioned way to produce energy. This perception prompts many to resist installation of digesters "in their backyard" and therefore low uptake of biogas technology. As indicated in the Government of Kenya (GoK) Session Paper No. 4 of 2004 the uptake of biogas technology in Kenya has been slow despite the promotional activities. We therefore sought in this study to determine whether the perception of livestock farmers in Embu district (Kenya) affect adoption of biogas technology. Embu district was chosen because it has a relatively high human-population density and has on average some of the richest people in Kenya according to UNDP report (Gisesa, 2010). Areas with high human population densities have climatic conditions with plenty of water and accessibility to fodder conducive to livestock farming, factors favorable for adoption of many biogas digesters. According to Moulik (1981), the biogas programme cannot cater to the needs of poor and marginalized people, because such groups of people fail the technical requirements to maintain a viable plant. A cattle waste-based biogas plant is economically or operationally viable when at least two cattle provide the necessary cow dung.

2. Research Questions

1 What is livestock farmers' knowledge of generation of cattle waste-based biogas methane?
2 What is the relationship between the farmers' perception and knowledge (know how) of the cattle waste-based biogas technology?
3 Is there a relationship between the farmers' perception and the level of uptake of the cattle waste-based biogas technology?
4 What other factors besides farmers' perception affect the uptake of the biogas technology?

3. Literature Review

Biogas generation by anaerobic digestion of matter in the absence of oxygen is preferred to aerobic digestion (in the presence of oxygen) because very little heat is generated and the final product has higher nitrogen content. GATE (1999) has categorized anaerobic digestion into a three-stage process in which specific bacteria feed on certain organic materials. In the first stage, acidic bacteria first break down the carbohydrates, proteins and fats present in the animal waste (manure) into simpler compounds namely; alcohol, carbon dioxide, hydrogen, ammonia and sulfides. This 'hydrolysis' or liquefaction stage is expressed as equation 1.

$$Carbohydrates + Proteins + Fats \rightarrow Alcohol + Carbon\,dioxide + Hydrogen + Amonium + Sulfides \quad (1)$$

In the second stage, acetogenic (acid forming) bacteria further digest the products of hydrolysis into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2) gases according to equation 2.

$$Alcohol + Carbon\ dioxide + Hydrogen + Amonium + Sulfides \rightarrow Acetic\ acid + Hydrogen + Carbon\ dioxide \quad (2)$$

In the final stage, methanogenic (methane forming) bacteria then decompose these products to form methane gas and carbon dioxide as given in equation 3.

$$Acetic\,acid + Hydrogen + Carbon\,dioxide \rightarrow Methane + Carbon\,dioxide \quad (3)$$

When cattle dung is the major constituent in fermentation, the resulting gas has composition of between 55-66% methane (CH_4), 40-45% carbon dioxide (CO_2), plus negligible amount of Hydrogen sulfide (H_2S) and hydrogen (H_2) gas (KVIC, 1993). Methane constitutes the energy-rich part of biogas.

Cattle waste-based biogas generation involves collection of the manure from cows, which are usually housed in a specially designed cattle shed from where they get fed with fodder and water. Where cattle urine is uncollected, the cow dung must be mixed with water and left to ferment in a digester. The water or animal urine enables both the digester's microbiological process and its hydraulic functioning. The processing water does not have to be of drinking quality but it should be available in significant quantities near the digester (Sasse *et al.,* 1991). The gas produced is then piped into the house. Cow dung slurry is composed of 1.8-2.4% Nitrogen (N_2), 1.0-1.2% Phosphorus (P_2O_5), 0.6-0.8% Potassium (K_2O), and 50-75% Organic humus (KVIC, 1983). After digestion, the bio-manure obtained has nitrogen content of 6kg/m^3 which is certified according to SPCR 120 (Held et al 2008). The carbon-nitrogen (C:N) ratio get narrowed during methane production, while a fraction of the organic nitrogen is mineralize to ammonium (NH_4^+) and nitrate (NO_3^-), the form which is immediately available to plants (Sasse et al., 1991). Application of bio-manure to farms improves the nitrogen status and structure of the soil reducing the need for mineral fertilizers.

