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Technology Transfer and Farm-based Renewable Energy Sources: The Potential of Biogas Technology for Rural Development in Tanzania

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Abstract
This case describes the potential of the biogas technology as alternative bio- fuel energy in the development of rural Tanzania. The case emanate from the study carried out to biogas users in 28 districts of ten 10 regions of Tanzania Mainland. The focus is on the potential of the biogas technology in the development of rural communities in Tanzania. Biogas technology has strong linkages in developing rural communities as it positively touches social, economic and environment components of communities' lives. The aim is thus to explore the potential of the biogas technology and its linkages towards rural development in Tanzania. The case demonstrates the interlink-ages between biogas technology and income generating activities like agriculture, employment, environment, time and money saving, hygienic improvement and gender empowerment that in turn brings about rural development.

***Key words*: ** Technology transfer- biogas user- costs and benefits - gender - rural development

1. Introduction

Technology transfer is defined as the diffusion and adoption of new technical equipment, practices and know-how between actors e.g. private sector, government sector, finance institutions, NGOs, research bodies and a local community within a region or from one region to another. The benefits of adopting a new technology need to be higher than available alternative and traditional technologies and must be easily accessed by the community. The technology needs to be adapted to the local conditions (appropriate technology) and meets the needs of the people. It is also vital that the technology is accepted by the recipients in consideration of the risks of adopting and cultural acceptability. Technology is not only the equipment, but also the knowledge required to fund, manufacture, operate and maintain the equipment, while transfer is the process of converting the concept of the technology into a sustainable framework that is understandable to the local people (Wilkins 2002).

Rural development concerns a wide range of farm and non-farm activities that take place in villages and small towns. Tanzania, like many developing countries has energy problems associated with developing its rural sector where the majority of population lives. The biomass energy resource, which comprises fuel-wood and charcoal from natural forest and plantations accounts for 93% of total energy consumption in the country which has significant impact on the process of environmental degradation (URT 2006).

Electricity is mainly generated from hydropower, which is prone to drought effects. Around 14% of households in the country use electricity as their main energy source for lighting 84% depend on paraffin and the remaining percent depends on other sources like solar energy. Use of electricity for cooking is less common, only about 1% of households use it. Large section (75%) of the population lives in rural areas where only 2% has access to electricity. Reasons that lead to this situation include high installation and operation costs, unstable availability, political interference and operational inefficiencies (URT, 2011). The impetus of this low access put more pressure on other available energy sources like kerosene, diesel, dry cells, biogas, solar, wind and other renewable energies. Due to the availability of feed stock (substrate) for the bio-digester in the rural areas, biogas can be a right portfolio to counter this deficiency as it primarily produces energy suitable for cooking and lighting.

The available natural gas in the country is the likely substitute for oil which exploration gained much impetus since the last decade. In energy analysis, Tanzania's proven natural gas reserve is the equivalent of 2.6 billion barrels of oil. Tanzania confirmed the amount of 10 trillion cubic feet of natural gas reserves in September 2011 up from the previous 7.5 trillion in January 2011 (URT, 2011). The available gas is used to produce electricity which feeds the national grid, a credible alternative to the seasonally fluctuating hydro power sources.

Following the existing energy crisis in Tanzania, the country is compelled to look for alternative sources. The energy policy does promote all alternative energy sources including renewable (hydro power, biogas, wind and solar) and non-renewable ones. However, the national policy objective for the development of the energy sector is to provide an input in the development process by establishing an efficient energy production, procurement, transportation, distribution, and end-user systems in an environmentally sound manner and with due regard to gender issues (TASEA, 2005).

The environmental friendliness coupled with the rising prices of imported fossil fuels, hydro-power energy, limited and skewed distribution of electricity grid in the rural areas along side with limited forest reserves that are used for firewood and charcoal (TDBP, 2009), have made biogas technology to be considered as one of the best alternative energy sources particularly for these areas. Biogas is the product of bacteria activity in the process of bio-degradation of organic material under anaerobic conditions which produces flammable gases (methane) in larger extent and other gases like carbon dioxide (CO_2), Hydrogen Sulphide (H_2S) and water vapor in relatively small quantities (Kiruiro e*t al*., 2007).

Historically, biogas technology was introduced in Tanzania in the early 1970s by the Government's Small Scale Industries Organization (SIDO) (Sasee *et al.,* 1991). During 1983, the Government's parastatal CAMARTEC (the Centre for Agriculture Mechanization and Rural Technologies), introduced biogas extension services as part of technical cooperation between

Tanzania and Germany. Under this arrangement, CAMATREC and GTZ were responsible for implementing the biogas project in Tanzania, and as a result a total of 707 biogas units had already been constructed by 2005.

