Final Report on

Technical Study of Biogas Plants Installed in Bangladesh

Submitted to:

National Program on Domestic Biogas in Bangladesh

A Partnership Program of Netherlands Development Organization (SNV)
and
Infrastructure Development Company Ltd (IDCOL)

Submitted by:

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EXECUTIVE SUMMARY

- Realization of the fact that the success of the proposed National Domestic Biogas Programme in Bangladesh depends heavily upon the workable and effective implementation plan that is based upon the grassroots reality of the sector, a study was proposed by SNV/IDCOL to collect and analyze information on present status of biogas plants and various biogas related issues from the users' level.
- The overall objective of the proposed study was to conduct a technical review of existing biogas plants constructed across Bangladesh over the past years to facilitate the preparation of implementation plan for the proposed National Domestic Biogas Programme. The field study was carried out during the period September 03 to October 09, 2005 in 72 randomly sampled biogas households from eight different districts representing all the six divisions in Bangladesh. These plants were installed by BCSIR (61 nos.), LGED (7 nos.) and GS (5 nos.) during the period 1997 to 2005. Analysis and interpretation of the result have been done with the data and information from only 66 households as the six plants were feared to be outliers.
- The average family size in studied households was 7.36, with a maximum of 25. The average land holding size of 5.25 acre, average cattle holding of 5.61, average annual income of BDT 219700, average annual expenditure of BDT127400 and literacy rate of 86% (female-81% and male-91%) indicated that biogas plants have been installed by relatively well-off peoples in the society. The corresponding national figures are 5.18, 1.38, 2.64, BDT 70104, BDT 53772 and 48.8% (female-44.5% and male- 52.8%) respectively
- Economic benefits including saving of time and money, environmental benefits, availability of subsidy and health benefits including the reduction of smoke-borne diseases were the main motivational factors for the users to install biogas plants. The average size of biogas plants was found to be 3.9 cum gas production per day, which is rather oversized if viewed from domestic purpose. The cost of installation ranged from an average of BDT 13575 for 100 cft gas producing plant to BDT 30500 for 300 cft size. 94% of the total plants were constructed without taking loans. Taking loan was not a common practice and the reason mentioned for not taking loans were good economic conditions (44%), attitude against the philosophy of taking loans (21.5%), cumbersome process of loan sanctioning (15%), higher interest rates (3%), lack of collateral to fulfill the requirements of credit institutions (1.5%) and ignorance on the availability of loan facility (1.5%).
- The outcome of the study indicated that the whole quantity of dung produced in the stable was not fed into the plant. It showed that out of the theoretical available dung (calculated based upon the number of cattle and poultry) of 5370.9 kilograms (81.37 kg/household on an average), 4327.7 kilograms (81%) was fed into the biogas digesters. However, the prescribed quantity of dung based upon the hydraulic retention time of 40-45 days for the Bangladesh context is 6362.5 kg, which is 19% more than the available feeding and 47% more than the actual feeding presently practiced. The average feeding rate thus was 17 kg per 1 cum gas production per day biogas plant, which is 68% of the required quantity. Only 26% of the households produced required quantity of feeding materials; 44% households produced less than half of the required quantity; 50% of the total plants received less than 50% of the prescribed quantity; and 83% plants were under-fed. The main reason for under-feeding was the non-availability of feeding materials mainly due to decreased number of cattle (64% of the plants) because of selling of cattle after the installation of biogas plants. Water-dung ratio was more than 1:1 in 56% of the plants. 15% of the households had attached latrines with the digester. Latrine attachment was not accepted in majority of the communities because of social taboos.

- The general quality of construction and workmanship involved in construction of biogas plants indicated that there are lots of rooms for further improvements. The overall condition of biogas plants was good in 3% of the cases, fair in 76% cases and poor in 21% of the cases. Non-compliance of overall quality standards, improper relative orientation of plant components, poor gas conveyance systems, problematic stoves and defective outlet chambers were observed to be major drawbacks.
- Biogas plants under study were categorized into three different groups in terms of their working conditions based upon some set of indicators. The outcome of the study indicated that despite number of defects and weaknesses, the functional status of biogas plants on an average was satisfactory. Out of the 66 plants under analysis, 31 (47%) plants were functioning satisfactorily, 21 (32%) plants were functioning partly and the remaining 14 (21%) plants were not functioning at all during the time of field investigation. The reasons for non-functioning were non-availability of feeding materials especially due to selling of cattle after the installation of biogas plant (responded by 6 users), poor workmanship during construction (responded by 5 users), sub-standard quality of construction materials and appliances (responded by 3 users), non-availability of repair and maintenance services (responded by 2 users), defects in pipelines (responded by 2 users) and poor operational activities (responded by 2 users). The number of functional plants was lower in number than that reported by a study carried out in 2004 by DPC Group, which suggested that 88.5% of the plants constructed by BCSIR during Phase I and 97.2% of the plants constructed during Phase II were functional. However, the functional rate is higher than the functional plants in Pabna District where the functional plants were reported to be just 50% (Ali, 2005).
- The theoretical amount of gas production from all the biogas plants under study based upon the daily feeding was 150.61 cum of biogas per day. Total biogas production based upon the gas being used was 74.71 cum per day. The calculated efficiency of biogas plants collectively was, therefore, 49.6%. The lower input to output ratio suggested either (i) the feeding material fed into the digesters was not fully digested and escaped out of the plant prior to its full digestion either because of short-circuiting (as a results of dead volumes in digester or displacement chamber) or higher water-dung ratio in the feeding, or (ii) the produced gas did not store in the gasholder, rather escaped in the atmosphere either because of undersized volume of gasholder or cracks in the dome, or (iii) the volume of displacement chamber was small as a result the produced gas could not be pushed to the point of application or (iv) biogas produced in the digester was not conveyed to the point of application efficiently because of the technical and operational defects in various components of biogas plant or (v) the total burning hours of gas stove and lamp were reported wrongly by the users. The likelihood of first, second and fourth hypothesis is high.
- Total burning hours of stove in the sampled households was calculated to be 220.25 with an average of 3.34 hours/household/day. The gas demand in these households was reported to be 388 hours with an average of 5.88 hours/day/household. Gas was reported to be sufficient only in 16 (24%) households. The total demand of biogas can be fulfilled if the average efficiency of biogas plants is increased from the existing 49.6% to 86%.
- Users' level of satisfaction on performance of their biogas plants was not as anticipated. 36% of the users were satisfied, 44% were partly satisfied and the remaining 20% were not satisfied at all with the functional status of their plants. The main reason of not satisfying was the non-functioning of plants because of lack of feeding materials and technical failures.
- The respondents rated easy and comfortable cooking, environment friendly technology, time saving and workload reduction, nutrient rich fertilizer, economic benefits; and health improvement as main merits, while tension due to problematic components of biogas plants,

foul smelling in kitchen when gas leaked, difficulty in maintenance to be the main demerits of biogas technology.

- Biogas plants in general were reported to have positive impacts on the users. The findings of the study revealed that a family saved an average of 1 hour 21 minutes per day as a result of biogas plant. The average annual saving of conventional fuel sources accounted to be: firewood- 1877 kg/hh/yr, LPG - 7 kg/hh/yr, dried dug cake - 512 kg/hh/yr and agricultural residues - 636 kg/hh/yr, the monetary value of which was calculated to be BDT 4947.10 per year/household, which a significant amount. 84.5% of the biogas households are experiencing financial benefit from biogas plants. When asked if they felt any decrease in expenditures incurred in fuel collection because of biogas plant, 35% replied it has gone down to some extent, 47% felt it has decreased significantly, 3% had no idea whether it has gone down and the remaining 15% told it has not gone down. Responses of 82% of the respondents mentioning that they experienced tangible financial benefit from biogas plants is encouraging in a situation that people often tend to overlook such gain because of the fact that biogas plants do not earn cash rather it only saves the expenditures involved in purchasing fuel sources.