About 0.028m^3 may be generated from one pound of cow manure at around 28^0C where 1.7m^3 of biogas equals one liter of gasoline. The calorific value of biogas is about 6 kWh/m^3 which corresponds to about half a liter of diesel oil. However, the net calorific value depends on the efficiency of the burners or appliances (KVIC, 1993). According to report by ETC Group (2007), households with 2 or more cattle under zero grazing are technically eligible to benefit from biogas technology because such animals produce enough dung to feed the biogas digesters. Biogas digesters also function as effective means of waste disposal. The decrease in waste is an important defense against climatic change. When used as vehicle fuel, biogas gives the smallest emissions of carbon dioxide and particulate matter of all vehicle fuels on the market (Held *et al.,* 2008). The methane molecule (CH_4) is the smallest of all hydrocarbons. Therefore, biogas is considered a clean fuel because combustion of energy-rich biogas methane produces negligible amounts of carbon dioxide. Biogas methane is a green house gas and therefore methane leakages during handling of biogas and bio-manure should be avoided (Held *et al.,* 2008). However, methane is rendered harmless when it is combusted to produce mainly carbon dioxide (CO_2) and water.

Cultural practices may also hinder general uptake of biogas technology, due to reluctance by some people to adopt different behavior particularly regarding use of latrines in biogas systems. Also traditional cooking practices may need to be altered. Moulik (1983), identified a common complaint that stable bread could not be properly roasted using biogas burners. He also reported that there was need to occasionally supplement biogas with firewood for prolonged cooking of beans and similar foods that require relatively high heat intensity to cook properly.

Since 1957 when Mr. Hutchinson built the first biogas digester in Kenya, both the Kenyan government (GoK) and the non-governmental organizations (NGO's) have constructed hundreds of biogas digesters in the country free of cost to consumers through demonstration projects (ETC Group, 2007). The potential in Kenya for biogas energy is estimated at 200,000 biogas plants if adopted by around one (1) million people (SNV, 2012). According to a report from Ministry of Energy, the potential for adoption of biogas energy is highest in the region of high population densities. Such regions have abundance supply of water and fodder for animal fed in zero grazing units (GoK, 2004). The report further points out that despite the potential benefits of biogas, the penetration rate of biotechnology (uptake) is still very slow and low. This state of affairs is attributed to factors like; poor management, high installation and maintenance costs, limited water supply and weak technical support. The slow and low uptake could also result from public opposition to renewable energy technologies (Toke, 2005; Upreti, 2004; Upham & Shackley 2007 and Warren *et al.,* 2005). The objective of this study therefore was to investigate the farmers' perceptions and opinions and also determine how this contributes towards acceptance of biogas technology.

4. Scope of the Study

The data was gathered from the farmers practicing zero grazing in Embu west district (Kenya). The respondents in the study were both livestock farmers who had installed and those who had not installed biogas digesters. The study focused on the cattle waste primarily the cow dung as the raw material for generation of biogas methane. One hundred and fifty six (156) livestock farmers participated in the study.

4.1. Methodology

The research design used in the study was survey. In surveys, the units of analysis are the individual people. Therefore, this research surveyed livestock farmers. The study comprised of both quantitative and qualitative survey methods. Questionnaires were developed and used as instruments of gathering data. The participants were chosen through the random sampling technique.

4.2 Data Collection and Analysis

The researchers visited the farms selected randomly within the district and collected data by directly talking with livestock farmers. The collected data was analyzed using the Statistical Packages for Social Sciences (SPSS-16.0). The analysis comprised of percentage analysis, cross-tabulations, and Chi-square tests. The research findings were grouped according to the research questions. These results were then presented as shown in following section.

5.0 Results and Discussion

5.1 The following are the general findings from study

- Both gender participated almost equally in study: male (53.2%) and females (46.8%).
- Most (19.9%) male respondents were 56 years or more while most (12.8%) females were between 36 and 45 years old.
- Most (37.2%) of respondents had farming experience of 10 years or more
- Majority (92.9%) of respondents practiced zero grazing.
- Majority (75.4) of livestock farmers reared two (2) or more cows.
- Minority (9%) of respondents had installed biogas digesters in their farms.
- Majority (95.5%) of respondents had adequate amount of water and fodder for livestock.
- Only 18.6% of respondents indicated the cost of digester was between USD40 to USD 90.