During 2008, CAMARTEC, under the Tanzania Domestic Biogas Programme (TDBP[1]), established the foundation for large scale dissemination of domestic biogas in Tanzania. Important components of this foundation include technology transfer, institutionalized technical training and an outline on quality control and management of plants. TDBP uses Implementing Partners (IPs) and biogas Construction Companies located in various areas to disseminate the technology to the community. The installed bio-digester plants at the household level are all of the Modified CAMARTEC Design (MCD) Model but of varying volume sizes ranging from $4m^3$, $6m^3$, $9m^3$ and $13m^3$. By mid 2011, the programme had reached 41 districts in 11 regions of mainland Tanzania scattered across four zones [North Eastern (Arusha, Manyara and Kilimanjaro regions); Coastal (Tanga and Coastal regions); Central (Dodoma and Singida regions) and Southern highland (Iringa, Mbeya and Ruvuma regions)], and a total of 2,500 biogas units were already in place.

1.1 The problem and its justification

Energy poverty remains a major problem and gender insensitive issue in Tanzania while the access to energy is a critical component of social development and economic growth. With rising energy and chemical fertilizers costs, growing climate change concerns, time and labour costs incurred on firewood and charcoal collection, biogas technology can rapidly reclaim its rightful place in this energy portfolio as already discussed above. By providing an alternative source of fuel, biogas can replace the traditional biomass-based fuels with a clean and particulate-free source of energy hence reduce the likelihood of chronic diseases that emanate from emissions associated with the combustion of bio-fuels (Heegde, 2008) which are more severe to women. TDBP's nationwide dissemination efforts are thus justified on these real life benefits that range from improvement of individual biogas user livelihood through lessened energy cost, reduced drudgery on household firewood collection, improved soil fertility through bio-slurry application, reduced respiratory disease and improved environmental conservation through reduced use of biomass-based cooking fuels.

This paper draws from the Biogas User Survey (BUS) that was carried out during the third and fourth quarters of 2012. BUS studies are essentially carried out by TDBP as a management tool to create community awareness, assess socio-economic impact of biogas on its male and female users and gauge users' experience and satisfaction with the programme's activities. The paper is

[1] (TDBP) is a tripartite public-private partnership programme between the Dutch Ministry of Foreign Affairs (DGIS), the Netherlands Development Organization (SNV) and Hivos which is hosted by the Centre for Agricultural Mechanization and Rural Technologies (CARMATEC) in Arusha.

not however specifically addressing the TDBP's objectives but rather attempts to use the BUS to empirically highlight the potential and relevance of biogas technology and its attributes in fostering rural development in Tanzania. The survey was part of the first author's research work while working as an intern- student at SNV Northern portfolio in Arusha. It therefore specifically reports on the empirical results of the survey in terms of the following:

i. The factors that promote dissemination of biogas technology in the rural areas,
ii. The gender-based household decision making towards biogas technology adoption,
iii. The economics of a biogas system investment by a user rural community,
iv. The costs and benefits of a biogas technology system to a user rural household.

2. Methodology

The study was carried out in 28 districts of 10 regions of Tanzania mainland. Data collection tool (semi-structured questionnaire) was designed and tested before implementation to reflect a positive research approach, i.e enabling the biogas users to take a leading role in informing on the respective socio-economic variables being probed. To rationalize the study according to the study's focus, respondents were biogas consumers who had used it for more than three months and responses were separately solicited from female and male spouses/respondents in a household.

TDBP maintains a strong rural focus which makes it such an important development stakeholder in Tanzania. The biogas dissemination initiative has strongly mainstreamed gender issues in all of its activities hence the need to disaggregate household responses along the two major gender groups i.e. males and females. A total of 210 respondents were surveyed across the four zones. Generally, the survey probed on the issues of social, economic and health effects of biogas on females and male users; and gauged the overall level of satisfaction of men and women users with TDBP services.

3. Discussion of the results

3.1 Promotion of the technology

Generally, a variety of methods can be employed to raise awareness of biogas technology to prospective users. These methods include the use of media (mass, print and virtual), brochures, posters, printed ware, incumbent users, programme staff and other interested stakeholders like NGOs. Likewise, the technology can be distributed to the community through involvement of a wider stakeholder base to include the private sector like partner organizations, biogas companies, appliance manufacturers and financial institutions.

In the TDBP initiative, the survey established that 'program staffs' were/are the major initial source of information in sensitizing biogas awareness to households followed by incumbent biogas users, biogas masons, friends and relatives and religious organizations. Other means like the media (radio and television), brochures and village sensitization seminars contributed to a lesser extent (Table 1). For a nationwide dissemination objective, one would have expected to see media playing a leading role in the sensitization exercise given the area coverage in question. The situation is however influenced by the fact that important aspects of achieving successful technology transfer are surrounded by interplay of complex factors that include affordability, accessibility, sustainability, relative advantages and acceptability on the part of potential prospective clients.

