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The benefits of the use of biogas energy in rural areas in Ethiopia: A case study from the Amhara National Regional State, Fogera District

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This study was conducted to assess socio-economic and environmental benefits of biogas energy and its challenges. The study used descriptive type of research design consisting of quantitative and qualitative research approach. The data collection instruments were household survey, key informants interview and self-observation to collect quantitative and qualitative data types. The study revealed that the biogas installation made each household to save on average 144 min per day from fuel wood collection, cooking, cleaning utensils/kitchen materials) and the reduction in the physical stress was also remarkable. Use of biogas provide an annual saving of 3833.28 Birr from fuel wood, Birr 1243 .20 from charcoal, Birr 128.50 from dung cake and Birr 266 and 717.65 from kerosene and chemical fertilizer, respectively, with net cash flow of Birr 1530 per HH/year. The households encountered lack of skills for adding raw materials to the biogas digester and fertilizer application to their farm land. Training for operation and liquid bio-slurry application is vital for the continuity of the project and revision of feeding material to the digester in different season needs consideration.

Key words: Biogas energy, environment benefits, biomass, alternative energy.

INTRODUCTION

Energy is undoubtedly a fundamental means for meeting the needs of life support system and development efforts now and for the future. The energy supply and use system has also many implications in the household economy, the indoor environment, women's activities, child safety, family nourishment and other aspects including local and global climate.

Energy plays a central role in national development process as a domestic necessity and major factor of production, whose cost directly affects price of other goods and services (Amigun et al., 2008). It affects all aspects of development, such as social, economic, political and environmental, including access to health, water, agricultural productivity, industrial productivity, education and other vital services that improve the quality of life. There is currently intense interest and strong policy direction to increase the proportion of energy derived from renewable sources

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(Thomas et al., 2010).

Worldwide, energy consumption and demand are growing since the past 50 years (OpenStax College, 2012). Most of the resources used like petroleum, natural gas, coal are not sustainable sources of energy. Numbers of countries in the world including Ethiopia are currently passing through the critical phase of population explosion and the growing population demands more energy inputs.

Global experience shows that biogas technology is a simple and readily usable technology that does not require overtly sophisticated capacity to construct and manage. It has also been recognized as a simple, adaptable and locally acceptable technology for Africa (Taleghani and Kia, 2005).

Fuel wood consumption is often portrayed as a cause of environmental degradation, and may lead to energy insecurity for rural African households; especially where the resource is commercialized (Hiemstra-van et al., 2009). The high dependence on wood fuel in the sub-Saharan Africa has resulted in an alarming rate of tree felling and deforestation that causes faster depletion of biomass resources. According to the UNEP (2010), nearly half of the forest loss in Africa is due to removal of wood fuel. On the other hand, rural women are the ones who are directly affected by the rural energy crisis (Amigun et al., 2012; Smith et al., 2005).

The price increase of fossil fuels (an economic process) boosts the demand for bio fuels, which causes changes in land-use cover through deforestation, increases greenhouse gas emissions through the drainage of peat marshes, expands use of agrochemicals and raises the likelihood of establishment of invasive species. A long-term intervention could be to reduce the demand for fossil fuel by changing consumer and producer behavior (UNEP, 2010).

Currently, many African countries experience frequent blackouts and the cost of electricity blackouts is not known. The continent's energy consumption and demand is expected to continue to grow as development progresses at rates faster than those of developed countries (Amigun et al., 2008).

Ethiopia has a population of 89.6 million people, of which 82.4% live in the rural areas (United Nations, 2007). Through the Ethiopia Rural Energy Development and Promotion Centre (EREDPC), the National Biogas Program (NBP) was also launched. The aim of the programme is to establish 14000 biogas plants between 2008 and 2012, in four regions of Ethiopia (EREDPC, 2008). The NBP utilizes cattle manure as the feedstock for biogas production (EREDPC, 2008). In 2009, some households had already started experiencing the benefits of the project such as: use of clean cooking fuel; income savings made in terms of time and money to search for fuel and purchase other traditional fuels (wood, charcoal and kerosene) respectively; and income generation from the sale of biogas to the neighboring towns (Hivos, 2009b).

According to Central Statistical Authority Welfare Survey of Ethiopia (CSA, 2004), the major types of cooking fuels used by all households are firewood, leaves/dung cakes and kerosene. At country level, about 81.4% of the households use firewood, about 11.5% cook their food by using leaves/dung cakes and only 2.4% use kerosene for cooking.

In Ethiopia, the demand for household energy is far greater than the availability. This can lead to vulnerability to deforestation, health impacts and increasing climate change. According to Fogera district Agriculture and Rural Development Annual Report (2010), in 2002-2006, the coverage of the forest in the district was 10,240 ha, while in 2009 the coverage declined to 4,795.26 ha which is a reduction of 53.17% from 2002 - 2006. This is due to over exploitation of fuel wood by the poor households to fulfill their basic needs.

The objectives of the study are to assess the social, economic and environmental benefits of biogas energy technology. This paper was aimed to identify the actual benefits of biogas energy, perception of users in terms of level of satisfaction on the biogas technology, the level of understanding their living environment, challenges encountered during usage/application and dissemination, identifying the indigenous knowledge of rural biogas user households to solve their problems regarding biogas energy application. Finally, the findings are used as input for government and nongovernmental organizations (NGOs) for the dissemination of biogas energy technology for the other target households.

MATERIALS AND METHODS

Description of the study area

Fogera district is one of the 106 districts of Amhara National Regional State and found in South Gondar Zone (Figure 1). The district is located in North West of Addis Ababa with a distant of 625 and 55 km north east of regional capital, Bahir Dar. It has an altitude of 1774-2410 m above sea level and characterized by an average rain fall of 1216.3 mm, minimum and maximum temperature of 16 and 20°C respectively, and black clay soil type. It has a population 228, 449 (52,905 households) that lives in an area of 117405 ha with an estimated population density of 108 people per square kilometer (CSA, 2007). The main resource of the district could be taken as forest area, which is presently encroached due to high population density and urbanization processes; in fact the forest is consumed in various purposes especially for fire wood, furniture and for house construction. It is observed that the forest will be surely destroyed in few years, if proper solutions are not taken in consideration (FDFED, 2009).

