BENEFITS OF USING BIOGAS IN HOUSEHOLDS: EXPERIENCE FROM A USER IN UGANDA

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ABSTRACT

This paper discusses the socio-economic benefits of using biogas based on the experience of a long term user as a typical example. A floating drum type of digester was installed with a capacity of 6.5 m^3 in the year 2000 at a total cost of US$ 1,830. The gas generated is used exclusively for cooking. For the user, his typical kitchen day consists of three meals for a household of 8 people. Prior to the installation of the biogas plant, the user was using liquefied petroleum gas (LPG) supplied in 15 kg cylinders at an average cost of US$ 23 per cylinder and used to consume an average of 3 cylinders in 2 months bringing a monthly expenditure on the kitchen fuel of US$ 35 including transport costs for the cylinder. The user has now totally substituted LPG with biogas which translates into an annual average saving of US$ 420. At this rate of saving, the break-even point for the full recovery of the installation costs is about five years. Since installation the digester has not had any significant breakdown, so no major maintenance has been required. The water used for mixing the cow dung into slurry is harvested rainwater. Thus according to his experience it indicates that the use of biogas offers a substantial cost saving on domestic energy. In addition to the economic benefits, other benefits include increased organic agricultural production when the sludge is used as fertiliser. The use of the slurry as bio-fertiliser on his small vegetable farm (about 0.5 ha), has helped him to save money that would have been used to buy the imported artificial fertilisers. Fermenting the cow dung in a biogas digester instead of composting it in open air provides several other advantages, ranging from a foul odour-free environment to improvements in the general health conditions in the home. Thus, a reduction in the unhealthy smell from the compost dumps where the cow dung used to be deposited, as well as a reduction in free methane gas (one of the green house gases, GHG) which used to be emitted direct into the atmosphere by the decomposing dung.

1. INTRODUCTION

Biogas technology is one of the fully developed renewable energy technologies from bio-wastes. Biogas is now used in developing countries as an alternative and a renewable source of energy for domestic applications. In Uganda the use of this form of energy is relatively recent.

In the lumen of most mammals are numerous resident micro organisms and among these is a class of useful bacteria which play a significant role in biogas digester. Anaerobic bacteria known as *methanobacteriacea (archo bacteria)* which through a series of complex biochemical reactions and collectively known as fermentation, convert the food passing through the gut into several chemical compounds one of which is the hydrocarbon methane. It is this gas that constitutes the bulk (>70%) and the main active component of biogas. Most animals expel this gas freely into the atmosphere every time they pass out the abdominal gases or when they dump solid waste. Besides being a clean fuel, methane together with carbon dioxide are the main greenhouse gases. As long as the conditions are right the fermentation process can continue outside of the animal's abdomen. These conditions are harnessed in the production of biogas in a man-made fomenter or bio digester which is used as an alternative fuel for domestic cooking and lighting in several developing countries around the world, in particular India.

The use of biogas as a source of domestic energy in Uganda is relatively new although there have been attempts in the past to introduce it in the country mainly with Chinese expertise with limited success. Recently Makerere University with a grant from the Rockefeller Foundation and the World Bank started popularising and introducing this form of energy to the rural communities. This in part is a response to the on-going massive deforestation in the country with its attendant environmental problems, caused by the increasing demand for timber and fuel wood or firewood. Fuel wood in the unprocessed form or as charcoal is most widely used form of energy in rural, peri-urban and some urban centres in Uganda. At a conservative estimate fuel wood constitutes over 90% of all the energy used for domestic purposes in the country. This in part is due to the fact that fuel wood is readily available and in most cases it is free to most people. If it is not free, it is perceived to be the cheapest form of energy available to the low income groups. This paper describes the hand on experience of one user of biogas in Uganda who is also a co-author of this paper (PJMS).