Table 1: Distribution of respondents' initial sources of information on biogas energy by gender

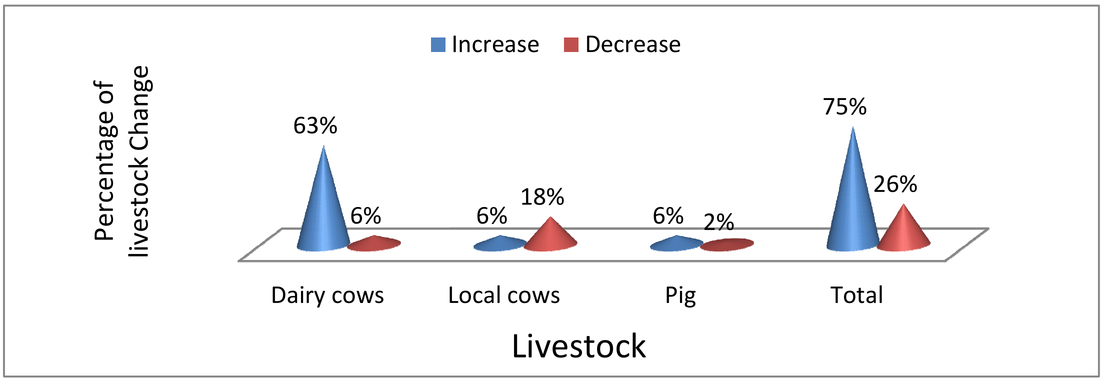
Information source	Gender of the household head		
	Male (n=181)	Female (n=29)	Total (n=210)
	Percentage of respondents (%)		
Brochure	1.4	0.0	1.4
Sensitization seminars	2.9	0.5	3.3
Program staff	16.7	1.9	18.6
Television	1.4	1.0	2.4
Radio	5.2	1.0	6.2
Religious organization	9.0	1.9	11.0
Friends/relative	9.0	2.4	11.4
Other biogas owners	11.9	2.9	14.8
NGO's	10.0	0.5	10.5
Mason/Company	11.0	1.0	11.9
Local authorities	1.9	1.0	2.9
Learn at college	5.7	0.0	5.7
Total	86.2	13.8	100.0

3.2 Pre-requisites for biogas technology adoption

Livestock and water availability are the two major pre-requisites for adoption of the biogas technology. Cattle, pig and human excreta are the main feedstock substrate for the bio- digester. The results (Fig 1) show that the number of livestock (improved dairy breed, local zebu and pigs) in the household changed after installing the biogas plant. It was further observed that biogas use discourages keeping of local cow breeds in favour of improved dairy breeds. Impliedly, this observation suggests that adoption of biogas technology is positively correlated with milk output as improved dairy cow produces more milk than indigenous breed. If this happens, then community's nutrition and incomes will improve too much to the delight of more women and children.

Despite the fact that livestock is the main producer of bio-digester substrate some families (about 5% of the sample) were found to have installed the bio-digester while owning no livestock. They fetched digester feeding materials (substrate) from nearby families for free. This does not only dispel the earlier notion that biogas users had to be livestock keepers but also it is a promising entrepreneurial opportunity for keepers in the near future.

Figure 1: Proportion of biogas users reporting change of livestock after biogas instalation



For a bio-digester to function properly, a biogas plant requires feeding a mixture of cow-dung and water or urine, in the ratio of 1:1 (Brown, 2006) thus imposing a significantly higher daily water demand over domestic needs. Majority of the interviewed biogas users (85%) use tap (piped) water as their main water source followed by river water (31%) despite some minor inter-zonal differences and availability of other sources as shown in Table 2. Other sources were also applicable in the villages, including few incidences where respondents had to pay for the drinking and non-drinking water.

Table 2: Water availability by zones

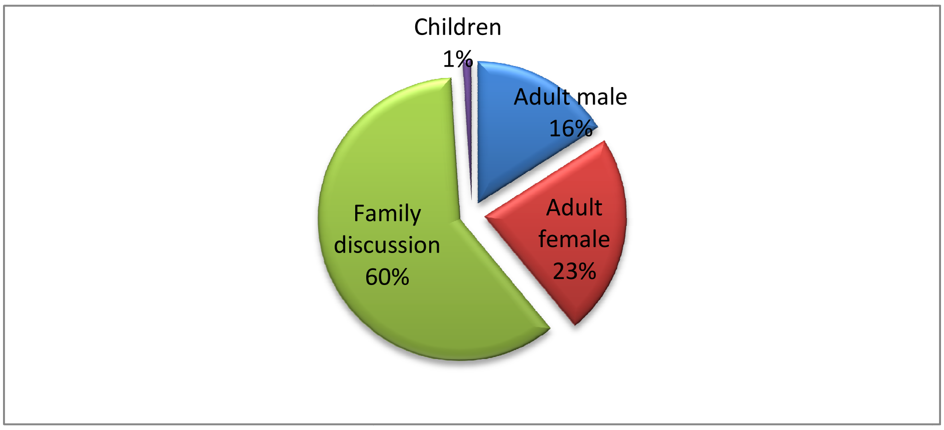
Water source	Location by zones				
	North East (n= 115)	Coastal (n= 47)	Central (n=16)	Southern Highland (n= 32)	Total (n= 210)
	Percentage of respondents (%)				
Rain water	2.4	1.9	1.4	2.4	8.1
Tap (85% water)	47.1	21	5.7	11.4	85.2
Well water	12.4	5.2	2.9	6.7	27.1
River water	20.5	5.2	0.0	4.8	30.5

3.3 Decision making on adoption of biogas technology

In Tanzania, any responsible adult family member can make installation decision but in most African culture, decisions are left to adult men who always head the family. In some cases, a family or rather adult woman can make decisions in case she is heading the family. In most cases, decisions are not made by children unless they have strong influence toward a particular end like education and financial stability (Fjortoft *et al.*, 2011).