Methods of data collection

This study uses both qualitative and quantitative approaches. As per Kothari (1990), for this study the quantitative approach was used for the analysis of household data collected through survey questionnaire; whereas, the qualitative approach is concerned with subjective assessment of attitudes, opinions and behaviors of

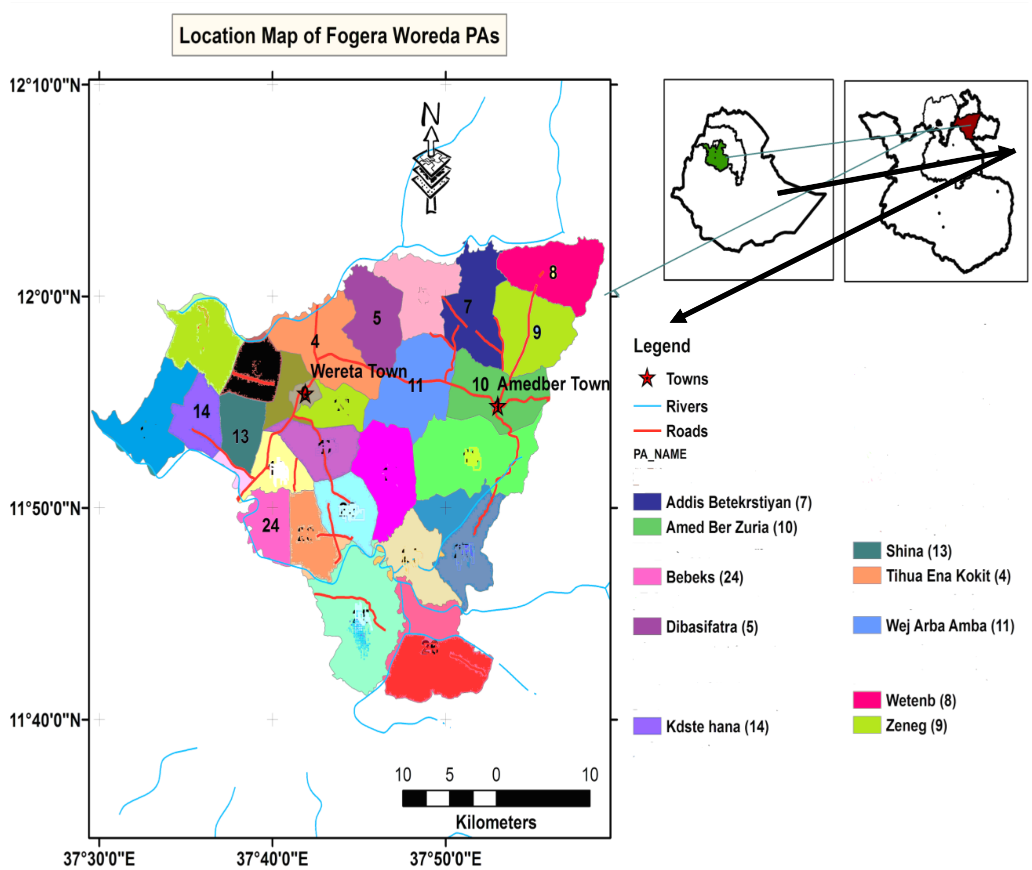


Figure 1. Map of the study area. Source: Fogera district Anti-Malaria Association Office, 2011.

biogas user households. Since the target population was manageable, by considering these parameters, this study used census study design. The data collection instruments were household survey questionnaire.

The biogas energy on which the study was conducted was selected purposefully and all the biogas user households were sampled. In addition to biogas users who work on biogas energy dissemination, the municipality sanitation and beatification process owners in the study area, agricultural and rural development officials were included purposively.

Primary data sources

Household data: Household data were collected through semi structured questionnaire. This survey was intended to gather information on demographic characteristics of households (household size, land size, education level and livestock number), household fuel consumption before and after biogas plant installation (consumption of charcoal, dung cake, fuel wood and kerosene).

Key informants interview: In addition to the household survey data, the interview was carried out on government and non-government partners and stakeholders who work on biogas energy technology dissemination. The key informants were NGO representatives from SNV-Netherlands/Ethiopia Field Office, government officials from the municipality, agriculture and rural development (department of alternative energy technology and animal science process owners).

Self-observation: The actual biogas plant status, toilet availabilities/toilet attached biogas plant/ and usage conditions, market value of household fuel at the local market (charcoal, fuel wood, kerosene and dung cake), state of waste management, utilization of spare time due to reduction of workload as a result of biogas plant were observed and snapped by camera, and voice of the users when they explained about the benefits of biogas were recorded in video to have evidenced data to the findings at their respective peasant associations (PAs).

Secondary data sources

Secondary data sources such as books, policy and published and unpublished documents, journals, and websites that were relevant and strengthened the study were reviewed and studied. Moreover, to have a deeper insight about biogas energy benefits and constraints of Fogera district, different organizations were visited and related documents about biogas energy were extensively used.

RESULTS AND DISCUSIION

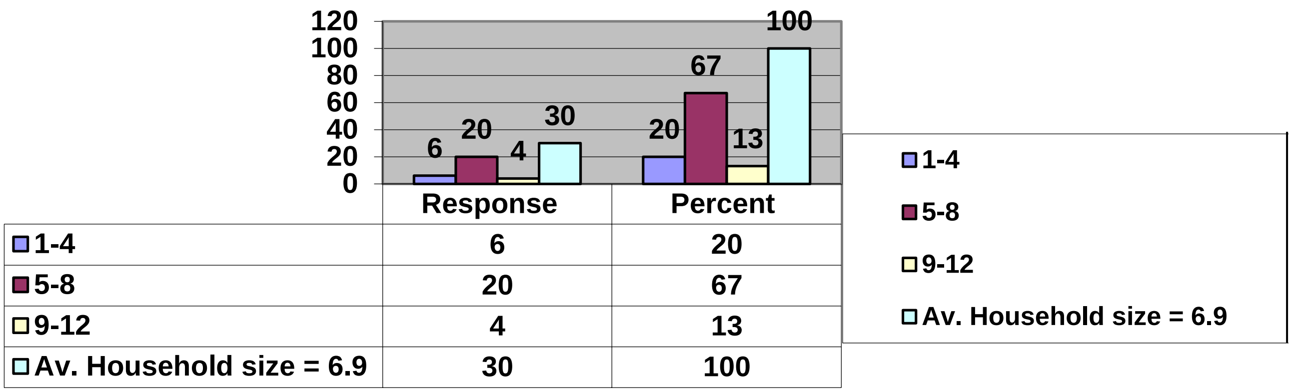
Demographic data

The demographic characteristics of the biogas user households are presented in data presenting tools such as Figures and tables. The average household size of the surveyed biogas user households was 6.9 (Figure 2).

