The role of Biogas Energy Production and Use in Greenhouse Gas Emission Reduction; the case of Amhara National Regional State, Fogera District, Ethiopia

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Abstract*—Energy is a key to development. About 94% of Ethiopian households depend on biomass fuel to meet their daily energy needs, while modern fuel due to lack of amenities and low income is either not available or not affordable for the majority of the population both in Ethiopia and particularly in the study area. This use of traditional fuel leads to environmental degradation and ecological imbalance and adverse human health impacts. The main objective of this study was to study the role of biogas energy production and use in greenhouse gas emission reduction in Fogera District, Ethiopia. The field work was based on survey/schedule questionnaire and interview (in Fogera district 30 biogas user households in March 2011). The primary data was used for calculation of greenhouse gas emission (Intergovernmental Panel for Climate Change guidelines). The study revealed that, biogas was used for cooking and lighting and, before biogas installation, the surveyed households were using to traditional fuels in high amount but not after. The total annual greenhouse house gas emission was 5,459kilogramg CO_2e/Household/year. Each biogas plant reduced the emission to 1612kilogramCO_2e/Household/year by saving 3847.2192 kilogram CO_2e/household/year (70.47%) due to reduction of firewood and kerosene usage at household.

***Keywords*—Renewable energy, Greenhouse gas emission, Biomass, Biogas**

1. Introduction

Energy is the basic factor contributing to development, and sustainable development is not possible without making energy systems more sustainable. No country has managed to develop much beyond a subsistence economy without ensuring at least minimum access to energy services for a broad section of its population **[1].** It is therefore, not surprising to find that the billions who live in developing countries attach a high priority to alternative energy services. Rising oil prices, growing energy security concerns and the human devastation caused climate change are increasing the attractiveness of alternatives to conventional fossil fuel based energy sources .This shows how energy is vital to development of the country. Overall, at least 1.6 billion people-one-fourths of the world's population-currently live without electricity and this number has hardly changed in absolute terms since 1970 and yet, the electricity required for people to read at night, pump a minimal amount of drinking water and listen to radio broadcasts would amount to less than 1 percent of overall global energy demand **[2].** From this, it can be concluded that how energy inhibits the economic and social amenity of the community in particular and country in general.

Two billion people – about 40 percent the total world population depends on fire wood and charcoal as their primary energy source. From these people, three quarters (1.5 billion) do not have an adequate, affordable supply **[3].** When people needs affordable energy for household activities but fire wood becomes increasingly scarce, women and children who do most of the domestic labor in many cultures spend more time in searching of fuel wood. In some places, it takes eight hours or more just to walk to the nearest wood supply and even longer to walk back with a load of sticks and branches that will only last a few days. In Sub-Saharan Africa, about 50 percent of all primary energy comes from biomass. In Ethiopia, however, dependency from biomass amounts to 94 percent, half of the biomass is used for baking *Injera* **[4].** Empirical evidences explained in the above shows how the world calls for alternative energy sources of environmentally and socio-economically feasible.

2. Materials and Methods

The study was conducted to describe the existing experiences and facts related with biogas energy benefits in greenhouse gas emission. Data about Interventions of biogas energy on environmental benefits to the biogas households were collected and analyzed; hence descriptive type of research was employed to address the objective of the study. Since the target population was manageable, by considering these parameters, this study used census study design. The instrument were, survey/schedule questionnaire.

The type of research brings to light the fact that there are two basic approaches to research, quantitative and qualitative approach. The former involves the generation of data in quantitative form which can be subjected to rigorous quantitative analysis in a formal and rigid fashion; the qualitative approach is concerned with subjective assessment of attitudes, opinions and behavior **[5].** Taking in to account the above facts about the research approach, the objective of the study, the availability of subjects and data, and the nature of the data collected, both qualitative and quantitative approaches were employed in this study.

2.1 Description of the Study Area

Fogera district is one of the 106 *districts* of Amhara Regional State and found in South Gondar Zone. The district is located in North West of Addis Ababa with a distant of 625 km and 55 km north east of the capital city of National Regional state, Bahir Dar. It has an altitude of 2410 meter above sea level and characterized by an average rain fall of 1216.3mm, minimum and maximum temperature of 16^{o}C and 20^{o}C respectively. It has a population 228, 449 (52,905 households) that lives in an area of 11,7405ha with an estimated population density of 108 people per square kilometer **[6].** The main natural resource of the district is could be taken 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 construction. It is observed that the forest will be surely destroyed in few years, if proper solutions are not taken **[7]**.