The study results revealed that decisions to install biogas plants are made by and through family discussions and consensus, followed by adult women, adult men and to a lesser extent educated and/or affluent sons/daughters (fig.2). The reasons for these results could be the fact that benefits of the technology accrue more to women than men hence compelling the former to take up a leading role towards its installation.

Figure 2: Biogas installation decision making at household level



3.4 Economics of adoption of biogas technology

3.4.1 Investment cost of a biogas plant

Initial investment cost has implication for the choice of plant type to install depending on the financial position of a prospect (for meeting equity contribution). Table 3 showcases incremental average investment[2] costs to be incurred by a prospect assuming different reference starting points for the shift. For instance, if the 4m^3 plant size is taken as the reference point (which needs Tsh 675, 800) one would be required to part with additional 26.4 %, 67.9 % and 11.7 % of this initial cost if they are to acquire the 6m^3, 9m^3 or 13m^3 plant sizes respectively. If the reference is the 6m^3 (which needs Tshs 854, 488 initial investment cost) then the percentage incremental cost will be 33 % and 73 % to acquire the much bigger two sizes respectively. Shifting from the 9m^3 (which needs Tshs 1,135,200) plant size to the 13m^3 will call for an increment of 30 % of the above investment cost i.e. Tsh 1,477,375 on average.

[2] Investment costs as per prices ruling during the 2011/12 financial year.

Table 3: Incremental percentage change in plant investment cost by size

Cost items	Plant sizes 4m^3	6m^3	9m^3	13m^3
	Investment cost in Tshs.			
Average initial investment cost (4m^3 base type)	675, 800 *(0.0)*	854, 488 *(26.4)*	1,135,200 *(67.9)*	1,477,375 *(118.6)*
Average initial investment Cost (6m^3 base type)	-	854,488 *(0.0)*	1,135,200 *(32.8)*	1,477,375 (72.9)
Average initial investment cost (9m^3 base type)	-	-	1,135,200 *(0.0)*	1,477,375 *(30.1)*

NB: Figures in parentheses represent %age change in investment cost for a shift from the assumed base type

3.4.2 Income sources of biogas users

Income sources for biogas users in Tanzania slightly vary across zones per gender. Livestock keeping and farming were reported to be the main income sources with the inclusion of private business, formal employment, remittances from relatives and pension (for the retired) (Table 3).

Table 4: Distribution of **r**espondents' income sources by gender in all zones

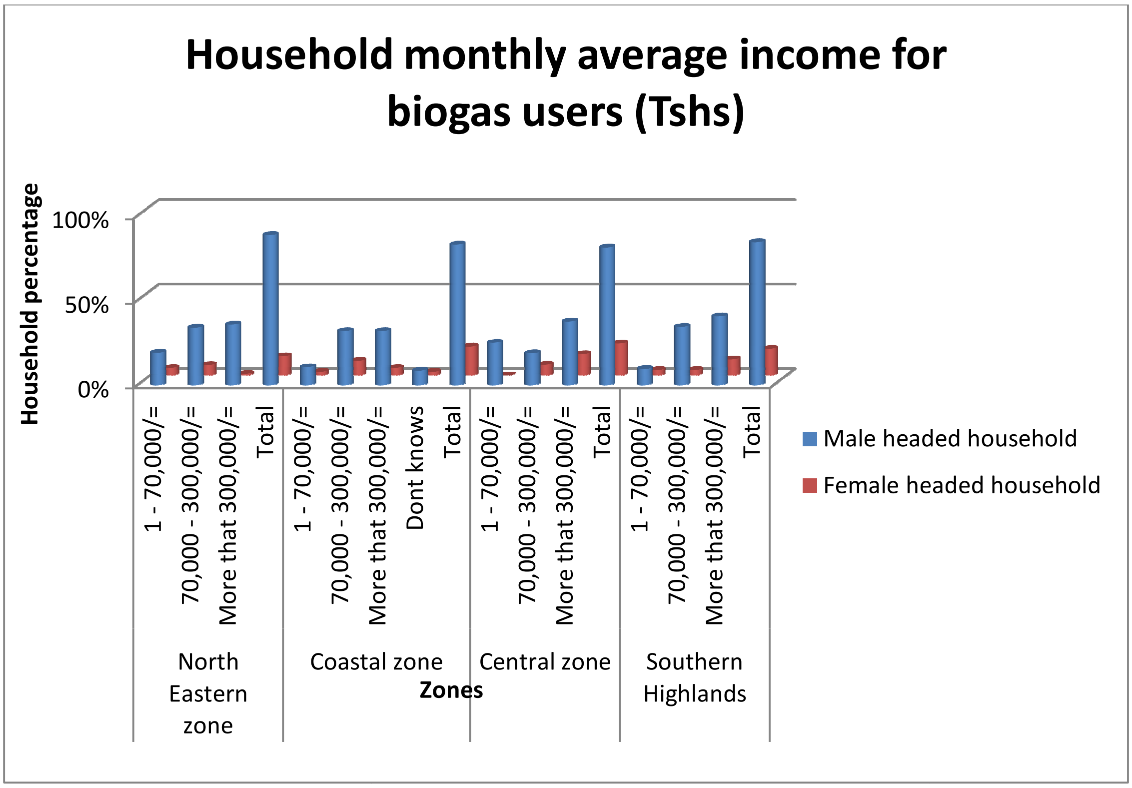
Income Source	Male (n=181)	Female (n=29)	Total (n=210)
	Percentage of respondents (%)		
Agriculture	73.3	12.4	85.7
Livestock	81.9	13.3	95.2
Private business	38.1	5.2	43.3
Employment	34.8	4.3	39.0
Remittance	9.5	1.9	11.4
Pension	12.4	0.5	12.9