Table 1. Possession of animals by biogas user households.

Types of animals	Average holding size /household	Remark
Cattle	12	
Sheep	2	
Goats	5	
Poultry	5	
Horses	1-2	28 Households have no horse
Donkeys	2	8 Households have no donkey

Source: Field survey, 2011.



	Response	Percent
1-4	6	20
5-8	20	67
9-12	4	13
Av. Household size = 6.9	30	100

Figure 2. Average household size of the biogas household. Source: Field Survey, 2011.

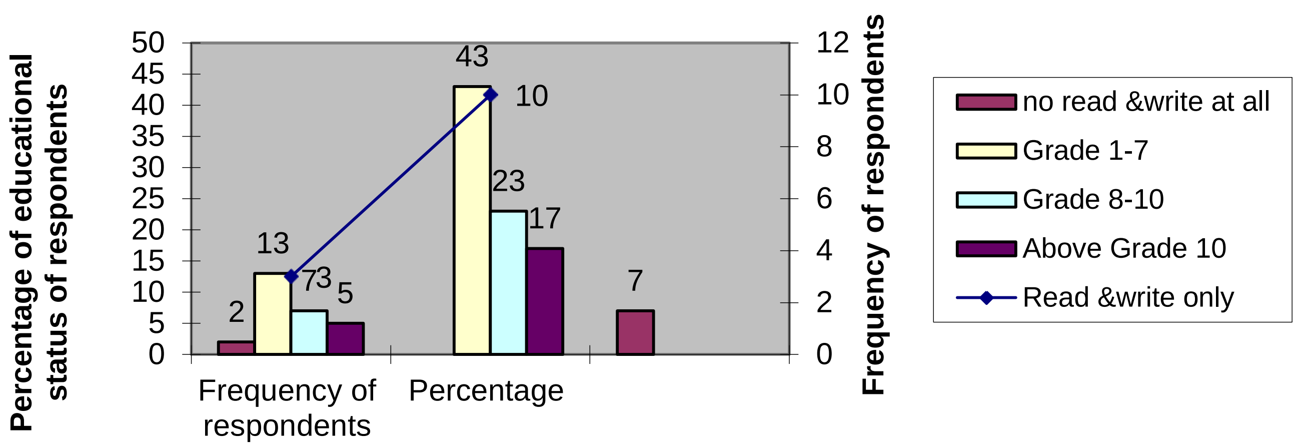


Figure 3. Educational status of biogas households. Source: Field Survey, 2011.

The surveyed biogas user households possess on average 12 cattle per household which is more than the minimum requirement of 4 cows for establishing biogas plant. The details are shown in Table 1.

From the total respondents, majority (83%) are well educated which are from grade 1 to 7, 8 to 10 and from 11 to 12 complete (Figure 3)

Environmental benefits of household biogas investment in the study area

Perception of households on impacts of traditional fuel on forest

All the respondents were asked whether using of Trade-

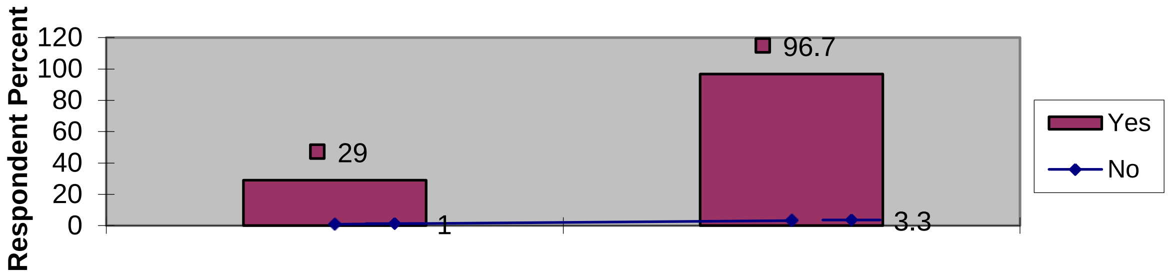


Figure 4. Respondents by knowledge of the impacts of traditional fuel on forest. Source: Field Survey, 2011.

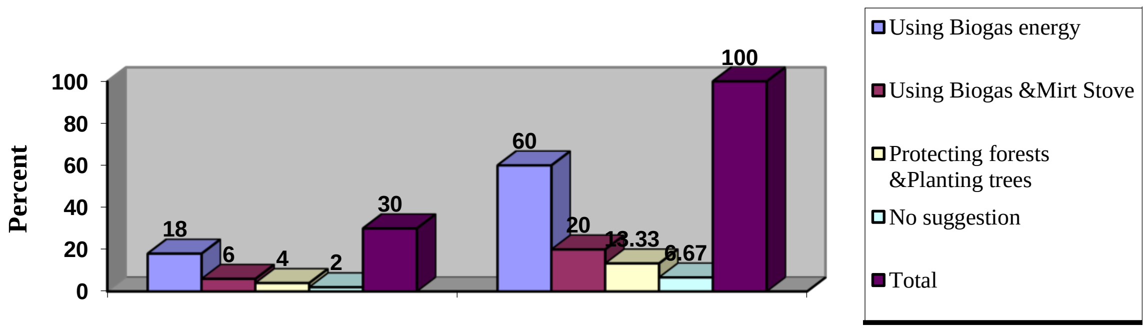


Figure 5. Mitigation measures of respondents' suggestion to minimize the problem of traditional fuel. Source: Field Survey, 2011.

tional fuel have direct impact on forest or not. Accordingly, the majority of the respondents (96.7%) perceived the negative impact of traditional fuel for the existing forest destruction and the rest (3.3%) did not perceive the impacts of traditional fuel for deforestation (Figure 4).