- 44 (67%) users were using bio-slurry in one or other ways where as the remaining 33% were not using it. Majority of the users (78%) who did not use the slurry drain it directly to watercourses. Households using slurry on farm reported that it is of high nutrient value than the farm-yard manure. The uses were: as organic fertilizer without composing (48%), as organic fertilizer after composting (7%), as fish feed (11%), sale to others as organic fertilizer (2%), and as organics fertilizer as well as fish feed (32%). Though the users expressed their views that the productions of crops and fish have increased after the use of bio-slurry, they could not exactly quantify the increment. Bio-slurry has been found to be beneficial in decreasing the use of chemical fertilizers. As responded by the user, saving of chemical fertilizer because of the use of bio-slurry varied from 10 kg to 800 kg per year; the average being 61 kg per household/year. Biogas households collectively saved 4015 kg of chemical fertilizer, the monetary value of which was about BDT 56,210. The average saving per household, thus, was BDT 851.66 per year.

- The FIRR of biogas plants calculated based upon the cost of installation was above 30% in all the cases except for 100cft gas producing plant without subsidy. This indicates that the return on investment made for the installation of biogas plant was above the opportunity cost in the capital market, which is about 12-15%. Likewise, when future anticipated quality improvement options were incorporated in the cost, the FIRR without subsidy were 10%, 20% and 24% respectively for 100, 200, and 300 cft gas producing plants. Corresponding values with subsidy of Rs.7000 were 22%, 29% and 31% which indicated that biogas plants are financial viable even without subsidy especially in the case of bigger sized plants. The benefit-cost ratio in the first case is more than 2 for all sizes of biogas plants except the smallest one (100 cft), even without subsidy. In the second case, it ranges from a minimum of 1.32 for 100-cft plants without subsidy to 2.12 for the largest plant (300 cft) with subsidy. Conclusively, in all the cases the B/C ratio exceeds one, which indicates the financial viability of all the biogas plants in the given conditions. In all the cases the B/C ratio exceeded one, which indicated the financial viability of all the biogas plants in the given conditions.

- Conclusively, facts such as installation of some 25000 biogas digesters; production of more than 1600 trained technical manpower through continuous training programs and refresher courses; mobilization of more than 50 agency holders in promotion and extension of biogas technologies; popularizing of the technology in the rural areas in the country benefiting directly about 150,000 people; show that biogas sector has started to grow in Bangladesh. Saving of 1877 kg of firewood, 512 kg of dried dung cake and 636 kg of agricultural wastes per year; saving of 1 hour 21 minutes per day and production of an average of 1.13 cum of biogas per day per plant from the sampled plants are some of the major benefits being received by the users. A platform, therefore, has already been built for the proposed biogas program in Bangladesh.

- Based upon the major finding of the study, the following recommendations are made to effectively implement the proposed Domestic Biogas Program in Bangladesh:
    - Biogas program has to be linked with government's initiatives.
    - There is high need to ensuring availability of feeding materials with integration of initiatives to aware people on modernized methods of livestock management
    - There is urgent need for the modification of the design of biogas plants to suit the gas use patterns in Bangladesh. This will help in optimization of the plant and there by reduction in cost of installation. Further in-depth study therefore, on performance of existing plants is recommended to optimize the size of biogas plants for further dissemination.
    - Equally important is the formulation of quality standards on construction, operation and maintenance of biogas plant giving special attention to the local conditions.
    - Formulation of effective repair and maintenance mechanisms is very important to safeguard the interest of farmers and get demonstration effects from the older plants.
    - Private sector development is pivotal for the wide scale dissemination of biogas technology. SNV/IDCOL should create a conducive environment for private sector development.
    - Biogas program should be integrated with other rural development and poverty alleviation programs. To penetrate more into poorer section of the society, a massive awareness campaign, a stable subsidy policy as well as group loans without collateral should be one of the strategies for implementation of the program.
    - Institutionalization and capacity building of the partner agencies should be one of the prime objectives of the biogas program. Effective partnership modality has to be developed and operationalised.
    - Proper orientation is needed to the users on toilet attachment and effective use of slurry.
    - Research and development should focus on finding out immediate practical and applicable solutions for day-to-day problems.
    - Future dissemination initiatives should be focused on context-specific motivational factors. Local plant owners, local governmental and non-governmental bodies, civil society organizations, functional groups, key community leaders and educational institutions could be mobilized effectively to promote and extend the technology.
    - Information and knowledge management has to be one of the key areas of concerns.
    - Sector coordination and networking should be strengthened and institutionalized.

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I place on record my sincere acknowledgement of SNV/IDCOL's confidence in placing this assignment in my care.

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ABBREVIATIONS

BPT	Biogas Practice Team
ASS	After Sales Service
BARC	Bangladesh Agriculture Research Center
BARD	Bangladesh Academy for Rural Development
BCSIR	Bangladesh Council of Scientific and Industrial Research
Cft	Cubic feet (28.3 liters)
FIRR	Financial Internal Rate of Return
GS	Grameen Shakti
HRT	Hydraulic Retention Time
IDCOL	Infrastructure Development Company Ltd.
LGED	Local Government Engineering Department
MOU	Memorandum of Understanding
NGO	Non Governmental Organization
O&M	Operation and Maintenance
RCC	Reinforced Cement Concrete
R&D	Research and Development
SHS	Solar Home System
SNV	Netherlands Development Organization
BDT	Bangladesh Taka
WB	World Bank

Exchange Rate (October 2005)

1 USD = BDT 69
1 Euro = BDT 81

1. INTRODUCTION

1.1 Background

Biomass accounts for significant share of the total energy consumption in Bangladesh. It provides basis energy requirements for cooking and heating in rural households and processing in a variety of traditional cottage industries in urban and semi-urban areas. Due to rapid increase in commercial energy consumption in most of the developed and rapidly developing countries, the share of traditional fuels in the total national energy use has been falling in recent years. However, actual biomass energy consumption in Bangladesh is still increasing like in other South Asian countries (Haq et. al, 2003). Much of the biomass fuel used in Bangladesh is consumed in traditional energy systems, which are characterized by low efficiency and emission of pollutants. Interest in modern biomass energy systems started to grow after the energy crisis of 1973. However, initial attempts to commercialize these resulted in a number of unfortunate failures; remarkable among these were rice-husk gasification in some industries. These failures, which can be attributed to a variety of reasons, created something of a setback in promotion of biomass energy technologies in Bangladesh. Therefore, the current phase of interest in modern biomass energy needs to be propelled by long-term considerations, for example, the need to augment national energy supply and climate change mitigation, and should be based on rather mature technologies.

In Bangladesh, the energy required for cooking often constitutes the biggest share of the total national energy consumption and is normally met mostly by biomass. Traditional biomass-fired cooking stoves have two major drawbacks: low efficiency and indoor air pollution created by pollutants released inside the kitchen. Reddy et al. [1997] caution, "because a large portion of the population is exposed, the total indoor air pollution exposure (from domestic biomass combustion) is likely to be greater for most important pollutants than from out-door urban pollution in all the world's cities combined." To overcome the negative consequences of traditional biomass use pattern, biogas digesters have been disseminated in Bangladesh.