The main livestock kept include cattle, poultry, pigs, goats, sheep and donkeys. With reference to the MCD model, the bio digester is fed predominantly with livestock dung (especially cattle's and pig's) as the main substrate. Generally, it was expected that 100% of the respondents would be livestock keepers as this was biogas user survey. However, few respondents (about 5% of the sample) do not keep livestock as discussed above.

3.4.3 Affordability of biogas technology by households

Income sources of biogas users give an indication of their ability to not only meet initial investment costs but also to repay loans and meet other associated operational and maintenance costs. Fig.3 profiles the users according to the average monthly income of the household head across the zones.

Figure 3: Monthly incomes of biogas user household heads across zones



Technology affordability is among the major factors contributing to its adoption. Among other factors, household's income influences adoption of biogas technology since most of the costs associated with the technology are borne on the owner. Since all of the interviewed households had already acquired biogas plants, the results in Fig. 3 suggest that all income categories i.e. small, medium and high could finance the installation.

3.4.4 Biogas use pattern

The results of biogas use pattern at the household level are summarized in Table 4. Cooking constitutes the major use (98 %) followed by lighting (56 %) across all zones. Minimal ironing was reported only in the Coastal and Southern Highlands zones.

Biogas use has multiple benefits in energy consumption as it provides users with great deal in saving domestic energy and the costs associated with it. Biogas users in this study reported average reduction on firewood use on domestic cooking by about 82%, charcoal use by 80%, amongst others (Table 6). Interviewed users also reported to have reduced the costs associated with these traditional domestic bio-fuels by over 80% and over 60% and 15% for kerosene and electricity respectively. This implies that funds which were previously spent on their purchase can now be reallocated to meet other household obligations like paying school fees for children, improving household diet, housing and improving the general family living standard.

Figure 4: Biogas use pattern at household level across zones

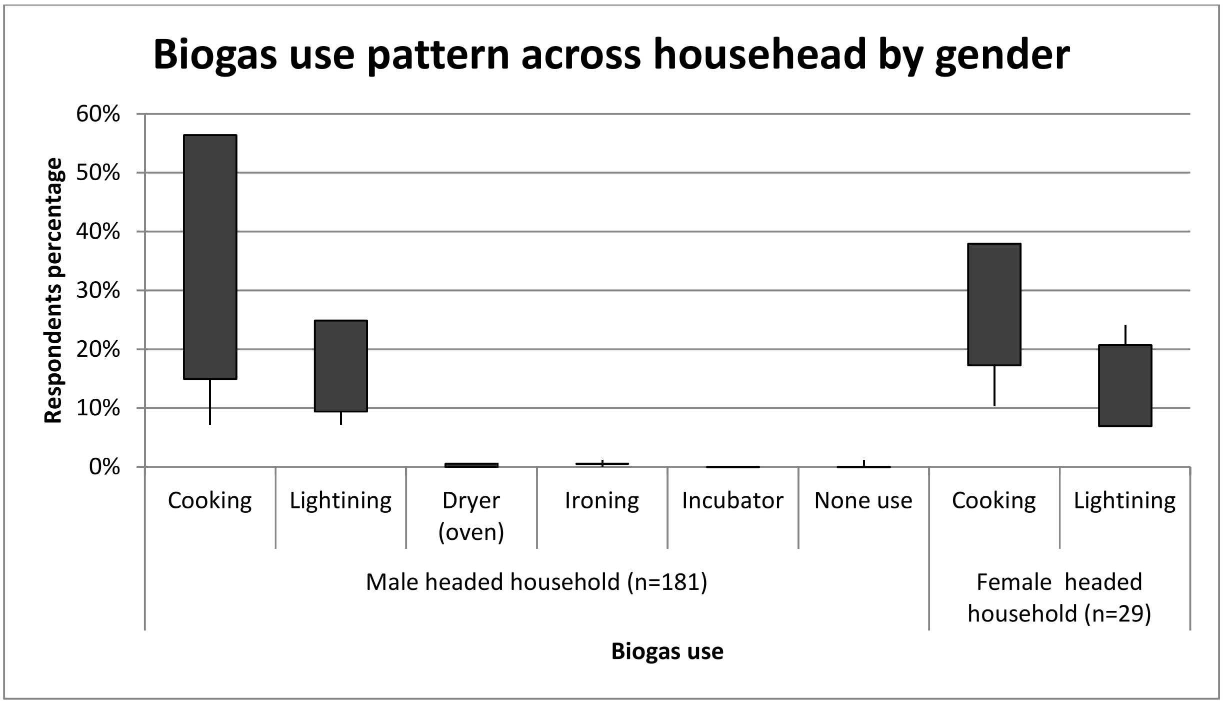


Table 5: Energy consuption pattern (% change of use and % change in energy cost)