Regarding the solutions for deforestation, (60%) respondents suggested the use of biogas energy (20%) the use of biogas and Mirt stove, (13.3%) protecting forests and planting trees as a solution to control forest depletion and the rest (6.67%) did not show suggestion to minimize loss of forest due to use of traditional fuel (Figure 5).

It can be concluded that majority (96.7%) of the respondents perceived the negative impact of traditional household fuel on deforestation, and this could be attributed to their relatively better educational background. Even, all the solutions suggested by respondents are true, the researcher recommended the households to use biogas energy due to its clean and smokeless technology and ability to replace and reduce the use of firewood, charcoal, dung cake and other imported household energy sources such as kerosene.

Contribution of biogas as cleaner production mechanism

Biogas potential in the study area of Fogera district is in favorable condition in respect of the climatic and availability of raw material for biogas production. The potentials are: Municipal waste, livestock and human population. Thus, potentials needs to be recycled as cleaner production such as biogas energy, to get dual benefits from getting energy and making the environment clean.

Livestock population in Fogera district: Documents gained from Fogera district Agriculture and rural development office, out of 302,800 livestock; 182,699 are cattle, 15,575 sheep, 25,956 goats, 64,227 poultry, 571 horses and 13,772 donkeys found in the district. Moreover, the annual dung production is about 666, 851,350 - 1,000,277,025 kg, which has a potential production from 24,006,648.6 to 36,009,972.9 m^3 of biogas annually. However, it is estimated that only 90% of the theoretical potential, that is, 21,605,983.74 to 32,408,975.6 m^3 (Av.27, 0074, 79.67 m^3) of biogas would be practically available since the number of animals also include the households with only one cattle or goat. This has a potential for saving fuel wood from 118,832,910.6 to 178,249,365.8 kg, charcoal from 34569573.98 to 51854360.96 kg, kerosene from 16226, 093.79 L to 24339,140.68 L and electricity from 34569,573.98 to 51854360.96 Kwh annually (Table 3).

Human population in Fogera district: In Fogera district, 228,449 people reside there (CSA, 2007), which have a potential to produce 228449*0.3*365 = 2,501,5165.5 kg of human waste annually (Nijaguna, 2002). Assuming that all people have pit latrines and if they properly utilized their excreta, this would have a potential of producing 25,015165.5 kg x 0.046 m^3 = 1,150,697.613 m^3 of biogas, which saves 6,328,836.872 kg of firewood,1,841,116.181 kg of charcoal, 864,173.9 L of kerosene and 1,726,046.42 to 1956,185.942 Kwh annually (Filed survey, 2011; Nijaguna, 2002).

Municipal waste of the town administration: Fogera district town administration generates approximately 34,500 kg wastes (34.5 tons) of solid waste and 40,000 L (40tons) liquid waste was generated per day. Among these, the municipality collects and disposed only on average 32,000 kg of solid waste and 20,365 L of liquid waste per day, which is 92.5 and 50.91% of the total solid and liquid waste, respectively. The main sources of waste are from residential and commercial activities in the town. These wastes are collected and disposed in open space except small amount of liquid waste used for urban agriculture as fertilizer. Due to this small amount of utilization, the disposed waste creates bad smell to town and its surroundings that will create health problems.

COMEC (2006) stated that, in Brazil the biggest part of municipal waste generation is deposited without any methodology/without technological aid like Fogera district municipality, but Brazil uses high amount of waste for biogas energy production as energy source and waste treatment mechanism. This is also contended by UNESCO (1992), biogas technology have attracted considerable attention in waste recycling, pollution control and improvement of sanitary condition in addition to fuel and fertilizer.

On the contrary, the municipality of Fogera district have no future plan to use the potential waste as energy source officially except personal motivation and promise of experts after interview. As can be seen from Table 4, the town administration was collected and disposed 52.365 tons of waste per day and 19,113.225 tons of waste annually.

Assuming that all wastes are properly utilized, this has a potential of 19,113,225 kg × 0.03 m^3 = 573,396.75 m^3 of biogas, which saves 105,122,737.5 kg of firewood, 30,581,160 kg of charcoal,14,354,031.98 L of kerosene and 28,669,837.5 to 32,492,482.5 Kwh electricity annually. Besides, all this potentiality presented above such as wastes from livestock population, human population and municipal are dangerous unless it is recycled as cleaner production such as biogas to have dual purpose, killing two birds with one stone principle like Brazil (as source of energy and as environmental sanitation).

*Pair of oxen ploughs, 1 hectare per day: this is called “Temad”, which is the name of local measurement.

Social benefits of household biogas investment in the study area

Benefits from replacement of traditional household fuel

As the household traditional fuel consumption decrease, the contact hour of the family member to the traditional stove also decreased. As a result, the type of adverse effects of biomass combustion on human health stated by WHO (1991) could be decreased.

Household fuel wood consumption: The study showed that in the surveyed area, the biogas user households used Cordia Africana (Wanza) and acacia for cooking among others, *Injera*[1]; Sauce (Wot), porridge and coffee/tea, before and after installation of biogas plant. However, after biogas plant installation, the traditional household fuel consumption was limited to baking *Injera*. As can be seen in Table 7, before installation of biogas plant, households used 3,596.4 kg of fuel wood/HH annually, but after installation of biogas plant each household uses on average 1062 kg of fuel wood/HH/year which is reduction of 2,534.4 kg (70.47%)/HH/ annually.

Household charcoal consumption: The average charcoal consumption in the surveyed households used 1 sack of quintal (27 kg) per month and 12 sack of quintal (324 kg) per year. As can be seen from Table 8, in the study area of biogas households, all of them used charcoal in different amount before installation of biogas plant. However, after installation of biogas plant, all the biogas households have been fully replaced with biogas energy.