2. THE GENESIS OF TURNING TO OVER BIOGAS

The user is a Chemist with many years of university teaching and academic administration. During the many years he spent as a practising Chemist, he became acutely aware of danger of overdependence on non renewable forms of energy such as fossil fuels. The oil embargo imposed by the oil producing countries in 1973 through OPEC was a painful reminder of this danger. The embargo led to a frantic search for alternatives. As a postdoctoral research fellow at Queen's University, Belfast, UK, he spent two years studying the possibility of using hydrogen as an alternative to the hydrocarbons which are derived from petroleum and in particular its storage in metals as a loose hydride. Other researchers elsewhere were examining other forms of renewable energy including wind, solar and biomass (more so biogas). Although the research tempo subsided when the embargo was lifted, the search goes on to this day. The user's interest in renewable energy was stimulated by his research work on hydrogen. His attention was drawn to biogas by two reasons; the concern for the environment and the high cost of electricity and petroleum products such as liquefied petroleum gas (LPG) in Uganda.

The user returned to Uganda at the end of the 1970s and started planning the construction of a bio digester at his residence but the plans had to be shelved due to the difficult political and economic period Uganda was going through at the time. Since biogas can be obtained from any biomass including the human excreta and hog manure, the user could have used any the available raw-material as feed for his digester but on social and cultural grounds this was not possible. First people would feel offended to be fed on food cooked with fuel derived direct from their excreta. The user carried out a small opinion survey within his family to test the acceptability of this idea. All objected to the use of the excreta. Secondary the health risks inherent in the handling of human solid waste could not be overlooked. These can only be minimised if a large quantity of the excreta is concentrated in one location such big schools or prison centres. For example in Rwanda human waste which had accumulated in the prison sewers has been used to generate biogas for the prison kitchens. The operation is clean and risk free because the raw-material is in one place and contact with humans is kept to a minimum. Pig manure which, by weight, gives a higher methane yield than cow dung was not available. It is also probable that objection to its use as a source of gas for cooking would have been raised on religious grounds. Islam forbids its followers to have anything to do with hogs. The only viable alternative the user had was cow manure and had to wait until he had accumulated 15 heads of cattle of his own to be able to construct a sustainable digester.