Interest in Biogas technology is growing in Bangladesh because of the increasing awareness of the importance of the renewable energy sources and their potential role in decentralized energy generation. The rate of growth of biogas technology is expected to accelerate in the future given the moderately high potential, mounting concerns on environmental protection and realization of the importance of biogas in enhancing rural livelihoods. Since the first oil embargo in 1970s, the threat of increased prices for petroleum products has increased interest in harnessing RETs especially the biomass. Over the succeeding years, interest has waxed and waned, fuelled by technological improvements and increased awareness of the equipment available to achieve this. More recently, an increasing realization of the impacts of conventional energy generation on the environment, especially thorough carbon emissions, has increased in the renewable options. The realization of continuing interest in assessing energy in rural areas, the inability of the national utility to meet this through grid extension, and the widespread availability of biogas resources has further contributed to interest in the technology. Recognizing that the exploitations of fossil fuels cannot be sustained and harnessing power from nuclear fusion is not suitable for developing countries like Bangladesh, biogas technology has to be considered as one of the main alternatives.

Realization of the importance of biogas technology to supplement the energy sources in the rural areas of Bangladesh, Netherlands Development Organization (SNV) has included Bangladesh under the framework of Asia Biogas Program that is being launched in five countries of the South and South East Asia.. The overall objective of the National Domestic Biogas Programme in Bangladesh is to further develop and disseminate domestic biogas in rural areas with the ultimate goal to establish a sustainable and commercial biogas sector in the country. During the four years period of the programme (January 2006-December 2009), the main target is to install and operationalise 36,450 domestic size biogas plants across the country. For smooth implementation of the program SNV has partnered with Infrastructure Development Company Ltd. (IDCOL), a Government owned investment company, which has proven success of dissemination of Solar Home System across Bangladesh with technical and financial assistance from The World Bank.

1.2 Study Rationale

Both SNV and IDCOL have realized that the success of the proposed National Domestic Biogas Programme in Bangladesh depends heavily upon the workable and effective implementation plan that is based upon the grassroots reality of the sector. These include information on physical status and functioning of existing biogas plants, users' perception on the technology, impact of biogas plants on the users, and capacity of the grassroots communities to adopt and internalize the technology. Information on these issues would help in deciding best suitable implementation modality for the program. A study was felt needed to collect information on these issues from the users' level so that the findings are reflected in the plan.

1.3 Objective and Scope

The overall objective of the proposed study was to conduct a technical review of existing biogas plants constructed across Bangladesh over the past years to facilitate the preparation of implementation plan for the proposed National Domestic Biogas Programme. Information on the following aspects were collected and analyzed:

a. Socio-economic characteristics of sampled biogas households (population pattern, family size, occupations, land holdings, agricultural production, livestock ownership, educational status etc.)
b. Construction, Operation and maintenance of biogas plant
c. General perception of users on the use of biogas
d. Physical status and functioning of biogas plant
e. Impacts of biogas on users
f. General recommendations for the proposed biogas program

1.4 Approach and Methodology

1.4.1 Study Tools

The study was conducted in close accordance with the objectives. Particular attention was paid to objectively verifiable indicators depending on the level of factual, quantitative and statistical information available, and the degree to which it was possible to quantify and extrapolate conclusions from field investigation and observation.

The main instrument of the study was the structured questionnaires and open-ended unstructured interviews with the respective plant user. Additional investigation tools included observations, especially of different components of biogas plants, household kitchen and slurry pits in the sampled households, and informal discussions with people in the survey clusters. The structured questionnaires were discussed in a panel of experts from various organizations involved in biogas promotion and extension in Bangladesh prior to the field-testing. The field-testing was done in two biogas households in Dhaka district and modifications were made accordingly.

During the field survey process, the study team adopted an interactive approach rather than a 'question and answer session' with the respondents to enhance the quality of data and information collected.

1.4.2 Sampling

In a meeting of concerned professionals, it was first decided that the plants constructed by three major agencies viz. Bangladesh Council of Scientific and Industrial Research (BCSIR), Local Government Engineering Department (LGED) and Grameen Shakti (GS) be included in the study. The number of plants from each agency was determined roughly in proportionate to the number of plants installed by them. The numbers of plants to be surveyed were decided to be around 70-75 in total, consisting of plant constructed by the three agencies. Two-stage random sampling method was used to select biogas households for the field investigation. At first, at least one district from each of the six divisions was selected based upon the number of plants installed in those districts. From a list of biogas households in those districts, a systematic random sampling method was used to select required number of biogas households from each district. The following table shows the districts and number of plants selected from each of them.

Table-1.1: Biogas Plants Sampled for the Study

Division	**District**	**No. of Plant sampled**	**Installed by**		
			BCSIR	LGED	GS
Dhaka	Manikgunj	11	10		1
	Gazipur	6		4	2
	Dhaka	2			2
Chittagaon	Comil1a	10	10		
Sylhet	Sylhet	11	10	1	
Barisal	Barisal	11	11		
Khulna	Jassore	11	10	1	
Rajshahi	Bogra	10	10		
	Total	**72**	**61**	**6**	**5**

As shown in the table 72 plants (61 BCSIR plants, 6 LGED plants and 5 GS plants) from 8 districts across Bangladesh were sampled for the study. The locations of sampled districts are shown in Figure-1.2.

Figure-1.1: Location of Sampled Districts

Given the total number of plants installed by BCSIR, LGED and GS (21860, 1130 and 70 respectively, till the end of September 2005), the sample size is not enough to be representative of the entire picture of biogas program in Bangladesh. Hence the finding of the study should be considered as indicative rather than representative.

1.4.3 Methodology

The whole study was divided into three major phases based upon the activities carried out:

a. Inception Phase: Desk Study and Mobilization

The collection of secondary data and information, formulation of field investigation methodologies, preparation of questionnaires, checklists and formats, logistic arrangements for field visits were the main activities carried out during this phase. The field visit itinerary was also prepared.

b. Investigation and Data Collection Phase: Field Study

Field investigation works (which consumed 20 days) using appropriate tools and techniques as described above was the main activities during this phase. Biogas plant owners, family members, some key persons in the communities were consulted and their opinion collected. The average time spent in one biogas household to collect data and information was 55 minutes with a maximum of 1 hour and 25 minutes to a minimum of forty minutes.

c. Concluding Phase: Data Analysis, Interpretation and Report Preparation

Once the field activities were completed, all the data collected from the field and from secondary sources were crosschecked, verified, cleaned and analyzed using appropriate computer software programmes (EPI Info, MS Excel and MS Word). The outcome of the analysis has been incorporated in a concise report.

Out of the 72 biogas households studied, only 66 have been included in the analysis due to two main reasons:

- All the 5 plants installed by GS were very new - less than 6 moths old. It was rather early to assess the functional status of plants as well as impact of these plants on the users.
- One of the plants installed under the framework of LGED biogas program was too big in size (9 cum) to be compared with other plants studied during the survey. This plant was taken as outlier, which may significantly misrepresent the study findings on various issues such as average plant size.

The general methodology followed during the study has been illustrated in the following diagramme.