Household dung cake consumption: All the surveyed households, before installation of biogas, the majority (43.3%), used 6-10 sacks of quintal (138-230 kg), 36.67%, used 1-5 sacks of quintal dung cake (23-115 kg), 13.3% used 11-15 sacks of quintal (253-345 kg), 6.67% used above 15 sacks of quintal (460 kg) per month with on an average consumption of 8 sack of quintal(184 kg)/HH per month and 96 sacks of quintal (2208 kg) used annually. After installation of biogas plant, as presented in Table 9, majority (60%) used 0.5 to 2 sacks of quintal (11.5-46 kg), 33% used 3-5 sacks of quintal(69-115kg), and the rest 7% used 6-8 sacks of quintal dung cake(138-184 kg) and on average of 3 sacks of quintal (63kg)/HH per month which is reduction of 5 sacks (115 kg)/HH per month, and 60 sacks (1380 kg) dung cake annually which is 62.5% from the total. This traditional household fuel consumption could contribute in

[1] Injera is Ethiopian Traditional food made from Teff (crop).

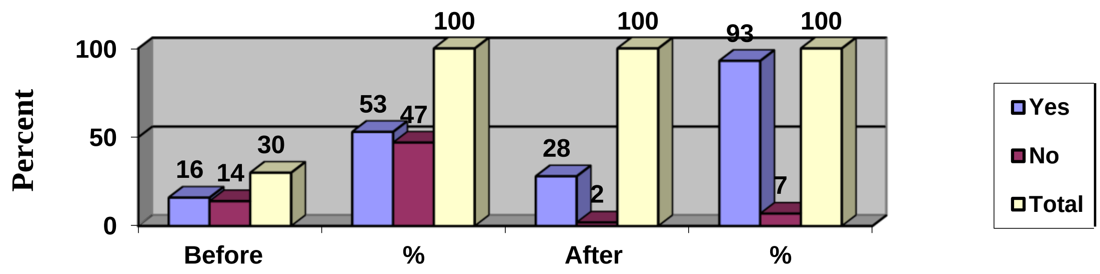


Figure 6. Possession of toilet before and after biogas installation. Source: Field Survey, 2011.

reducing the health impacts of households that appeared due to indoor smoke. Bajgain and Shakya (2005) stated that, the burning of fire wood, dung cake and agricultural residue creates many hazardous particles. Cooking is usually done indoors; this can lead to severe health problems. The particles from the smoke can give rise to acute respiratory infections among the people who are in contact with the smoke.

Benefits of biogas on health and sanitation of biogas user households

The study showed that in the surveyed area, after installation of biogas plant, the construction of toilet is increased which can be compared to IEIA (2002), study that was carried out by SNV/BSP of Nepal, showing that the record of toilet construction is higher among biogas users. Before installation of biogas plant, toilet possession of the surveyed HHs were 53%, while after installation of biogas, the possession of toilet reached 93% (Figure 6). From these toilet owners, 13% of them have attached their toilet to their biogas plant and the majority (80%) of respondents ready to attached their toilet to the biogas and the system is already installed which shows promising to use the integrated biogas plant for the near future. Only few (6.65%) respondents have no toilet at all. As data gained from the household survey, these two respondents cannot read and write at all. It seems that education has its own impact on dissemination of technology.

The biogas user households were asked to express their opinion about the difference in using traditional fuel and biogas energy use in relation to health impact. They replied by remembering what the local nurses and doctors recommend about negative impacts of traditional fuel on health and by adding their indigenous knowledge gained from experience. A comparison of the status of household in terms of frequently complained health problems, from the total of respondents, 21 (70%) were complain in eye illness, respiratory disease (such as common cold) and headache which accounts for 56.6, 6.6 and 6.6% respectively (Table 5).

Bajgain and Shakya (2005) stated that, the particles from the smoke can give rise to acute respiratory infections and eye ailments among the people who are in contact with smoke. These peoples are mainly women, children and infants, while in this study, the major victims were women, children and old people due to access to kitchen activities frequently and stay at home during food preparation. It has the same connotation with the study of Bajgain and Shakya (2005).

After biogas plant installation, the households reduce the use of traditional fuel such as firewood and dung cake, and limited these fuel only for *Injera* baking purpose which replaces the use of traditional fuel for cooking sauce (Wot), porridge, tea/coffee and at the same time the households replace kerosene and charcoal by lighting biogas lamp, and by using biogas stove for cooking sauce (Wot), porridge, tea/coffee etc. Due to this reduction of traditional fuel, after installation of biogas only 8 (26.6%) respondents complained about eye illness and head ache. The major victims were females due to baking of *Injera* by using firewood and dung cake but the frequency is less when compared with previous (before use of biogas energy). The direct effects of biogas plant on health and sanitation were found to be more visible than indirect ones; since, the study revealed that smokeless biogas had greatly benefited the plant owners by contributing to a significant reduction in eye related problems and respiratory diseases.

Biogas technology reduces contact hours to open stove fire, that is, after biogas installation the contact time is on average twice a week only for baking *Injera* and the rest activities are accomplished by biogas energy which is clean and smokeless.

Time saving and workload reduction

In the study area of the surveyed households, biogas installation makes each biogas household to save on average 144 min per day from fuel wood collection, cooking, cleaning utensils/kitchen materials, and the reduction in the physical stress was also remarkable. Women and children are the groups that collect fire wood traditionally. Table 6 depicts the time comparison that has been estimated to save up to 51 min on average every day due to installation of biogas energy. Gautam et al. (2005) stated that today's use of biomass in list developed countries does not provide any use of sufficient lighting during the dark hours. The time consumed in collecting fire wood and other bio fuel carried out by women and children results in less time available for education. This means, as the study revealed that, children have time to go to school and they could use the biogas light for studying overnight unlike the previous time that they were used to kerosene for lighting purpose only from 2 to 3 h, and it has dangerous smoke that could affect respiratory organ and cannot be afforded by the poor. On the other hand, biogas gains equity of work among family members in accomplishing works such as slurry mixing which was accomplished by household members. Biogas households use their spare time/saved time in better care of family, in keeping household sanitation, education and other social affair. Due to absence of managing firewood and charcoal during cooking of sauce, porridge and tea/coffee, women could accomplish additional works at the same time.