5.2 The following are findings about livestock farmers' knowledge of generation of cattle waste-based biogas methane

- Most of respondents (71.8%) were either moderately or very well informed about biogas generation.
- About 67.9% of the farmers who participated in the survey indicated they were either fairly knowledgeable or very knowledgeable about how a digester works.
- Most (63.3%) of the farmers interviewed had visited a working digester.
- Majority (89.7%) of the farmers knew the benefit of using biogas to reduce daily task of gathering fire wood-fuel.
- Majority (85.9%) of farmers knew that the use of biogas energy could help in reducing respiratory diseases.
- Majority (84%) of respondents indicated that limited knowledge of the workings of a digester could limit them from installing a biogas digester.

5.3 The following are findings about sources of livestock farmers' knowledge of generation of cattle waste-based biogas generation indicated as source (percentage).

- Fellow farmers (30.0%). This source held the greatest influence as a source of information on biogas technology.
- Media (20.5%). Through informative programs on TV, national and vernacular radio stations
- NGOs (11.0%).
- Min of agric officers (13.3%).
- Agricultural trade fairs (3.8%).
- Faith based (Church) seminars (2.4%).
- Schools (10.0%).
- Environmental conservation agencies (2.9%).
- Unrevealed sources (6.2%).

5.4 The following are findings about perception and attitudes of livestock farmers on generation of cattle waste-based biogas methane

- Majority (93.6%) of the livestock farmers were positive about investing in biogas technology.

- Majority (75.6%) of respondents thought their neighbors' opinion of biogas digester was positive.
- Most (55.1%) of the farmers were positive about purchasing biogas from their neighbor who had excess.
- Majority (90.4%) of the farmers considered it worthwhile to engage the potential users of biogas technology with dialogue.
- Majority (82.1%) of the farmers thought that the digesters would not affect the landscape.
- Majority (85.9%) thought that biogas technology was useful in conserving the environment.
- A large percentage (47.4%) of the respondents would not have difficult in using cattle waste-based biogas energy in cooking certain traditional foods like githeri and ugali since the cookers are incapable of providing very intense heat.
- Majority (61.5%) of farmers considered biogas digester as a waste disposal system.
- Most (55.5%) of respondents considered residual organic waste (bio-manure) to have superior nutrient qualities over usual fertilizers and cattle dung.
- Majority (84%) of the livestock farmers indicated that limited knowledge of a working digester could limit them from installing a biogas digester.
- Majority (89.7) of respondents said that the regular supply of biogas reduces task of gathering firewood.
- The proportion (36.5%) of farmers who preferred biogas digesters installed above the ground was almost equal to the proportion (40.4%) of farmers who preferred digesters installed underground.

5.5 *The following are the findings of Cross tabulation*

- Majority (59.6%) of respondents knew of biogas generation from visits to an operational digester. They were also positive about investing in biogas generation.
- Majority (93.6%) of farmers were positive about investing in biogas technology but only 9% had installed the digesters. This indicates low uptake of technology despite positive perception of respondents.

5.6 *The following are the findings of Chi-square tests*

- There is a significant relationship (χ=23.56, p< 0.05) between farmers' perception and knowledge (via visitation to a working digester) of cattle waste-based biogas methane. More model digesters should be constructed widely for farmers to visit and interact with biogas generation plants.
- There was no significant relationship (χ=0.591, p< 0.05) between farmers' perception and uptake of cattle waste-based biogas methane technology. The null hypothesis of the study is true.

5.7 *Other factors besides knowledge and perception contributing to low adoption of biogas technology included:*

- Lack of installation capital (31.3%) and
- Lack of knowledge of digester's operations (37%)
- Shortage of trained technicians to install & service digesters (14.4%)
- Lack of exposure to a working digester (6.3%)
- Low gas pressure (2.9%)
- Preference for electricity (1.9)
- Broken down digesters (no maintenance) (1.4%)
- Less than 2 cows (1.4), inadequate supply of dung to feed digesters
- Distance from farm to house (1.0%)
- Use LPG gas, wood, charcoal (0.5%)
- Labor involved in feeding the digesters (0.5%)
- Lack of interest (1.0%).