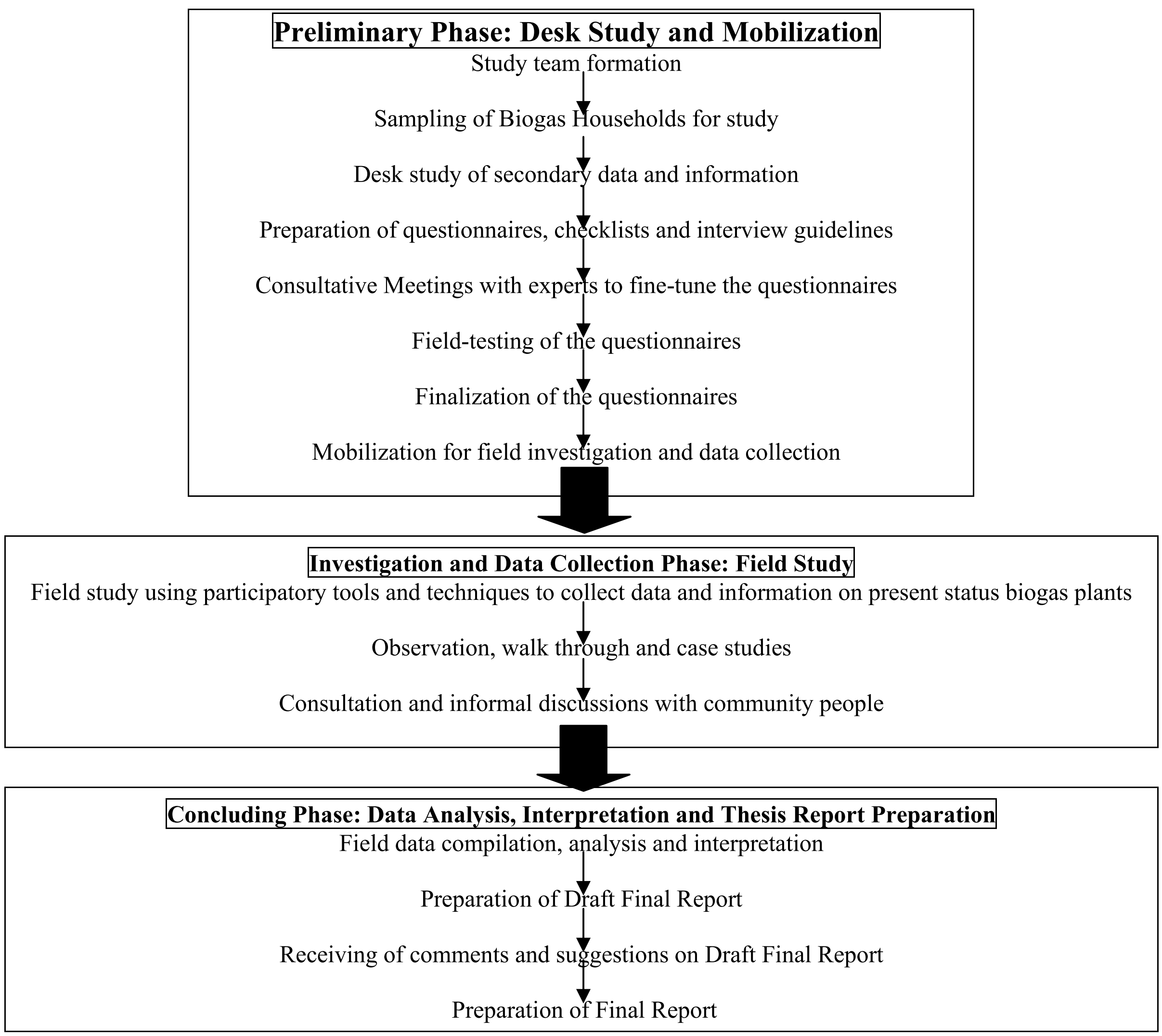


Figure-1.2: Methodology Adopted during the Study

1.5 Limitations

The study team has attempted to be as participatory and consultative as possible during field investigation. However, as like in every studies/surveys of this type, this study has its limitations as described hereafter:

a. This study was conducted in selected areas in the eight districts as mentioned above. Given the limited sample size and confined coverage, the findings of the study may not represent the whole country. However, the outcome will be significantly same in areas with similar socio-economic, cultural and geographical settings. The outcome of the study therefore is more indicative than representative.
b. The source of primary data and information was mainly the household survey. It should be noted that views and findings contained in this report are those derived from the responses of the respective respondents.
c. Among many others, the study had intended to explore some basic family/household level information on land holding, income and expenditure. It is possible that there were some shortcomings in dragging actual information on these aspects. It was felt that some of the respondents had general tendency of hiding exact information due to various reasons while some others were hesitant to talk about it, some claimed ignorance and some mentioned an amount that proved to be very low or high later on. The same was the case on time spent on different biogas related activities and total burning hours of biogas stoves. Since it was a survey of the users there was no actual measurement and as far as quantifiable data and information were concerned, recall method was used, which may not be very exact.
d. Despite genuine efforts, this study having been conducted within a short period of timeframe and with many other constraints might possess some errors methodologically and in the findings presented here in.

2. SOCIO-ECONOMIC CHARECTERISTCS

The outcome of the study indicated that most of the individual biogas households were well off by rural Bangladeshi standards, as characterized by higher income level, large and medium land holdings, plenty of livestock, and many educated family members. The findings on socio-economic characteristics of the plant owners under study are described below:

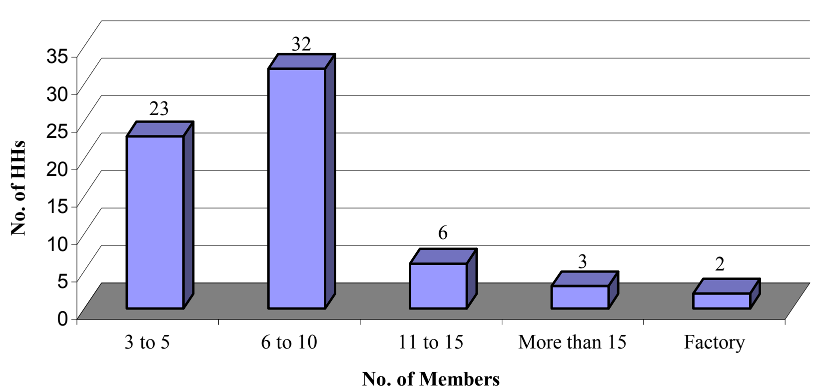
2.1 Demography

The total population of the 66 households under study was found to be 486 among which 237 (48.8%) were female members and 249 (51.2%) were male members. The average family size was 7.36, which is higher than the national average size of 5.18 (Report of the Household Income & Expenditure Survey, 2000). Household with maximum number of family members had 25. The oldest person was of 101 years age, a female member in Comilla district. Table-2.1 and the Figure-2.1 show the population composition and distribution of family members respectively in the studied households.

Table-2.1: Population Pattern

Age Group	No of People		
	Male	Female	Total
Less than 6 (Infants)	12	20	32
6 to 16	53	51	104
17 to 45	132	125	257
46 to 60	32	21	53
61 to 75	14	11	25
Above 75	6	9	15
Total	**249**	**237**	**486**

Figure 2.1: Disrtibution of Family Members



As can be seen from the table, economically active population has share of 64% in the total population size. Interestingly, 28% of the populations are below 16 years of age. Another fact as seen is the predominance of 6-10 member-sized families among the biogas users, which comprises of 48.5% of the total households under study. The finding indicated that biogas plants have been installed in households with comparatively higher number of family members. The family size in 30 households remained same before the installation of biogas plants and during the time of survey whereas it was decreased in 14 households and increased in 22 households. The change was reported mainly due to marriages and permanent migration of some of the family members.