Economic benefits of household biogas energy investment

Saving from fire wood purchasing expenditure

Due to the installation of biogas plant, there is an annual reduction of fuel wood consumption approximately 79 bundle of fire wood (2528 kg) per year per household and provides each biogas households an equivalent saving of 3833.28 Birr per year at the local rate of Birr 48.40 per 32 kg of fire wood (Table 7).

Saving from charcoal purchasing expenditure

In the surveyed area, after household biogas investment, purchasing of 12 sacks of quintal (324 kg) of charcoal is fully replaced by biogas stove. This amount of charcoal provides each biogas household an equivalent saving of 1,243.20 Birr per year at the local rate of Birr 103.60 per 27 kg of charcoal (Table 8).

Saving from dung cake purchasing expenditure

Due to household biogas investment, 60 sacks of quintal (1,380 kg) of dung cake are saved. This has an equivalent saving of Birr 1,542 annually at local rate of Birr 25.70/sack of quintal dung cake.

Saving from kerosene purchasing expenditure

Besides the above household fuel, all the surveyed households used kerosene for lighting on average of 1.78 L per month per household and 21.36 L per year. Each household spent Birr 22.1789 and Birr 266.1456 per month and per year, respectively. After installation of biogas plant, all the surveyed HHs substituted their kerosene consumption fully by biogas lamp. This shows that Birr 266.1456 was saved annually at the local rate of Birr 12.46/L of kerosene per household (Table 10).

Savings from chemical fertilizer purchasing expenditure

Further, reducing chemical fertilizer has an effect on households' expense, from the total surveyed households, in the demographic characteristics of respondents, 27 of them have an average 1.453 ha/HH agricultural land and the rest have no agricultural land rather they have backyard farm used for managing the biogas slurry and cropping of cash crops such as khat (Chat). Before installation of biogas plant, the surveyed households used an average of 153.26 kg of chemical fertilizer per household annually/crop season/ in an equal proportion of dap and urea in their agricultural land to grow well the crop and increase the production but with an annual expenditure of Birr 1065.16/HH. After installation of biogas, due to use of bio-slurry fertilizer, the average household chemical fertilizer consumption in the crop season was reduced to 50 kg/HH which is saving of 103.26 kg of chemical fertilizer per household per crop season. This has an equivalent saving of Birr 717.657/HH/ crop season with an average local rate of Birr 695/100 kg of chemical fertilizer (Table 2).

Besides the above listed economic benefits of biogas, improving the hygiene and thereby reducing diseases also has an economic value. If people can avoid diseases it also means their working time will not be reduced as a result. The study also revealed that, household family illness due to use of traditional fuel also have an implication on health expense for treatment (Table 11).

In Fogera district, the cost of investment per plant varies due to personal contribution made by the respondents during construction work in the form of labor, variation in the year of construction, size of plants and access to the delivery of construction materials such as stone and sand/gravel. The total investment cost of the plant was an average of Birr 8,762.48 and Birr 9,813.46 for 6 and 8 m^3 respectively and Birr 8,832.55 for an average plant size of 6.14 m^3 for ease to calculate the approximate payback period of the plant. For a plant with total investment cost of Birr 8,832.55, the payback period was 5.77 years to recover investment of biogas plant per household without subsidy, whereas with subsidy of Birr 4,199.25, it could take only 2.7 years, which seem affordable as compared to study conducted by Li et al. (2005) and Woods et al. (2006). The calculation was based on saving from fuel wood, charcoal, dung cake, kerosene and chemical fertilizer (Table 12).

The shorter payback period makes biogas plant affordable for most peri-urban and rural households, even in poor areas (Li et al., 2005). The payback period for

Table 2. Land holdings of the surveyed households.

Land holding type	Average land holding /household in *Temad and ha	Number of respondents who have	Percentage of land holder respondent
Agriculture land	5.8 Temad = 1.453 ha	27	90
Grazing land	1.56 Temad = 0.39ha	16	53
	Common grazing land	14	47
Forest land	1.2 Temad = 0.3ha	5	17

Total land holding: 187.86 Temad = 46.971ha; Av. landholding/HH: 3.91 Temad = 0.978ha. Source: Field Survey, 2011.

Table 3. Total number of livestock and biogas produced per kg of animal dung.

Type of animals	Total number of animals	Daily produced dung/animal in kg	Total dung available per day in /kg/	Gas produced per day/ m^3/
Cattle	182,699	10-15	1,826,990-2,740,485	65,771.6-98,657.5
Sheep	15,575	0.75-1	11,681.25-15,575	420.525-560.7
Goats	25,956	0.75-1	19,467-25,956	408.807-545.076
Poultry	64,227	0.06-0.2	3853.62-12845.4	1,965.35-6,551.15
Horses	571	14-16	7,994-9,136	7,274.54-8313.76
Donkeys	13,772	12-15	165,246-206,580	134,675.49-168,362.7
Total	302,800		2035231.87-3010577.4	210,516.312-282,990.886

Source: Fogera District Agricultural and Rural Development Office, 2011 and Nijaguna, 2002.

Table 4. The annual collected and disposed waste in the town administration.

Type of waste	Unit	Daily generated	Daily collected and disposed waste	Remark
Solid	kg	34,500	32,000	
Liquid	Liter	40,000	20365	
Total		74,500	52,365	

Source: Fogera district municipality Office, 2011. NB: 1 kg of solid waste equal to 1 L of liquid waste (Nijaguna, 2002

Table 5. Analysis of health benefits before and after installation of biogas.

Health problems	Before			After		
	Number of respondent	Percent	Major victim	Number of respondent	Percent	Major victim
Eye illness	17	56.7	Females, child and old	6	20	Females
Respiratory disease	2	6.6	Females and child	-	-	-
Headache	2	6.6	Females and old	2	6.6	Females
No complain	9	30	-	22	73	-
Total	30	100		8	100	

Source: Field Survey, 2011

Table 6. Analysis of average time for daily works before and after biogas installation.