2.2 Sources of Data

2.2.1 Primary Data Sources

The study was employed survey questionnaire/schedule and interview schedule to collect first hand information from the respondents and interviewees respectively. The researcher prepared and interviewed the respondents through the schedule questionnaires. Observation of biogas plant status, toilet facilities and usage conditions, market value of household fuel on the market were observed and taken by the help of 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 (PAs). Interviews were also conducted to officials before, after and during the questionnaire were collected.

2.2.2 Secondary Data Sources

Secondary data sources such as books, policy documents, published and unpublished documents, journals, and websites that were relevant and strengthened the researcher's understanding about the study were reviewed and studied.

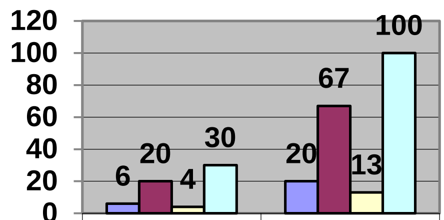
3. Results and Discussions

3.1 Demographic Data

The demographic characteristics of the biogas user households are; household size, educational status, potential of livestock and landholdings. These elements are presented in data presenting tools such as figures and tables as follow.

3.1.1 Household size

As illustrated below Fig 1, the average household size of the surveyed biogas users was an average 7.



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

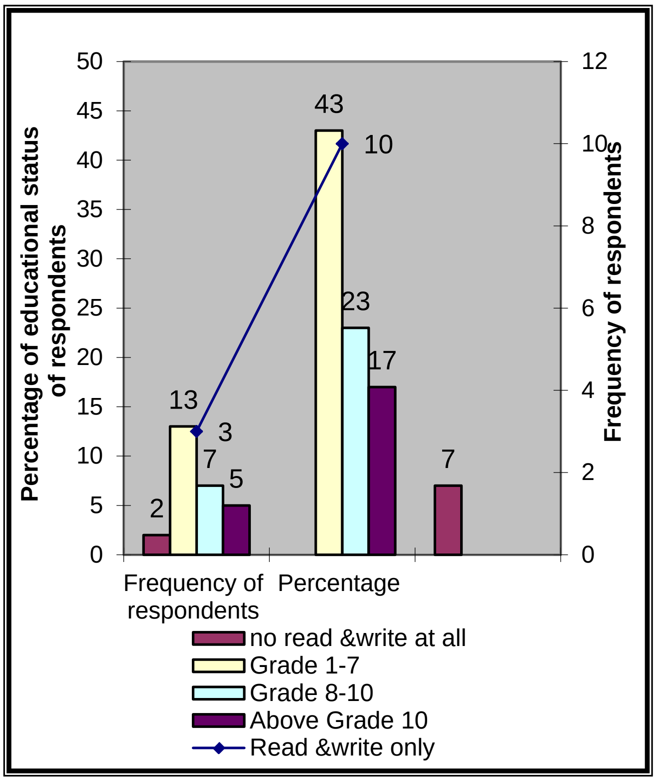
1-4
5-8
9-12
Av. Household size = 6.9

Source: *Field Survey, 2011*

Figure 1. Average household size of the biogas households

3.1.2. Educational Status of Biogas User Households

Educational status of biogas user households in the surveyed biogas households are from not read and write at all to above grade 10, as presented below Fig 2, 2 respondents (7%) haven't education, 3 (10%) read and write only, 13(43%) grade 1to7), 7(23%) grade 8 to 10 and the rest 5 respondents were above grade 10 who are grade 11 to 12 complete.



Source: *Field Survey, 2011*

Figure 2 Educational Status of Biogas households

3.1.3 Livestock Potentials of Biogas user Households

As presented below on table 1, 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 and each household contains on an average of 2 sheep, 5 goats, 5 poultry and 2 households have 1 and 2 horses and 22 households possesses 2 donkeys on average.

Table 1: Possession of Animals on Biogas user Households

Types of animals	Average holding size /HH	Remark
Cattle	12	
Sheep	2	
Goats	5	
Poultry	5	
Horses	1-2	**28 HHs haven't**
Donkeys	**2**	**8HH haven't**

Source: *Field survey, 2011*

3.1.4 Total Land Holdings of Biogas Households

The land holdings of surveyed biogas households are agricultural, grazing and forest areas. About 27 (90%) of respondents have an agricultural land of an average of 1.453 ha and the rest 3(10%) have not at all. On the other hand, 16(53%) have on an average of 0.39 ha grazing land and the rest14 (47%) have limited common grazing land and 5(17%) of respondents have their own protected forest area of an average 0.3 ha and the rest25 (83%) have not at all and the rest are presented below on table 2.