2.2 Economic Status

2.2.1 Occupation

The survey indicated that the primary source of income for the majority of the households (74%) was agriculture. It was remarkable that 64 out of the 66 households under study had at least one member with cash earning job. The major occupations of the family members have been given in the following table.

Table-2.2: Occupation of Household Members

Primary Occupation	No of People		Total	Percentage
	Male	Female		
Infants	12	20	32	6.6
Agriculture	28	3	31	6.4
Small Business/Self Employed	47	1	48	9.9
Teaching	10	4	14	2.9
Government Services	13	0	13	2.7
Other services	32	2	34	7.0
Students	70	63	133	27.3
House-wife	0	118	121	24.9
Contractor	1	0	1	0.2
Servant	14	16	30	6.2
No job/Old People	15	10	22	4.5
Retired Service Holders	7	0	7	1.4
Total	**249**	**237**	**486**	**100**

2.2.2 Land Holdings

The average land holding size of the households under study was 5.25 acre (3.67 acre -arable and 1.58 acre – non-arable) per households, with a minimum of 0.13 and maximum of 54 acres. The average size is much higher than the national average of 1.38, which indicates that the biogas plants are installed in comparatively bigger holding households. The standard deviation of 7.97 indicates that the gap of smaller and bigger land holdings is quite a large. The outcome of the study indicated that majority of the households (51.5%) lease their lands to others for cultivation and receive a lump sum cash from the tenants per year. Table 2.3 shows the land holding patterns in the households under study.

Table-2.3: Land Holding Pattern

Land Holdings in acres	No. of HHs possessing		Total HHs
	Arable	**Non-arable**	
0	7	29	0
0.1 to 1	12	24	15
1.01 to 2	14	5	13
2.01 to 3	10	4	7
3.01 to 4	4	1	8
4.01 to 5	5	1	6
5.01 to 10	8	0	9
10.01 to 20	5	1	6
More than 20	1	1	2
Total	**66**	**66**	**66**

2.2.3 Agricultural Production

The major crops cultivated were paddy, wheat, potato, oilseeds, jute, vegetables and fruits. Paddy was reported to be surplus in 39 hhs, wheat in 1 hh, potato in 7 hhs, oilseed in 2 hhs, vegetables in 8 hhs, fruits in 1 hh and jute in 6 hhs. The average amount earned from selling of agricultural crops was reported to be BDT 41338 per household per year. The average contribution of paddy, wheat, potato, oilseeds, vegetables, fruits and jute were BDT 31651, 257, 2087, 145, 6335, 254 and 609 respectively. Likewise, the average share of fish and animal product was BDT 18300. In total, annual income from agricultural production and livestock product was BDT 59638 per households per year.

2.2.4 Livestock Farming

The biogas households owned, during the time of survey, 370 cattle (cow, ox and buffalo) at and average of 5.61 cattle per household which is much higher than the national average of 2.64. The maximum number of cattle was 63 and the minimum was zero. The following table shows the number of cattle owned by household during the time of survey and three years back.

Table-2.4: Number of Cattle Owned

Number of Cattle	During the time of Survey (hh)	3 years ago (hh)
0	11	8
1-3	24	9
4-5	11	12
5-10	12	27
More than 10	8	10
Total	66	66

Eleven households did not keep any cattle. 29 of the 370 cattle were reported to be open-grazed and the remaining were stall-fed. The number of cattle before three years was reported to be 511 with an average of 7.74 cattle per household. The decline in cattle size (2.13 cattle/household within three years time) was significant and if this trend continues biogas households will face acute shortage of feeding materials after some years. Table-2.4 above shows an alarming trend of declining in cattle size in the biogas households. Number of households without cattle has increased from 8 to 11 and households with cattle size more than 5 has decreased from 37 to 20. The numbers of goats, poultry and duck/pigeon were 31 (in 8 hhs), 5059 (in 38hhs) and 441 (in 19 hhs). Interestingly, the numbers of goat and poultry were 55 (in 8 hhs) and 8546 (in 41 hhs) three years ago.

2.2.5 Income-Expenditure Pattern

The annual income and expenditure in the biogas households were calculated to be BDT 219700 and BDT 127400 per household respectively which is significantly higher than the national average of BDT 70104 and BDT 53772 respectively. The annual average saving therefore was BDT 92300 per household. Expenditure was higher than income (deficit) in 6 households in which deficit ranged from BDT 2800 to BDT 37,000 per year. One household has balance of income and expenses. The surplus in 59 households ranged from BDT 1000 to BDT 364000 per year. The biogas owners have pucca houses in 16.6% cases, semi-pucca houses in 72.7% cases and kuchha houses in 10.6% of the cases.

2.3 Educational Status

The overall literacy rate in the sampled households (excluding the infants) was 86%, which is much higher than the national average of 48.8% (Report on Sample Vital Registration System, 1999-2002, BBS). The female and male literacy rates were calculated to be 81% and 91% respectively as against the national figures of 44.5% and 52.8% respectively. The educational status of the members in the studied biogas families has been given in Table-2.5.

Table-2.5: Educational Status of Household Members

Education	No. of People		Total
	Male	Female	
Illiterate/Not attending Schools	22	41	63
Grade 1	16	9	25
Grade 2	4	8	12
Grade 3	2	2	4
Grade 4	11	6	17
Grade 5	19	20	39
Grade 6	9	10	19
Grade 7	7	10	17
Grade 8	15	20	35
Grade 9	15	20	35
Grade 10	38	38	76
Grade 11	6	5	11
Grade 12	30	16	46
Bachelors Degree	30	11	41
Masters Degree	13	1	14
Infants	12	20	32
Total	**249**	**237**	**486**

More female members (41) were illiterate than male members (22). Out of the 45 persons who had education higher than graduation, 33 (73%) were male members. The data on educational status of the biogas family members indicated that though the numbers are much higher than the national average, the pattern is similar to that of the nation as a whole, where the figure are better for male than female.

3. CONSTRUCTION, OPERATION AND MAINTENANCE OF BIOGAS PLANT

3.1 Construction

3.1.1 Plant Location

The biogas households sampled for the study represented eight districts from all the six divisions in Bangladesh. All the plants were located in easily accessible areas, where basic infrastructure services existed. Easily accessible approach roads to and electricity grid connections in all the sampled households indicated that these plants were installed in relatively developed areas.

3.1.2 Reason and Year of Installation

The respondents were asked to give most important reasons/motivating factors for the installation of biogas plants. As per them, the most popular motivating factors were the economic benefits including saving of time and money (35hhs), environmental benefits (30hhs), availability of subsidy (17hhs) and health benefits including the reduction in smoke-borne diseases (12hhs). The following table shows the responses of the respondents on the reasons for the installation of biogas plants.

Table-3.1: Motivating Factors to Install Biogas Plant

Motivating Factors	No. of HHs*
Economic benefits (saves time and energy)	35
Environmental benefits (saving of forest, clean surrounding etc.)	30
Subsidy	17
Health benefits	12
Non-availability of other fuel sources	9
Motivation from other plant owners	9
Motivation from service provider	7
Social benefits/Prestige	6
Fertilizer of higher nutrient value	5
Proper use of cattle dung	4
Pressure from neighbors (in the case of poultry)	3
Use digester as septic tank	2
Fish feed	1
Adopt the new technology and make the village ideal living place	1

** more than 1 response from some respondents*

It is encouraging to note that nine plant owners (14%) were motivated by other plant users to install biogas plants. This indicates the potential of existing plants to become tool for promotion and extension of the technology. In other countries like Nepal and India where biogas plants have been disseminated to a significant extent, the benefit of biogas to replace the conventional fuel sources is the main motivating factor to install biogas plants. However, only 13% of the respondents told this to be the main motivating factor in Bangladesh. Interestingly, environmental benefits of biogas plants like saving of forest, clean surrounding, proper use of waste materials etc. were valued much more in Bangladesh than in other developing countries.