Daily works	Average time in minutes per day		Av. time saved per day in min/HH	Implementers
	Before	**After**		
Fuel wood collection	76	25	+51	Women and Children
Cooking	240	164	+77	Women and Children
Fetching water	30	56	-26	Women and Children
Cleaning utensils	54	35	+19	Women and Children
Livestock caring	35	35	-	Men and children
Dung cake collection and moulding	57	19	+38	Women and Children
Slurry mixing	-	15	-15	All Family members
Total	**492**	**349**	**+144**	

Source: Field Survey, 2011. +shows saved time due to household biogas investment.

Table 7. The amount of fuel wood consumption before and after installation of biogas plant.

Before installation of biogas plant			After installation of biogas plant		
Amount of fuel wood /HH/month in bundle/	**Number of respondent**	**percent**	**Amount of fuel wood /HH/month in bundle/**	**Number of respondent**	**Percent**
4-7	10	33	1-2	16	53
8-11	12	40	3-4	12	40
12-20	8	27	5-6	2	7
Total	30	100		30	100
Av. Bundle/HH/Month = 9.366(299.7kg)			Av. Bundle/HH/Month = 2.766(88.5kg) Difference = 6.6bundle (211.2kg)		

1 Bundle of fuel wood weighs on average 32 kg; price of 1 bundle of wood = on average Birr 48.40 (local market, February 14, 2011); 1 US$ = Birr 16.66 (National Bank of Ethiopia) (NBE, March 10, 2011) Source: Field Survey, 2011.

Table 8: Amount of charcoal consumption per household per month before Installation of Biogas Plant

Amount of charcoal in sack of quintal/HH	Number of Respondent	Percent	Remark
0.5	13	43	1 Sack of quintal Charcoal weighs on average 27 kg
1	7	6.67	
1.5	10	34	
Total	30	100	

Average used /HH/month/ in sack of quintal = 1; Price of 1sack of quintal of charcoal at local market = Birr 103.60 Average used/HH/year in sack of quintal = 12, that is, 324 kg; 1 US$ = Birr 16.66 (National Bank of Ethiopia) (NBE, March 10, 2011) Source: Field Survey, 2011.

Table 9. Amount of dung cake consumption per household per month before and after installation of biogas plant.

Before installation of biogas plant			After installation of biogas plant		
Amount of dung cake /HH/month in kg	**Number of respondent**	**Percent**	**Amount of dung cake /HH/month in kg**	**Number of respondent**	**Percent**
1-5	11	36.67	.5 -2	18	60
6-10	13	43.3	3-5	10	33
11-15	4	13.3	6-8	2	7
≥ 16	2	6.67	-	-	-
Total	30	100	Total	30	100

Average sack of quintal dung cake /HH/Month = 8; Average sack of quintal dung cake /HH/Month = 3 (5 sack of quintal saved). 1 quintal sack of dung cake weighs on Average 23 kg. Price of 1 quintal sack of dung cake = on Average Birr 25.70 (Local market, February 14,2011). 1 US$ = Birr 16.66 (National Bank of Ethiopia) (NBE, March 10, 2011). Source: Field Survey, 2011.

Table 10. Amount of kerosene consumption per HH before installation of biogas plant.

Amount of kerosene in liter/HH/ month		Number of respondent	Saving of kerosene after installation of the plant/ in liter
	1 to 2	26	
	>2	4	
Average household consumption in liter			
Per month	1.78	30	1.78
Per year	21.4	30	21.4

Price of 1 liter of kerosene = on average Birr 12.46 (Trade transport Office of town Adm., February 1, 2011); 1 US$ = Birr 16.66 (National Bank of Ethiopia) (NBE, March 10, 2011); Source: Field Survey, 2011.

Table 11. Fertilizer consumption before and after biogas Installation.

Particulars	Fertilizer used	Number of respondent	Percent
Before biogas installation	Farmyard Manure and Chemical fertilizer	26	100
Total		26	100
After biogas installation	Farmyard Manure and Bio-slurry	23	88.46
	Farmyard Manure, Chemical fertilizer, Bio-slurry	3	11.54
Total		26	100

Source: Field Survey, 2011.

Table 12. Saving of chemical fertilizer due to household biogas investment.

Amount of Average chemical fertilizer used before installation of biogas/HH/crop season in kg	Amount of chemical fertilizer before installation of biogas/HH/crop season in kg	Difference/saved due to installation of biogas plant	Percent
153.26	50	103.26	67.37

100 kg of chemical fertilizer on Average = Birr 695 (Fogera District Agricultural and Rural Development (2011), 1US$ = Birr 16.66 (National Bank of Ethiopia) (NBE, March 10, 2011). Source: Field Survey, 2011.

Table 13. Households' level of satisfaction.

Particulars	Number of respondent	Percent
Fully Satisfied	26	87
Moderately Satisfied	4	13
Not Satisfied	-	-
Total	30	100

Source: *Field Survey, 2011.*

Chinese type fixed dome biogas digester depends on how the biogas digester is used, what substrates, size, price on fuel wood, etc and without any subsidies would be around 3.6 to 5.8 years of payback period (Woods et al., 2006). The regional biogas coordination office and SNV/Ethiopia, estimated the cost of annual maintenance and miscellaneous expenses to be Birr 200 and 100 per plant, respectively. These costs are reserved in bank in the name of the plant owners dedicated from the subsidy.

Perception of users on benefits of household biogas energy

All the surveyed biogas plants were operational except temporary problems of lamp and other accessories. Due to this, the responses were quite satisfactory (Table 13, plate 1 and 2, box 1). There was significant satisfaction in terms of reduction of household fuel consumption, cease to expend for chemical fertilizer and HH traditional fuel, improvement in health and sanitation, time saving and studying for students among others.