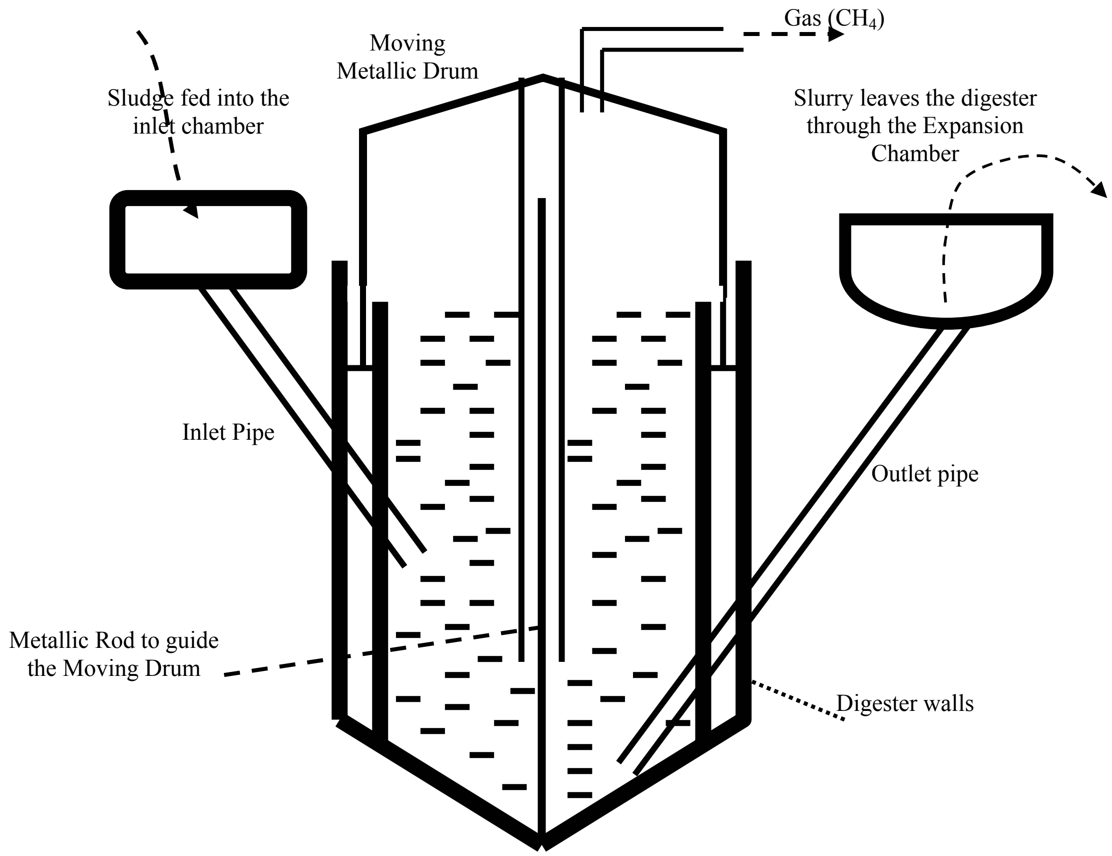

Figure 1: Cross Section of a Floating Drum Bio-digester

3. CONSTRUCTION OF THE DIGESTER AND BIOGAS PRODUCTION

The user opted for the floating dome type of digester. The choice was influenced by the desire to visually monitor the rate of gas consumption and therefore to be able to make an on-the-spot decision when to recharge. Unlike the fixed dome, the floating dome moves up and down following the rise and outflow of the gas in and from the digester. If the rate of gas consumption exceeds its production rate, the drum sinks into the digester. The converse of this process is true. Since the user had no hands on experience in the design and construction of a biogas digester, he enlisted the technical expertise of two experienced engineers from the Appropriate Technology Unit of the National Agricultural Research Organisation (NARO) based at Namalere Research Station, near Kampala the capital city of Uganda. The engineers settled for a well known Indian design with slight modifications (see figure 1).

Construction began with the excavation of a cylindrical hole in the ground, 15 feet (4.57 m) deep with a 6 foot (1.83 m) internal diameter which would have provided a gas holding capacity of 441 ft^3 (12.5 m^3). The labour for the excavation was provided in kind by members of the family. At a depth of 11 feet (3.35 m), the excavation reached the water table and the hole flooded. The user's residence is close to the shores of Lake Victoria. Excavation stopped and the leak had to be sealed with a 5.0 ft (1.53 m) thick layer of hard core and cement rich concrete which reduced the depth to 6ft (1.83 m). To compensate for the lost depth the hole had to be built upwards during the lining process. The lining was made up of well fired clay bricks. These bricks have low porosity and do not easily disintegrate under pressure. The final depth that could be attained was only 10 ft (3.05 m).The protruding top of the pit had to be reinforced with a mound of compacted earth which gave the pit a conical shape like a volcano (pipe and cone). Building the pit upwards an extra 4ft (1.22 m) raised the construction cost by about a third and the flooding delayed the completion of the excavation by about a week.

When whole construction which included the construction of the pit, the slurry mixing tank or inlet chamber (about 1 m^3), the discharge receiver or outlet chamber (also about 1 m^3) and setting up the piping system, it took a month and a half to complete. Then the digester was charged with slurry mixed in the approximate ratio of one part fresh cow dung (about 1.5 tonnes of fresh cow dung) and one part rain harvested water which was free of chlorine. The slurry in the pit was left uncovered for a week to give it time to settle and initiate the fermentation process. At the end of this period the pit was covered with a 300 kg all steel dome or drum (see figure 1) and whole system was connected to a two burner stove in the user's kitchen which is 10 metres from the digester. As soon as all the connections were made, gas production and delivery was instantaneous. The system was commissioned on 10th May 2000. Given the size of the floating drum and the depth of the pit, the user is able to realise a maximum of 6.5 m^3 of gas only at any one time. And in order to keep the costs to a minimum, no attempt was made to install gas scrubbers which would have removed water vapour, carbon dioxide and the foul smelling hydrogen sulphide. In fact the user has found the presence of hydrogen sulphide in biogas desirable because its odour serves as a warning signal of leaks in the system. The other components of biogas are odourless. During the combustion process hydrogen sulphide is oxidised to water and sulphur dioxide. Although sulphur dioxide is a component of the acid rain, the quantities so produced in a small scale domestic operation are insignificant in comparison with what the automobiles generate on a daily basis. The water vapour has a tendency to condense in the gas delivery tubes and if it is not frequently blown out of the system, it causes flame instability. Flame instability can also be caused by too much carbon dioxide in the system.