Among the 66 plants under study, the oldest plants (3 numbers) were in operation for more than eight years and the youngest plants (8 numbers) were operating for about two years. 25 plants were in commission for more than two years, 15 plants in service for more than three years, 4 of them in use for more than four years, 5 plants were functional for more than five years and 1 plant was in use for more than six years. The remaining 5 plants were working for the last seven years.

3.1.3 Decision Making for the Installation

When asked the respondents on who made the final decision to install biogas plant, 57% of them told that the decision was taken after discussions in the family, followed by the household head – the males in 35% and the females in 5% of the cases; and the younger members – son or daughters in the family in 3% of the cases.

The respondents told that they knew about the technology through service providers (33%), biogas users (23%), friends and relatives (20.5%), government officials (7.5%) and the publicity media (4%). The remaining 12% knew about it through more than one of the above-mentioned mediums.

3.1.4 Type and Size of Plant

All the 66 plants sampled for and analyzed during the study were of fixed dome design adopted from a Chinese model of biogas plants with slight modifications. In this type of design, the volume of the plant remains constant but the gas pressure varies. The construction of plant is a skilled mason's work and requires special training. Since this type of plant can be constructed at the site with the locally available materials excluding cement, the design is become popular. Three different models, introduced by BCSIR, LGED and GS, were studied.

Among the 66 plants of BCSIR and LGED studied, 41 plants were of capacity of 100 cft gas production per day, followed by 4 of 125 cft, 11 of 150 cft, 6 of 200 cft, 3 of 250 cft and 1 of 300 cft. The average size of biogas plants under study is 3.9 cum gas production per day, which is slightly higher than those practiced in Nepal and India where the average sizes are 1.60 cum (2005) and 2.2 cum (2002) respectively. The size of the plants were reported to be selected based upon the recommendations from the service providers who used quantity of feeding materials, affordability of farmers and gas requirement in the family as main decision making criteria.

7.5% of the respondent felt that the size of the plant was small for them to meet the fuel need. Similarly 9% of them recommended that the sizes need to be increased in the future if biogas technology is to be made popular among the rural people.

3.1.5 Construction Management

LGED implemented biogas project from October 1998 to June 2003. The organization did not recruit any new staff for the implementation of the project. Construction works were mainly carried out by the trained technicians produced by LGED itself. LGED headquarters initially engaged only one NGO to implement the whole project. Subsequently the number of NGOs was increased to 7 in the later stages. These NGOs contacted the farmers to motivate them to install biogas plants and provided service once the farmer was ready to do so. LGED engineers at grass root level supervised the construction works and the Executive Engineers of the concerned districts made payments. In order to attract the farmers, a subsidy of BDT 5000.00 per plant was provided to the farmers and additional BDT 5000.00 was provided to the NGOs as grant.

BCSIR implemented the project in two phases. At the initial stage they appointed 128 Sub-Assistant Engineers, provided training to them and mobilized them to install biogas plants. They were assigned responsibilities for motivation, installation and after-sales-service throughout the country during the first phase of Biogas Pilot Plant Project (July 1995 to June 2000). In addition, 898 youths were trained to support the project. The biogas farmers received an investment subsidy of BDT 5,000 under the project. MoUs were signed between BCSIR and several other institutes like BRAC, LGED and DLS for research, training and dissemination of the biogas technology. The investment subsidy for the owner was increased to BDT 7,500 per plant in the second phase of the project that started in July 2000 and ended in June 2004. In addition to the employment of diploma civil engineers, an agency system was introduced on incentive basis. About 50 agencies were recognized at the district level where the program was to be launched and provided with a lump sum fee of BDT 5,000 per plant as overhead costs. About 1,000 masons and youths were trained under the project as well. At headquarters level, a Project Director and a few staff members were responsible for the coordination, monitoring and supervision of the project. To give incentive to the engineers, there was also provision of BDT 1000.00 as bonus.

Grameen Shakti is implementing the project through its appointed staff members. There is no provision of subsidy or grant to the farmers to install biogas plants. The organization is implementing the project with its own internal resources. Plants are constructed with the farmer’s cash contribution and a service/supervision charge of 10% of the cost is collected from the owners. The organization also provides 75% of the cost as loan, which is recoverable in two years with 8% interest.

The study findings revealed that biogas plants were constructed by skilled masons with good knowledge on biogas plant in 68% of the cases, followed by skilled mason without knowledge on biogas plant in 29% cases and unskilled masons in 3% of the cases. Though 67% of the plant owners felt that some technical standards were set by the service providers as regards the quality of construction materials and construction methods, 75% of them did not know about those standards. 59% of them expressed that there was set technical standard on the plant design. The rest of the respondents believed that no such standards were set.

3.1.6 Financing for Construction

Biogas plants in Bangladesh, in majority of the cases, are financed in two ways – a flat rate subsidy from the government on the investment cost and cash contribution from respective plant owners to fill gap. The subsidy provided by the government is insufficient to meet the total cost of installation and a gap exists which the farmers must bridge. This gap is either filled by cash of their own or by credit received from financing institutions on some pre-defined terms and conditions. Total investment cost of biogas plants ranged from BDT 11,800 for biogas plant of capacity 100cft gas production per day to BDT 30,500 for plant of capacity 300cft cum gas production per day. Minimum, average and maximum costs of installation of biogas plants are shown in the following table:

Table3.2: Cost of Installation of Biogas Plant

Size of Plant (cft gas production per day)	Average Cost in BDT	Maximum Cost in BDT	Minimum Cost in BDT
100	13575	15500	11800
125	15750	17600	12450
150	18500	23000	15200
200	20100	24000	15800
250	23850	28000	17000
300	30500	30500	30500

Only 4 plant owners took loans form local cooperatives (2 cases) and their friends and relatives (2 cases). Those who took loans from friends and relatives did not pay any interest rates while in the other two cases the interest rates were 10% and 12%. Interestingly, all of them who took loans have already paid the whole amount of the loan and none of them have any liabilities.

The outcome of the study revealed a fact that taking loan for constructing biogas plant is not a common practice in Bangladesh. The reasons as mentioned by the respondents not to take loan were: good economic condition (44%), attitude against the philosophy of taking loans (21.5%), cumbersome process of loan sanctioning (15%), higher interest rates (3%), non-availability of credit facility (12%), fear that loans may degrade social prestige (1.5%), lack of collateral to fulfill the requirements of credit institutions (1.5%) and ignorance on availability of loan facility (1.5%).

My grand father has warned me not to take loan. He used to say, 'never take a loan even if you die without food – taking loan is like meeting with death. Better to die without food than with the burden of loan amount.