Average energy change per week	Amount before	Amount after	% change	Cost before	Cost after	% change
Firewood kg	113.0	21.0	-82.0	7,940.0	1,163.0	-85.0
Charcoal kg	13.0	3.0	-77.0	3,590.0	525.0	-85.0
Kerosene lts	1.5	0.7	-53.0	2,939.0	1,072.0	-64.0
Electricity	-	-	0.0	3,029.0	2,586.0	-15.0
Other LPG's (kg)	1.2	0.2	-83	931.0	128.0	-86.0

3.4.4 The benefits of biogas technology

3.4.4.1 Agriculture improvement

Many biogas users in Tanzania are farmers and use bio-slurry for farming activities in the cultivation of vegetables, fruits, cereals and commercial crops like coffee. Majority (79%) of the interviewed biogas users had experienced the increase of harvest after bio-slurry application. Among the economic benefits of biogas is the production of this quality fertilizer which can substitute for the expensive chemical fertilizers. Biogas users are much benefited with the bio-slurry in replacing chemical fertilizers as reported by (70%) of users who had previously been using industrial chemical fertilizers.

Bio-slurry application was also reported to have significant benefits over the rest of other forms of fertilizers in terms of effectiveness (89%) and its superiority over cow dung/ farm yard manure (79%). The responses implied users' awareness of the economic and environmental benefits of biogas technology from their own evidence-based observations. Biogas users in Tanzania use bio-slurry in a variety of ways including farm fertilizer, fish farming, house plastering, insect repellant and as a source of income through selling.

3.4.4.2 Health, sanitation and education

Biogas technology has significant health benefits. Respiratory and eye problems are commonly associated with smoke-filled rooms when biomass based fuel is used i.e. it is associated with smoke from fuel wood stoves. The use of biogas stoves is expected to significantly reduce this menace. However, this is not always the case in Tanzania since smokeless rooms are not always considered a benefit to some users, because smoke is traditionally used to ward-off insects. Some users of biogas stoves have indicated that the stoves fail to keep away insects and especially mosquitoes. Smoke is also associated with the increase in the risk of developing blindness, inflammation of the cornea and pink eye in children of pregnant women**.** All interviewed biogas users reported improved eye and respiratory health (Table 6).

Table 6: Reported health problems in user households

Health problem	Family member		
	None (n=210)	Female adult (n=210)	Total (n=210)
	Percentage of respondents (%)		
Respiratory problem	100	0	100
Eye Problem	100	0	100
Coughing problem	100	0	100
Fire incidence/accident	100	0	100
Allergic reactions	99	1	100

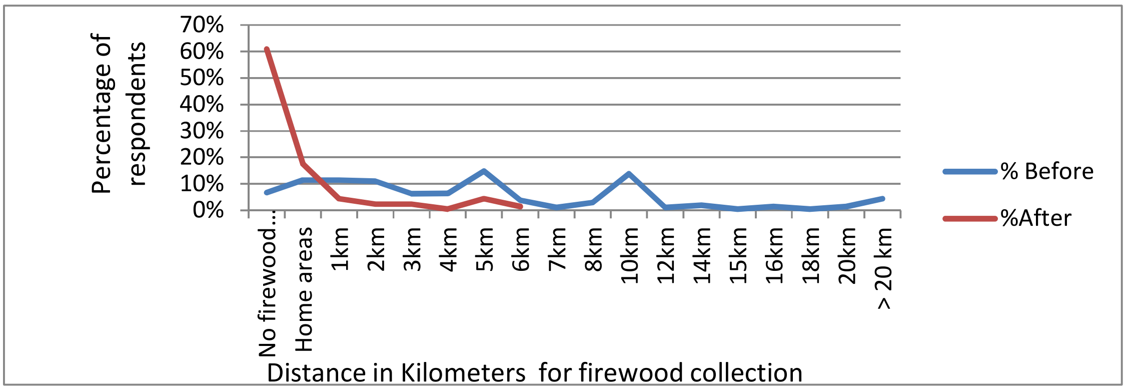
Biogas technology is also associated with improvement in hygiene. The more fully the sludge[3] is digested, the more pathogens are killed. High temperatures and long retention times are said to be more hygienic. Some organisms are killed in biogas plants during fermentation process. These micro organisms include typhoid, paratyphoid, cholera and dysentery bacteria. Others include hookworm, bilharzias, tapeworm and roundworm which die completely when the fermented slurry is dried in the sun (Brown, 2006). Biogas has also benefits in nutritional patterns of users.

[3] **Sludge** refers to the residual, semi-solid material for feeding bio-digester.