The other important aspect of a successful biogas plant, which should not be over looked, is good digester management. It should be remembered that a bio digester is a living system and therefore for the micro organisms which are responsible for the gas production to remain alive and active for a long time, optimum operating conditions must be maintained. These include, among others, use of clean water free of silt or mud and chemicals such as soap, detergent and excess chlorine; removal of debris from the cow dung before mixing it into a slurry and avoiding as much as possible using manure from cows which are on antibiotics. The inlet and outlet pipes should be regularly unblocked to avoid clogging. Also on cold occasions or when the sky is overcast, gas production declines and as such the digester should be built in a place well exposed to sunlight and the float painted in black to let in as much heat as possible in order to keep the digester within the optimal operating temperatures (35^0C - 60^0C)[1]. The user has seen many biogas plants fail basically because of bad management.

4. ECONOMIC BENEFIT ANALYSIS

One of the reasons why the rural communities in Uganda are taking long to adopt biogas as an alternative to fuel wood is the high start-up capital. The digester discussed in this paper is a floating drum type of digester with a gas capacity of 6.5 m^3 and for this user the entire system cost the equivalent of US$ of US$ 1,830 (UgSh. 2,836,100). This system can be looked at as being at the top of the range which is financially out of reach of an average person. There are however efforts to make this form of energy cheap and therefore affordable to ordinary person. For example the Department of Agricultural Engineering at Makerere University has designed an all plastic digester which costs about US$ 60 (UgSh. 100,000). This is still in the development stage. Despite the high initial investment, biogas has realisable economic benefits.

The cost of constructing the digester has been divided according to the ain activities which include civil work, the construction of the drum (dome), the setting up of the piping system and the burner. The shares of the costs as referred to these activates are summarised in the graph figure 2. The graph shows that the civil works scoops the biggest share to the total costs.

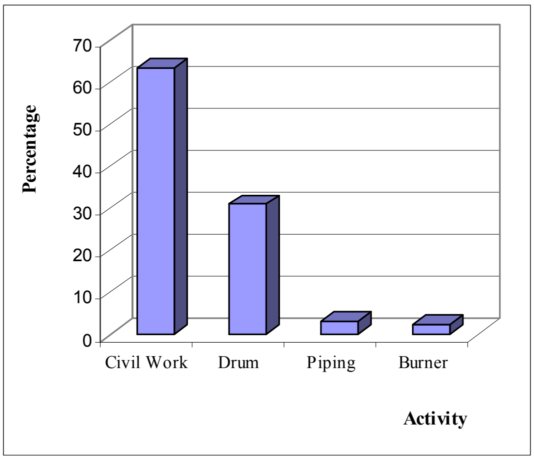

Figure 2: Percentage shares of the costs of different activities

On many occasions his food consisted of items that demand long cooking hours such as dry kidney beans which can take up to 4 hours to cook moreover on high heat. On average it takes the user about 6 hour to prepare the daily meals. The gas is used exclusively for cooking. For this user, his typical kitchen day consists of three meals for a household of 8 people. Prior to the installation of the biogas plant, the user was using liquefied petroleum gas (LPG) supplied in 15 kg cylinders from the petroleum vendors at an average cost of US$ 23 (UgSh. 35,000) per cylinder and used to consume an average of 3 cylinders in 2 months bringing a monthly expenditure on the kitchen fuel of US$ 35 (UgSh. 52,250) including transport costs for the cylinder. The user has now totally substituted LPG with biogas which translates into an annual average saving of US$ 420 (UsSh. 630,000). At this rate of saving, the break-even point for the full recovery of the installation costs is about 4.5 years.

In this case study, the user does not use electricity for domestic cooking applications, though he supplements other fuels with charcoal. Therefore if the se of biogas is compared to other alternatives such as electricity and charcoal, then the saving is obtained as follows. Considering standard electric heater/plate rated 2 kW and operated for 6 hours to prepare the daily meals the average annual energy consumption will be 4380 kWh. The average tariff for domestic consumers in Uganda is 10 US$ cents; this gives an annual average saving on electricity to be US$ 438. At this rate of saving, the break-even point for the full recovery of the installation costs is about 4.5 years
The average cost of charcoal is about US$ 8 per bag and the consumer can use 2 bags of charcoal per month. The annual expenses on charcoal are totalling to US$ 192. Translating this total into a saving the break-even point for the full recovery of the installation costs is about 10 years.