- *Md. Zibrail Hassan from Bogra, when asked if he would have preferred to take loan to construct biogas plant if credit facility was accessible*

BCSIR provided a flat rate subsidy of BDT 5,000 and BDT 7,500 during the first and second phases of biogas program respectively to the farmers who installed biogas plants. In the second phase, an addition of BDT 5000 was provided to the service agencies to meet their overhead costs and costs of masons and other manpower. Likewise LGED provided investment subsidy of BDT 5,000 as incentive to motivate farmers to install biogas plants. The biogas plant owners contributed cash in the range of BDT 4000 to 23000. Two plant owners also received additional subsidy of BDT 5000 from local NGOs. According to 79% of the respondents, the cost of installation of biogas plant is reasonable where as the remaining 21% expressed their view that the cost is quite higher.

Government subsidy on the investment cost has been one of the main motivating factors to install biogas for 26% plant owners. Interestingly, 53% of the respondents told that they would not have installed biogas if subsidy was not provided.

3.2 Operation

The key to proper operation of biogas plant is the daily feeding with mix of right proportions of dung and water, frequent draining of condensed water in the pipeline through the water outlet, cleaning of stoves and lamps, oiling of gas valves and gas taps, cleaning of overflow outlet, checking of gas leakage through pipe joints and gas valves and adding of organic materials to slurry pits. As long as these tasks are carried out reliably and carefully the plant will function properly. The subsequent sections describe the finding of the study as regards the operation of the biogas plants.

3.2.1 Plant Feeding

a. Feeding Materials

The amount of gas production in biogas digester depends upon the quantity of feeding added to it daily provided the plant is technically all right. Cattle dung and poultry droppings were the two major feeding materials used. Besides these, kitchen and household wastes, human excreta, urine of animals, water hyacinth and urea were also used to feed biogas plants. The following table shows the composition of feeding materials being used in biogas plants

Table-3.3: Types of Feeding Materials in Use

SN	Feeding materials being used	No of plants
1	Cattle dung only	43
2	Cattle dung and urine	2
3	Cattle dung and human excreta	6
4	Cattle dung and water hyacinth	2
5	Cattle dung and urea (occasionally)	1
6	Cattle dung and poultry dropping	2
7	Poultry droppings only	6
8	Human Excreta and Kitchen Wastes	1
9	Human Excreta and poultry droppings	2
10	Kitchen wastes and water hyacinth	1
	Total	66

The outcome of the study indicated that the whole quantity of dung produced in the stable was not fed into the plant. It showed that out of the theoretical available dung (calculated based upon the number of cattle and poultry) of 5370.9 kilograms (81.37 kg/household on an average), 4327.7 (81%) is fed into the plant. However, the prescribed quantity of dung based upon the hydraulic retention time of 40-45 days for the Bangladesh context is 6362.5 kg (based upon 0.75 kg/cft gas production per day), which is 19% more than the available feeding and 47% more than the actual feeding presently practiced. The average feeding rate thus was 17 kg per 1 cum gas production per day biogas plant, which is 68% of the required quantity. The following tables give information on available feeding and the quantity of feeding materials received by the plants under study.

Table-3.4: Dung production

Quantity of feeding materials produced (kg/day/hh)	Number of hhs
Nil (no production)	5
Less than 15	3
15 to 25	4
25.1 to 50	24
50.1 to 75	12
75.1 to 100	4
100.1 to 150	5
More than 150	9
	66

Table-3.5: Quantity of Feeding Material Produced

Size of Plant (cft gas production/ day)	Recommended Quantity of Dung (kg/day)	Total No. of Plants surveyed*	Available Feeding (% of Prescribed Quantity)					
			Less than 25%	<25% but >50%	<50% but >75%	<75% but >100%	<100% but >125%	More than 125%
100	75	41	3	14	10	4	2	8
125	100	4	1	1	0	1	1	0
150	115	11	3	3	3	0	1	1
200	150	6	3	0	0	0	2	1
250	175	3	1	1	0	0	0	1
300	225	1	1	0	0	0	0	0
		66	12	19	13	5	6	11

* *Users of non-functioning plants were also requested to give answer on how much they used to feed when plant was functional*

Table-3.5 shows that 31(47%) households produced feeding materials less than half of the required quantity. Only 17 households (26%) produced the required quantity of feeding materials. However, the outcome of the study shows that all the produced feeding material was not fed into the digester and hence the number of underfed plants was higher. The following table illustrates the feeding patterns.

Table-3.6: Biogas Plant Feeding Pattern

Size of Plant (cft gas production/ day)	Recommended Quantity of Dung (kg/day)	Total No. of Plants surveyed	Actual Feeding (% of Prescribed Quantity)					
			Less than 25%	<25% but >50%	<50% but >75%	<75% but >100%	<100% but >125%	More than 125%
100	75	41	3	14	10	6	6	2
125	100	4	1	1	0	1	1	0
150	115	11	3	5	1	1	1	0
200	150	6	3	0	1	2	0	0
250	175	3	1	1	0	0	0	1
300	225	1	1	0	0	0	0	0
Total		66	12	21	12	10	8	3

It is apparent from Table-3.6 that 50% of the total plants under study received less than 50% of the prescribed quantity of feeding materials. There are significant numbers of under-fed plants (83%). The main reason for under-feeding is the non-availability of feeding materials mainly due to decreased number of cattle (64% of the plants) due to selling of cattle after the installation of biogas plants. Another noted fact is that users were not aware of the total quantity of dung to be fed into their plants daily. When asked question in this issue, 36 respondents (55%) expressed their ignorance on the required quantity of feeding. Those who replied also were found to be misinformed. Only 7 out of the 30 respondents told the correct quantity. 17 of them replied far-less quantity, 4 replied lesser quantity and the remaining 2 told more quantity then needed.

It is encouraging that some of the plant owners (8 out of the 11 nos.) collected dung from outside who did not own cattle or who did not have enough quantity of feeding materials.

b. Water-Dung Ratio

The outcome of the study revealed that the water-dung ratio was higher than 1 in 56% of the plants. The ratio varied from 2:1 to 3:1 in these cases. Likewise, 41% of the plants received equal volume of dung and water. The remaining 3% of the plants received less water than dung. One of the significant facts noted during this study was that the users tend to increase the volume of water to compensate the feeding materials. In other words, when less dung than needed is available, more water is used and when enough/more dung is produced, users tend to use lesser quantity of water. Higher water-dung ratio was clearly visible in the slurry coming out of the outlet chamber in majority of the plants, being the slurry very thin and diluted.

c. Night-soil Feeding

The concept of connecting household latrines to biogas digester is unacceptable in much of Bangladesh for a variety of socio-cultural and religious reasons. The thought of using gas from such a source for cooking purpose remains very much taboo. Majority of the respondents said their relatives or neighbors would never come for a cup of tea if they knew it has been cooked with gas produced from night-soil. The present study revealed that out of the 66 biogas households under study, all of them have constructed latrines in their premises and only 10 of these households have attached latrines with the biogas digesters. 8 of them were motivated by the service providers and the remaining two decided by their own with advice from friends and relatives to attach toilet to the biogas digesters. One of these users had stopped feeding of night-soil to biogas digester after reluctance from friends and relatives to continue using night-soil for gas production.