With easy access to energy, the number of warm meals may increase. Whole grain and beans may be cooked longer, increasing their digestibility, especially for children. Water may be boiled more regularly, thus reducing the risk of waterborne diseases

Studies by Bastiaan (2007) and David (2009) revealed some indirect benefits of the technology to children education. The time and distance saved from the use of biogas has enabled children to attend school, which previously was not possible as they were involved with household chores as well as collection of fuel wood and water (Fig, 4). Biogas also impact rural school children as the households that used biogas lamps for illumination had provided convenient means for reading or studying even in the evenings.

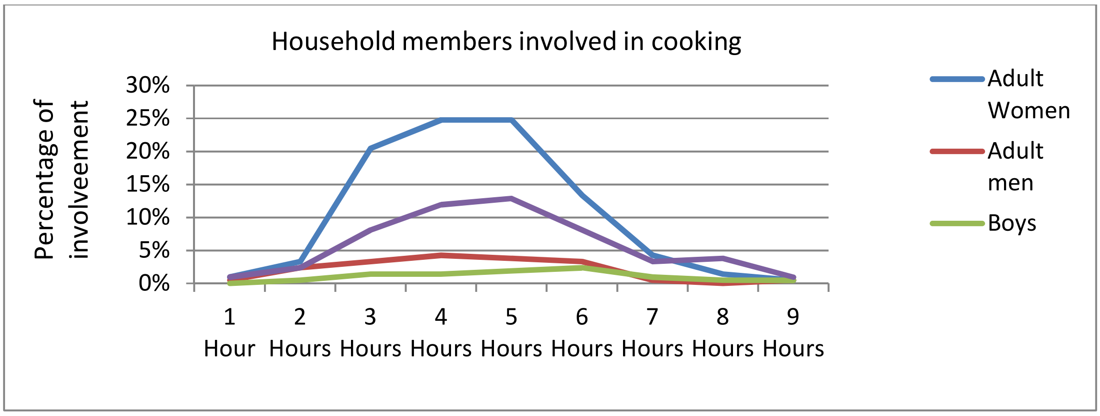
Figure 4: Change in distance covered on firewood collection before and after biogas plant in the study area



3.4.4.3 Gender

Biogas systems have been able to meet both the practical and strategic gender needs for family members who are responsible for preparing and processing food and working in the kitchen. A biogas system provides a direct benefit to the women and female children by reducing the drudgery and danger to personal safety related with procuring fuel wood. Less fuel wood has to be collected which results in saved labor. As a result of the user friendly nature of biogas stoves, the traditional role of cooking is changing to where it is reported that male members of the family are increasingly engaged in cooking (fig.4) than was before biogas. Not only that but also kitchens have increasingly been used as a family rooms because they are now smoke free and better lighted. Members of the family can gather in the kitchen and discuss internal household and external community matters. This situation provides female members of the family opportunity to take part in the discussion thus fulfilled some strategic gender needs as well. Moreover, biogas reduces workload hence enabled women folks to earn additional income, organize and attend meetings, increase awareness, achieve literacy and gain financial security

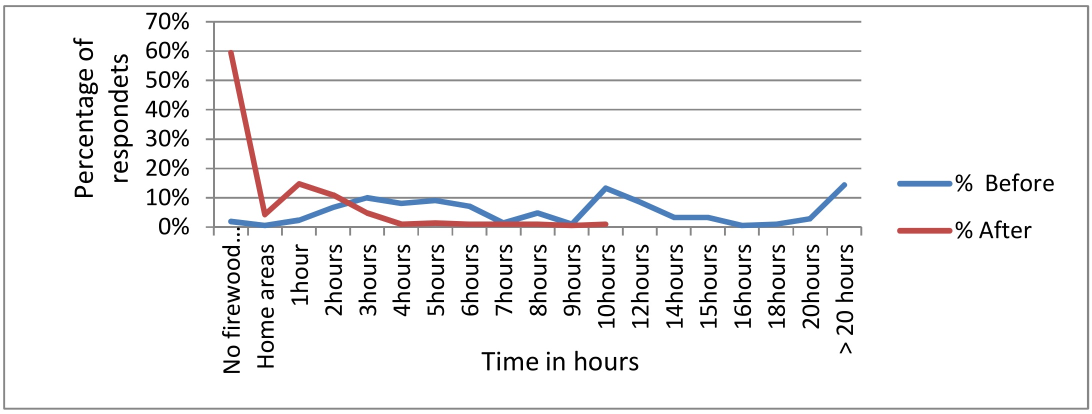
Figure 5: Household members involved in cooking after biogas in the study area



3.4.4.4 Time saving

It is widely recognized that access to energy services has strong linkages with development (Heegde, 2008). Most rural households in developing countries are forced to draw on traditional biomass materials like wood, charcoal, agricultural residue and animal dung, to meet their daily domestic energy needs. By doing so they not only exhaust these resources, but also pollute the air they breathe at home by burning these substances. The collection of the traditional fuels devours precious daylight hours that children and women in particular might otherwise spend at school, in income generating or social activities. It has been revealed in this study (Fig. 6) that there is a remarkably big difference in time spent for firewood collection i.e. the 2% of non-firewood user group prior to biogas plant installation had grown to 61% following installation. The same applies to the distance covered which had seen a reduction of about 50% (from over 20kms to about 10kms). The precious time saved by this innovation could then be used in other productive activities.