Table 2: Land Holdings of Biogas Users

Land holding type	Average land holding /HH In *Temad and ha	Number of respondents having	Percentage of land holder respondent
Agriculture land	5.8 Temad = 1.453 ha	27	**90**
Grazing land	1.56 Temad =0.39ha Common grazing land	16 14	**53** **47**
Forest land	1.2Temad = 0.3ha	5	**17**
Total land holding : 188 Temad =47ha			

Source: *Field Survey, 2011*

Av. landholding /HH: 3.91 Temad = 0.977ha

3.2-Findings and discussion

The findings of the study are the original data, quantitative or otherwise, derived or taken from the original sources and which are results of questionnaires, interview and observations. Findings do not directly answer the specific questions asked at the beginning of the study but the findings provide the bases for making the answers. Therefore, based on this, the findings of this study and discussions are presented as follows.

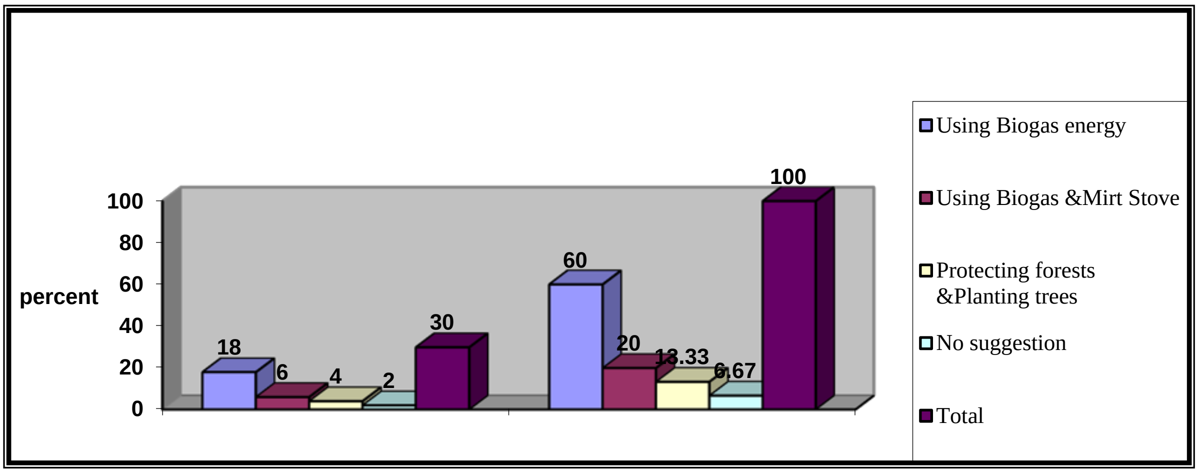
3.2.1 Status of Household Energy Consumption

The main household energy used in the study area was dry wood, charcoal, dung cake and agricultural residues and kerosene. This finding is supported by previous literatures such as **[3].** Two billion people – about 40 percent the total world population depends on fire wood and charcoal as their primary energy source. From these people, three quarters (1.5 billion) do not have an adequate, affordable supply.

3.2.2 Suggestions of Respondents to Minimize the Negative Impacts of Traditional Fuel use on Forest products

From the total of biogas energy users in the study area, 18 respondents gave suggestion to use biogas energy, 6 respondents suggest to use biogas energy and Mirt stove 4 respondents suggest protecting forests and substituting the loss of vegetation by planting trees. The rest 2respondents not gave response at all.

* Pair of oxen ploughs 1hectare per day and this is called "Temad", which is name of local measurement.



Source: *Field Survey, 2011*

Figure 3 Mitigation Measures of Respondents Suggestion to minimize the problem of Traditional Fuel

3.2.3 Greenhouse Gas Emission Reduction due to Household biogas energy investment

The human influence on the climate comes from emissions of three green house gases (GHGs) in particular carbon monoxide, methane and nitrous oxide **[1].** In the study area, the surveyed households used fuel wood, charcoal, dung cake, kerosene and agricultural residue which have contribution in emitting the above mentioned greenhouse gas (GHG) elements in different amount. Before installation of biogas plant, the surveyed households used 3596.4kg of fuel wood /HH/ year which emits 5459.3352kg of carbon dioxide equivalent (CO_2e) gas /HH/year, but after biogas installation, each biogas household saved 3847.2192kg carbon dioxide equivalent (CO_2e) gas (70.47%) per year that were emit to the atmosphere and have reduction of consumption to 1062kg of fuel wood (1612.116kg GHG emission) per year due to use of biogas energy fuel for cooking.