In the study, Majority (92.9%) of the one hundred and fifty six (156) livestock farmers who participated in this study practiced zero-grazing. However, the biogas technology uptake was very low since only fourteen (9%) of the farmers had installed biogas digesters in their farms. The study also revealed that livestock farmers in Embu west district had a positive perception of cattle waste-based biogas generation. The Chi square tests yielded a value of χ = 0.591, p >0.05 which indicated that there was no significant relationship between uptake of cattle waste-based biogas and farmer's perception. Therefore perception seemed to have no effect on the uptake. The study also revealed that most farmers were knowledgeable about cattle waste-based biogas generation as revealed by correct responses they gave regarding advantages of biogas generation. The main source of this information was fellow farmers during formal and informal farm visits, societies, and self-help groups-interactions. Further Chi square tests indicated significant relationship (χ=23.56, $p< 0.05$) between farmers' perception and knowledge of cattle waste-based biogas methane. Thus livestock farmers in Embu district had a very positive perception and were quite knowledgeable about biogas technology despite the minimal installation of the cattle waste-based biogas digesters. However, the high level of knowledge about cattle waste-based biogas had no direct relationship with uptake of this technology. Other factors besides perception contribute to the low uptake of this technology. Some of the factors given by the farmers besides perception and knowledge included lack of installation capital, shortage of trained technicians for installing and servicing the digesters, lack of exposure to a working digester, low gas pressure, preference of electricity and natural gas and failure of digesters. The cost factor coincides with results from earlier research (ETC Group, 2007). The few (9%) livestock farmers who had installed digesters, reared two or more cows and had other sources of income besides agriculture.

5.8 Suggestions

Trained technicians:

Number of trained technicians should be increased to service digesters and provide basic training to farmers on operation of digesters.

Popularizing biogas generation

Promotional efforts to popularize use of biogas energy should be focused on reaching farmers during their formal and informal farm visits, societies or cooperative meetings and self help groups- interactions and media. Environmental NGOs and pressure groups should be engaged in these efforts because the general public appear to trust these groups more than government and industry.

Upgrading biogas

The energy content of biogas should be increased by removing carbon dioxide in a process called biogas upgrading. Upgraded biogas has same properties as natural gas and is used as fuel in specially designed vehicle.

Government subsidies

Government should consider reducing tax on biogas digesters and increase subsidies to livestock farmers to enable them adopt biogas technology due to its many benefits like reduced health complications though use of clean energy. The cost of installing biogas digesters should be reduced.

Enhanced source of information on biogas generation

Government to establish a 'one stop' information source center that avails data, information and best practice on biogas energy

Reviving the model digester

The model digester once installed by agricultural trade fairs should be revived and also devolved to selected demonstration farms. Feeding of digesters should be simplified to reduce the labor burden.

Methane leakage

Methane is a green house gas. Therefore, digesters should be upgraded to avoid its leakage during treatment. Biogas producers should regularly carry out inventory for gas leaks.

6. Conclusion

The livestock farmers in Embu west district who participated in this study had a positive perception on cattle waste-based biogas methane despite the fact that the uptake of this biogas technology was low in the district. The hypothesis that low uptake of cattle waste-based biogas technology was due to negative perception of the farmers was found not to hold. The hypothesis that farmers may have a negative perception towards cattle waste-based biogas generation was because of the nature of the material waste involved, its smell and the work involved before biogas is generated. The study also revealed that most farmers were knowledgeable about cattle waste-based biogas generation. However, the high level of knowledge about cattle waste-based biogas had no direct relationship with uptake of this technology. Conversely the livestock farmers in Embu district had a very positive perception and were quite knowledgeable about biogas technology yet there was low uptake of the cattle waste-based biogas technology. The research indicated that installation cost was the major setback in uptake of the cattle waste-based biogas technology. The inability to raise enough capital for a biogas digester for most of the farmers in Embu west district is consistent with existing research in other district in Kenya (ETC Group, 2007). The research findings also indicated that other factors like, shortage of trained technicians for installing and servicing the digesters, lack of exposure to a working digester, low gas pressure, preference of electricity and natural gas and breakdown of digesters contribute to the low uptake of biogas technology. These findings underscore and add to the growing literature on the uptake of biogas technology and will assist the government and industry understand the reason behind public 'reservations' in the adoption of biogas technology as well as develop strategies for enhanced promotion of renewable energy technologies. Therefore, given that the farmers in this region in Kenya have a positive perception on biogas generation and are very knowledgeable about it, funding them towards cattle waste-based biogas digesters installation would be a worthwhile venture considering the benefits that will be achieved.

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