Figure 6: Firewood collection time saving after biogas plant installation in the study area



3.4.4.5 Challenges of biogas technology

Reported challenges facing biogas users ranged from insufficient production of gas lack of spare parts, lack of follow up, poor quality appliances and poor construction workmanship. Other challenges include lack of after sales services, water clogging in gas pipes, poor internal plastering and cracking of bio-digester which is caused by incorrect setting of plant (Table 7). However these problems differ across zones, insufficient gas production 81.8%, lack of spare parts 34.1% and poor construction workman ship 27.3% being the lead problems were reported more in coastal zone. These problems in turn are expected to lessen potential biogas users who are expected to install biogas system.

Table 7: Challenges of installed bio-digesters

Experienced problem	Location in zones				
	North East (n= 15)	Coastal (n= 19)	Central (n= 6)	Southern Highland (n= 6)	Total (n= 44)
	Percentage of respondents (%)				
Poor quality appliances (lamps and stoves)	6.8	6.8	11.4	2.3	27.3
Poor construction workmanship	9.1	18.2	0.0	0.0	27.3
Insufficient gas production	34.1	38.6	2.3	6.8	81.8
Lack of follow up by masons	11.4	4.5	0.0	4.5	20.5
Lack of after-sales services	13.6	4.5	0.0	4.5	22.7
Lack of spare parts/appliances	11.4	11.4	4.5	6.8	34.1
Incorrect setting of plant	2.3	4.5	0.0	2.3	9.1
Water clogging in gas pipes	15.9	2.3	0.0	2.3	20.5
Poor internal plastering	4.5	6.8	0.0	0.0	11.4
Cracking of bio digester	2.3	2.3	0.0	0.0	4.5

4. Conclusions and Recommendations

4.1 Conclusions

The key determining factors for use of biogas technology have been shown to be the presence and availability of livestock and water for supply of digester substrate and enhancement of fermentation process respectively. However, evidence from other countries (e.g. Rwanda) has it that human excreta can also be suitable alternative source of digester substrate. This suggests that use of biogas technology may not be limited by absence of livestock thus both livestock and non-livestock households (even urban households!) can benefit from it if this advantage is exploited.

The study has affirmed empirically the many benefits that the biogas user households realize from the technology. Household level decision making on its use/adoption has been found to be made by both adult males and females and educated daughters and sons in a family. This gives a clue as to the right targeting for any country-wide dissemination initiative that may be undertaken. This study was geared towards assessing the potential of biogas technology in the development of rural Tanzania with the focus to analyze the level of gender involvement in it. Awareness of biogas technology in the four zones has so far been through the TDBP project staff and biogas masons. Mass media (radio and television), brochures and village sensitization seminars contributed to a lesser extent. For a countrywide dissemination, media should be involved much more to augment the efforts of the program staff and masons.

Major costs involved include installation, operation and maintenance costs. These costs are, by and large, laid onto the biogas owners irrespective of gender differences though assistance from the program (TDBP) and other support organizations like Community-Based Organizations (CBO) e.g. savings and credit organizations, churches and banks is sometimes available. In this study, prospects of all income brackets (low, medium and high) were found to have managed to finance plant installation signifying that it is not the level of income that really matters but rather the way the installation process is structured.

Majority of biogas users (males and females) are highly satisfied with the biogas technology. In some cases however, there have been some isolated cases of lackluster performance on the delivery of after-sale services on the part of the TDBP program. This has given rise to a number of complaints from the users which are blamed on a variety of causes including inferior appliances, poor construction workmanship and poor follow up by project staff. Insufficient production of biogas, lack of spare parts, poor quality appliances, and poor construction workmanship were also identified as major challenges. Beside all these challenges biogas system still remains to be the best alternative farm-based energy source that rural Tanzania can easily access and benefit from.

4.2 Recommendations

In view of the findings of this study, the following are recommended:

i) For nationwide dissemination to be successful, media (radio and television), given their wider outreach, should be made to play a major role in sensitizing and making communities aware of the benefits of biogas technology which is easily accessible and affordable to them. The awareness campaigns should also target at breaking the stigma on the use of human excreta as bio-digester substrate. If the latter is achieved, it will represent a revolution in biogas technology utilization as it will not only break the overdependence on livestock waste but will also enable urban households to access it.

ii) The technology can achieve a great deal in environmental conservation especially in reducing the escalating deforestation following the use of charcoal and firewood as energy sources for many rural and urban households. Along this line, the Government becomes not only a major stakeholder but also an interested party. The promotional effort for the technology should thus attract public-private partnership initiatives that will ensure its successful nationwide dissemination. The public-private partnerships could be forged in the areas of friendly policy formulation, provision of water (piped or otherwise) and access to investment capital by leveraging prospective users' position to acquire requisite credit (by for example putting up a guarantee fund to that effect).

iii) The incumbent promoters of the technology should look for a way to put in place or appoint reputable dealers to supply genuine parts for the bio-digesters to users in different zones. The appointed dealers should be innovative enough to include the parts that will increase the scope of uses that the technology can be put into i.e. not only cooking-related parts but also for ironing, lighting, refrigeration etc.

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