Besides, the surveyed households also used kerosene for the purpose of lighting in the home during night time for studying and accomplishing household activities. As presented on table 8, before installation of biogas plant, on average each household consumed 1.78 liter of kerosene per month and 21.36 liter per year by lights only from 2 to 3hrs per day. This amount of kerosene was emitted 53.05822 kg carbon dioxide equivalent (CO_2e) gas per year to the atmosphere. After installation of biogas, all the biogas households have substituted it by lights gained from biogas lamp. This has a potential to save 53.05822kg of greenhouse gas that were emitted to the atmosphere per Household/year.

Table 3 Fuel Wood Consumption and Greenhouse Gas Emission (GHG) per Household (HH) before and after biogas installation

Particulars	Av. Fuel wood consumption in kg/HH/month	GHG	Emission in kg/month/HH	Emission in kg/ HH/ year	Emission in kg/CO_2e/HH/yr	Total emission in kg CO_2e/HH/yr
Before	299.7	CO_2	421.3782	5056.5384	5056.5384	
		CH_4	1.1988	14.3856	302.0976	**5459.3352**
		N_2O	0.0272727	0.3272724	100.6992	
After	88.5	CO_2	124.431	1493.172	1493.172	
		CH_4	0.354	4.248	89.208	**1612.116**
		N_2O	0.0081	0.0972	29.736	
Difference	**211.2kg**					

Source: *Field Survey, 2011*

Table 4: Greenhouse Gas Emission from Kerosene per Household

Particulars	Av. Kerosene consumption in liters /HH/month	GHG	Emission in kg/month/HH	Emission in kg/ HH/ year	Emission in kgCO_2e/HH/yr	Total emission in kg CO_2e/HH/yr
Before	1.78	CO_2	4.37346	52.4815	52.4815	
		CH_4	0.000638	0.007656	0.14952	**53.05822**
		N_2O	**0.0001121**	**0.0013452**	**0.4272**	

Source: *Field Survey, 2011*

The total annual greenhouse gas emission before installation of biogas was 5512.3923442kg of carbon dioxide equivalent (CO_2e) gas /Household/year. These were from fuel wood and kerosene. after installation of biogas plant, as stated on table 4.9, average methane leakage from slurry tank per plant per year was 900.145kg of carbon dioxide equivalent (CO_2e) gas from an average size of biogas plant (6.13 m^3). On the other hand, kerosene was replaced by biogas lamp and reduces 53.05822kg of carbon dioxide equivalent (CO_2e) gas. 3000.133 kg of carbon dioxide equivalent (CO_2e) gas/Household/year was net saved due to use of biogas energy at household. **GWP**[1] of CO_2 =1, CH_4=21[2] and N_2O=31 **[8].**

Table 5. Total Annual Greenhouse Gas Emission Reduction due to biogas investment

Fuel Type	Annual GHG Emission in $kgCO_2e/yr/HH$		Emission Difference
	Before biogas installation	After biogas installation	
Fuel Wood	5459.3352	1612.116	**+3847.2192**
Kerosene	53.05822	-	**+53.05822**
Av. Methane Leakage	-	620.4051	**-900.145**
Total	**5512.39**		**+3000.133**

Source: *Field Survey, 2011*

NB: - + Shows saved Greenhouse Gas due to biogas Plant installation

-900.145 shows expected methane after biogas plant installation.

3.2.4. Estimation of Methane Leakage from Slurry Tank

Before biogas installation, there was no methane leakage from slurry tank but after biogas installation, there is leakage of methane.

Table 6. Estimation of Methane Leakage from Slurry Tank

Plant size (m^3)	Number of plants	Av. Methane Leakage per plant per day	Total Methane Leakage cu.m per day	Total Methane Leakage cu.m per year	Total Methane Leakage in kg per year
6	28	0.165	4.62	1124.2	
8	2	0.17	0.34	124.1	
Total	30	0.335	4.96	1248.3	

Av. Plant size = 6.13

***Density of Methane = 0.71kg/cu.m**
Average Methane Leakage = 4.96/30 = 0.1654 cu.m/day/plant = 0.71*0.1654*365= 42.864kg/yr/plant

Average methane Leakage in CO2e per Plant per year = 42.864*21* = 900.145kgCO_2e

Source: *Field Survey, 2011.*

[1] Density is concentration of gas in relation to its size.
[2] 21 is GWP(Global Warming Potential of CH_4)
* Density is concentration of gas in relation to its size.
* 21 is GWP(Global Warming Potential of CH_4)

3.2.5. Contribution of Biogas to 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.

A: Livestock Population in Fogera District

As it is indicated on table 7 below, documents gained from **[9],** 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. The daily dung production from livestock alone could be about 1,826,990kg to 2,740,485kg which has theoretical potential to produce from 65,771.6 m^3 to 98,657.5m^3 of biogas.