LPG, electricity and charcoal are used in emergencies, in case of low production and during breakdown. Breakdowns have been rare and far between. The user expects to reach the break even point at the end of the year 2000. By the end of the year he will have recouped his initial capital investment. This type of digester entails minimum maintenance and therefore almost nil recurrent expenditure apart from the small labour cost for the recharging, removal of the spent sludge and collecting fresh manure from the cow shade. Currently this labour is provided in kind by members of the family. The 20 litres of water which each charge of about 20 kg of cow manure requires would be an additional cost but the user has a 10,000 litre rain water harvesting system. The digester is recharged once every two days.

Since installation the digester has not had any significant breakdown, so no major maintenance has been required. The water used for mixing the cow dung into slurry is harvested rainwater. Thus this user's experience indicates that use of biogas offers a substantial cost saving on domestic energy. In addition to the economic benefits, other benefits include increased organic agricultural production when the spent slurry is used as fertiliser. The use of the slurry as bio-fertiliser on his small vegetable farm (about 0.5 ha), has helped the user to save money that would have been used to buy the imported artificial fertilisers. Fermenting the cow dung in a biogas digester instead of composting it in open air provides several other advantages, ranging from a foul odour-free environment to improvements in the general health conditions in the home. These include a reduction in the unhealthy smell from the compost dumps where the cow dung used to be deposited, as well as a reduction in free methane gas (which is one of the green house gases, GHG) which used to be emitted direct into the atmosphere by the decomposing dung.

5. OTHER ACCRUING BENEFITS

Additional to the direct economic benefits, the use of this form of energy derived direct from nature has other benefits. One of them is the cleaning up of the home environment. Keeping several cows confined in a small space results in rapid accumulation of manure which has to be disposed of regularly in order to keep the animals in good health, and manure disposal has its own problems. The user has been practising zero grazing, up to 15 cows, for many years. Before a bio digester he was dumping the manure in open shallow pits until it fully fermented and sufficiently cooled to be applied to his crops as organic fertiliser. This process used to generate an unpleasant smell which used to offend members of the family. The bio digester eliminated this problem because the manure ferments in a sealed enclosure. Hydrogen sulphide hardly leaks out of the digester.

This user is a passionate gardener and grows most of his vegetables such as tomatoes, cabbages, onions, leeks, egg plants, to mention a few. He has found the spent sludge which comes out of the digester as a discharge an excellent bio fertiliser for all varieties of the vegetables. It also augers well with the now cherished organic farming. The advantage here is that the sludge can be applied to the crops straight from the digester without having to wait for it to cool because by the time it expelled from the digester, it is fully fermented and sufficiently cool. Being in a semi liquid form also makes it easy to apply it evenly on the crops.

Besides being source of energy for cooking, biogas is also a viable alternative for home lighting. The technology is available which makes use of an older pressurised mantle lantern technology. Instead of pressurising and vaporising kerosene it is biogas which is fed into the fuel tank of the lantern in a continuous stream and pressurised with a plunger by a manual pumping action. The gas is then released under pressure through a jet and burned in a mantle, which in turn glows white thus providing the light. This technology is widely used by some progressive farmers in the Arusha – Moshi region of Northern Tanzania where the user saw such a system in practical use in one of the farmers' home he visited in the early 1990s. It was and still is the intension of this user to make his biogas plant a dual purpose system. However cost and a high water table are holding back for the moment.

From this user's point of view, the availability of biogas at his residence has not only reduced his monthly energy bill, it has also freed him from over dependence on the imported and expensive petroleum based fuel for his domestic use.

6. CONCLUSION

This paper has presented, at least in a nutshell the experience of one of the growing number of biogas users in Uganda. As more and more people become aware that energy derived from fossil fuel is not only harmful to the environment but also increasingly expensive and finite the more they will embrace the renewable energy sources such biogas. The format of this paper is different from the usual presentations at conferences such as this one because it presents an end user's experience. It is usually the experiences of the technical experts which are normally heard. We are grateful to this user for sharing his personal account on biogas. No doubt there is a lot to improve in the production and use of this valuable energy resource and to make it more affordable to the low income earners who are the majority in rural Africa. This continent is abundant with livestock which is a good source of raw material for this form of energy.

7. REFERENCES

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