Plate 1. User while lights biogas stove

Plate 2. User while cooking with biogas stove.
Source: *Field Survey, 2011*

Mrs. Debre Tsega one of biogas user, lights her stove, emitting a full blue clean fire. *"Did you see how fast it sets fire?" This is one of the main benefits". It used to take a long time to get an appropriate fire with charcoal, fuel wood and dung cake. "It makes life a lot easy".*

With full Charm, Waga Alem leads us to her kitchen, which is equipped with a stove and a lamp that both run on biogas plant. With a big smile she speaks about the changes this new technology brought to her daily life. *"Look at my kitchen it has never been so clean and see the time to cook Shero (local Sauce) it's a matter of less than 5minutes. Before I got biogas, I used to cook with charcoal, wood, dung cake and agricultural residue which produced a lot of smoke and takes time to give fire and it brought a bad smell. This now belongs to the past and its history"*.

Box 1. Opinion of the users.

Conclusions

The use of biogas has a potential to reduce the demand for wood and charcoal use, hence reducing greenhouse gas emissions. In addition, the slurry and waste from the biogas plants provides a high quality fertiliser that can be used to improve the soil fertility and increase productivity in agriculture dependent rural communities of the study area.

In the study area, the biogas user households benefit from reduced indoor smoke, improved sanitation and better lighting. The biogas installation make each household to save on average 144 min per day from fuel wood collection, cooking, cleaning utensils/kitchen materials),and there is also reduction in the physical stress and health improvement.

The economy of a biogas plant is characterized by initial high investments costs, some operation and maintenance costs, mostly free raw materials (animal dung, weeds, plants, sewage sludge, human wastes, municipal wastes, etc.) and income from replacement of purchasing traditional fuels. In addition, the slurry and waste from the biogas plants provides a high quality fertilizer that can be used to improve the soil fertility and increase productivity in agriculture dependent rural communities in the study area. Use of biogas provide an annual saving of 3833.28 Birr from fuel wood, Birr 1243.20 from charcoal, Birr 128.50 from dung cake and Birr 266 and Birr 717.65 from kerosene and chemical fertilizer, respectively with Net cash flow of Birr 1530 per HH/year.

There are some challenges that must be tackled in order to ensure sustainable future of biogas technology. These challenges were seen from two angles: from the users' side and on the disseminators' side.

Attitudinal problems

According to the field survey, due to unavailability of demonstration areas for biogas plant in the nearby peasant associations (PAs), from the total surveyed users of biogas, 4 of them did not believe on gaining of light and cooking fuel from dung and human excreta until they saw it on the due date.

Lack of awareness on lamp care

Due to awareness problems on the technology, and lack of responsible technology disseminator technician, from the total respondent, in the majority (40%) their biogas lamp was broken due to improper lamp care (4) and feeding amount (4).

Standard problems in feeding amount of the raw material to biogas digester

The users complained about fixed standards of the raw material amount of the digester that were recommended by the disseminator to feed the biogas digester. Since the cellulose content of the grass that the cow eats is not equal throughout the year, the chemical content of the grass makes the biogas lamp to break. From 40% stated above, (4) respondents complained the constant standard of feeding amount recommended by technicians of biogas disseminators, Surprisingly, 4 respondents stated that, "the power/cellulose/content of dung that we add per day throughout the year is not equal, due to this, the power (in their expression) of the grass that the cows eat in the summer season makes the lamp to break". Currently, these households use their own indigenous knowledge and make correction about the feeding amount without any externality advice on the side of the responsible bodies.

Bio-slurry management problems

Due to awareness problems, 2 respondents have not reserved bio slurry storage tank. As a result, they faced problems in using efficiently the bio slurry for their farm.

Missed application of liquid bio-slurry in their back yard farm

Unknowingly, 4 respondents' cash crop such as Khat (Chat) had got dry due to missed application of liquid bio-slurry. After the problem appeared, one user uses his indigenous knowledge by understanding the cause through experience without external technical assistance about liquid bio-slurry application. As stated by this respondent, "the chemical content of the liquid bio-slurry is dangerous unless it mix with water during application".

Fear of the future due to unavailability of accessories /appliances

The biogas accessories are lamp, stove, connecters, gas pipes, pressure meter. Not less than 3 users have no slurry mixture and this doubles the time to add dung to the digester. Such problems make the user to fear the future about getting these appliances due to absence of the appliances in the local market as they need. Currently, 12 respondents have no lamp either one of the two (8 m^3 owners) or from one of the one (6 m^3 owners) but some of the user uses local materials to gain light from biogas and 1 user encounters problems of stove, 3 users problems of connectors and 1 user problems of pressure meter. Even lamps are guarantee of up to two years by the disseminator to be replaced when broken, for sustainability of the technology; users fear the cost of lamp which is Birr 85 per lamp.

The challenges encountered by biogas disseminator organizations, non-governmental organizations (SNV/Ethiopia) and the local government organizations raised their problems for not disseminated as expected.

Variation of market price and cost of installation

The criteria for disseminating the biogas plant to the community in the study area was; purchasing power and willingness of the user, having at least 4 cows, accessibility of water and construction material, area for slurry management. However, according to regional biogas coordination office and SNV/Ethiopia regional branch office, "due to construction material cost variation (such as cement) by not less than 50% in 2010/11, cost are born by the user and absence of loan to the poor inhibits the dissemination of household biogas investment as planned and or expected".

Lack of users' promotion

Even the promotion and awareness of users were the responsibility of the local government bodies such as district agricultural and rural development, higher government bodies and energy officials, the higher government bodies are not aware of biogas energy benefits and there is no sufficient experts at district level, and in the PAs there is no expert at all that follows biogas energy affairs.

Recommendations

Mainstreaming and promotion of biogas technology in different development activities

Government commitments to the development and promotion of renewable energy sources are advisable. It could be helpful to learn from the experiences gained in the developed world but should adapt to the needs and situation in the study area and in Ethiopia in general.

Develop training programs

Develop training programs for engineers, artesian, users, and all professionals involved in biogas dissemination.

Good understanding of the relation between capital costs and plant size

It can provide useful information in assessing economic viability of biogas plants, and providing means whereby decisions are taken on developmental of a new project.

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