Moreover, the annual dung production is about 666, 851,350kg - 1,000,277,025kg, which has a potential production from 24,006,648.6m^3 to 36,009,972.9m^3 of biogas annually. However it is estimated that only 90 percent of the theoretical potential i.e. 21,605,983.74m^3 to 32,408,975.6m^3(Av.27,0074,79.67m^3) of biogas would be practically available since the number of animals also include the households with only one cattle or goat and hence do not have enough dung volume even feed the smallest size (4m^3) which requires 24 kg of dung per day. This has a potential for saving fuel wood from 118832910.6kg to 178249365.8kg, Charcoal from 34569573.98kg to 51854360.96kg, Kerosene from 16226, 093.79litre to 24339,140.68 liter and electricity from 34569,573.98 Kilo watt hour /Kwh/ to 51854360.96 Kilo watt hour/ Kwh annually **11]**

From the total of 302,800 Livestock, Cattle and Poultry constituted the highest numbers and others are presented on table 7 below.

Table .7 Total Numbers 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**

B: Human population In Fogera district

Documents gained from **[6],** in Fogera district 228,449 people reside, which have a potential to produce 228449*0.3*365 = 25015165.5kg of human waste annually (one individual person generates 0.3 kg of waste per day **[10].**

Assuming that all people have pit latrines ,and if they properly utilized their excreta, this would have a potential of producing 25015165.5kg*0.046m^3 = 1,150,697.613m^3 of biogas, which saves 6,328,836.872kg of firewood,1,841,116.181kg of charcoal,864,173.9 liter of kerosene and 1,726,046.42Kwh to 1956,185.942Kwh annually.

C: Municipal Waste in Fogera Town Administration

As presented table 8 below, documents gained from Fogera district municipality, the town Administration generates approximately 34,500kg (34.5 tones) of solid waste and 40,000 liter (40tonne) liquid waste was generated per day. Among these, the municipality collects and disposed only on average 32,000kg of solid waste and 20,365 liter of liquid waste per day, which is 92.5 percent and 50.91 percent 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 usage, the disposed waste creates bad smell to town and its surroundings that will create health problems.

According to **11],** 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 **[12].** Biogas technology has 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 not 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 14, 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 19,113,225kg*0.03m^3 = 573,396.75m^3 of biogas, which saves 105,122,737.5kg of firewood,30,581,160kg of charcoal,14,354,031.98litre of kerosene and 28,669,837.5Kwh to32,492,482.5Kwh electricity annually. Besides, this all 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, two birds with one stone principle like Brazil. That is, as source of energy and as environmental sanitation.

As illustrated below in table 8, 34,500kg solid waste were generated daily and 40,000kg of liquid waste which is 11,68,000 kg and 74,332,25 liter solid and liquid waste respectively annually. From thus, 92.5% of solid and 50.91% of liquid waste is collected and disposed **[13]**

NB: 1kg of solid waste equal to 1 liter of liquid waste **[10].**

Table 8. The Annual Collected and Disposed Waste in the town Administration

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

4. Conclusions

In the study area of biogas households used biogas for cooking and lighting. As the study revealed that, due to household biogas investment some Greenhouse Gas emitter household fuels such as fire wood and kerosene are reduced and fully replaced, this reduction of household fuel saves the potential of3000kgof CO_2e/Household/year.

Besides this global benefit of biogas plant, the document analysis showed biogas used for cleaner production at local and household level by recycling the dangerous wastes. In the study area, there is 28,731,574m^3 of biogas from the potential of livestock population, human population and wastes generated from the municipality which has dual benefits as cleaner production to clean environment and as energy sources.

5. Recommendations based on Findings

Recommendations are made which will be beneficial to local and national Governments, the communities and other partners such as non Governmental organizations and institutions to tackle the existing challenges.

The biogas user households use cow dung only as raw material. Therefore, users should be made aware of the feeding materials of any other biodegradable materials that can be used for the production of biogas energy.

The use of biogas is imperative for clean environment by using wastes from people, livestock, and locality at large. To this end, environmental impact assessment (EIA) should be considered prior to any form of investment in urban agriculture. Therefore, the environmental protection, municipality, health and energy offices in Fogera district should work in collaboration, conduct environmental impact asesement, and put in to action integrated clean environment mechanisms – biogas use in their locality to reduce adverse effects in clean environment. There should be a policy of clean development Mechanism and Carbon trading in international market. Since the benefit of biogas is both to urban and rural households by replacing kerosene and charcoal fully and reducing dung cake and fire wood consumption, the Government should work together with community and private sector in order to disseminate the technology at all areas and levels of the community.

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