I am in favor of attaching latrines with biogas digester. I know there is no difference between gas produced from cattle dung and night-soil. But what can I do? My father and mother do not allow me to attach toilet to biogas plant. I would have joined it if they had not opposed. Moreover, people do not accept food cooked with biogas produced from latrine-attached plant. I cannot overlook the incidence that took place in front of my eyes. The owner of the tea stall who had good business in the town had to close his business once the customers knew that the tea is cooked with biogas produced from latrine attached biogas plant.
- A respondent in Manikgunj responding on why he did not attach latrine to biogas digester

Some of the responses of plant users as regards the latrine connection to biogas plants were:

- Gas from latrine attached plants are considered to be un-sacred (50%)
- People are hesitant to handle bio-slurry from latrine-attached plants (12%)
- Though we know that the gas received from night-soil and that received from cattle dung is same, it is still not possible to attach latrine with biogas plant as the elderly members object the ides (8%)
- There are no social and religious taboos in attaching latrines to biogas plants; however, we do not think this is necessary (30%)

3.2.2 Frequency of Operational Activities

Besides feeding of plants, other operational activities were reported to be carried out on as and when needed basis. As regards the frequency of operation of different activities, the responses were as given in Table-3.7.

Table-3.7: Frequency of Operation of Biogas Plant Components

Operation Activities	Frequency of Operation (hhs)										
	Daily	Once in two days	Once in three days	Once in four days	Once in a week	15 days	Monthly	Half yearly	Never	As and when needed	Not applicable
Plant Feeding	43	5	1	2	1	-	-	-	-	-	14*
Use of Main valve	2	-	-	-	-	-	-	-	50	-	14*
Checking leakages	-	-	-	-	-	-	-	-	52	-	14*
Use of Water drain	-	-	-	-	-	-	-	-	-	-	66 (Not installed)
Cleaning of outlet	-	-	-	-	-	-	-	-	40	12	14*
Composting/ maintaining compost pits	-	-	1	-	4	-	-	-	8	39	14*
Oiling of gas tap	-	-	-	-	-	-	-	-	-	-	66 (Not installed)
Cleaning of gas stove	-	-	-	-	-	-	-	-	-	52	14*
Cleaning of gas lamp	-	-	-	-	-	-	-	-	-	6	60 (not installed)

** 14 plants that were not functional reported that they do not carry out any of these activities*

It is clear form Table-3.7 that majority of the plant owners lack knowledge on different operational activities needed to be carried out regularly for the trouble-free functioning of biogas plant and its components. This was due to ignorance and negligence of the users, as they have not been provided with training on operation of biogas plants.

The outcome of the study also suggested that the operational cost of biogas digester was virtually nil except for 2 plants who purchased dung/poultry droppings from outside. The zero operational cost was due to the dung obtained from livestock they owned and labor for feeding and other operational activities incurred no expenditure as these were carried out by the family members themselves. However, if the labor spent to collect water and feeding the plant is considered operation cost in average comes to be BDT 90 per plant per month assuming the wage of labor to be BDT 120 and 8 hours working day.

3.3 After-sale-services

Lack of service center and dearth of effective after-sales-service (ASS) provisions were reported by all the users to be the major hurdles for them to have trouble-free functional plants. Upon being asked how the required repair works were managed, 35% of the respondents replied that they called the service provider to fix the problems. 29% of the total respondents told that they received the after-sales services from the service providers regularly, though there are no mandatory provisions of such services. Likewise, 35% of them told that they received required services on as and when needed basis. Another 35% replied that they did not receive any service after the plant was handed over to them from the service providers. The remaining one user answered that maintenance service was not provided even when requested time and again with the service provider.

3.4 Training and Orientation to Users

In fact, the functioning of biogas plant is basically determined not only by the quality of construction and workmanship involved but also by the quality of operation and maintenance efforts from the users. The users should be provided with basic orientation on various aspects of operation and maintenance such as proper feeding of the plant, optimal use of biogas, effective application of slurry, timely maintenance of plant components and improving cooking environment. The following table illustrates the responses of the users when being asked if they have received any training on operation and maintenance of biogas plants from the service providers.

Table-3.8: Training on O&M of Biogas Plant

Type of training received	% of households
No training received	14%
Training not provided but leaflet/booklet/manual provided	18%
One day orientation training provided by service provider	14%
Short term O & M training (7days or less)	1.5%
Long term O & M training (more than 7 days)	3%
On the spot instructions from mason/company supervisors etc.	48%
Training provided by other NGOs (not the service provider)	1.5%

It is evident form Table-3.8 that there is high need of training to educate the users on basic operation and maintenance of the installed plants. Existing physical status and functioning of majority of the plants under study also suggested that the users were not fully aware of the importance of effective operational activities and timely repair works for trouble-free performance of biogas plants.

3.5 Maintenance

Effective and timely management of routine repair and maintenance works are key to the sustainability of biogas plants. As long as operational activities are carried out efficiently and routine maintenance works are carried out in time, biogas plants function properly. During the field study, when respondent were asked if they could carry out repair and maintenance works by their own, only one respondent replied in positive. All the respondents expressed urgent need of training on minor repair and maintenance works to effectively manage their biogas plants.

Out of the 66 biogas plants under study, 38 plants (57%) have received some sorts of maintenance works. Likewise, 24 (36%) plants are still in need of repair works. The following were the major repair works carried out as responded by the users:

Table-3.9: Major Repairs Works Carried Out

Repair works carried out	Positive responses (No. of Plants)
Pipeline repaired	7
Main gas valve repaired/replaced	14
Gas stove repaired/replaced	32
Gas lamp repaired	2
Structures repaired/renovated	11

The following table shows amount spent on repair works.

Table-3.10: Amount Spent on Repair Works

Total amount spent in the last 12 months	No. of Plants	Total Amount Spent (BDT)
None (no expenditure)	23	0
Less than BDT 100	8	600
BDT 100 to 300	13	2450
BDT 301 to 600	9	4200
BDT 601 to 1000	5	3750
BDT 1001 to 2000	6	7150
More than 2000	2	4350
Total	66	22500

As shown in Table-3.10 a total of BDT 22500 was spent by the plant owners to repair their plants. Major share of this maintenance cost was reported to be taken by the gas stove followed by structural components. The average maintenance cost per plant was, therefore, found to be BDT 340 per year.

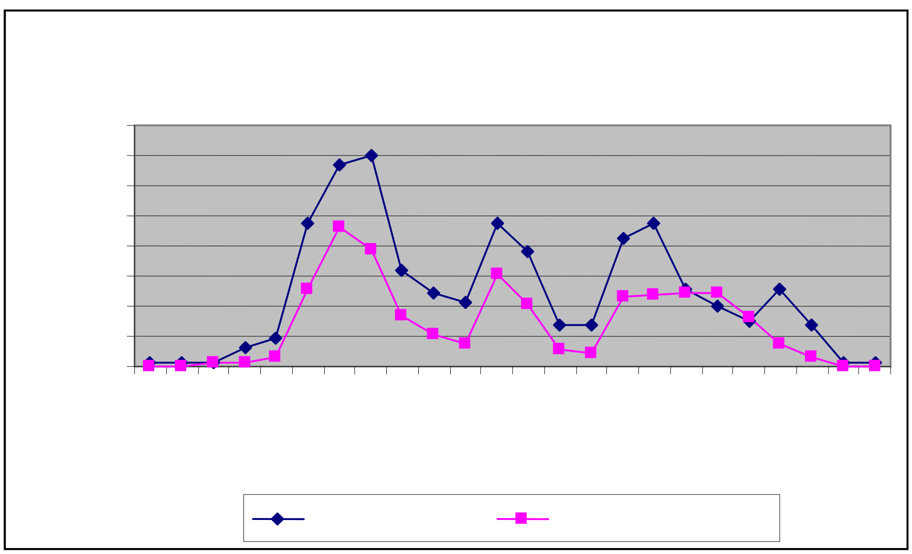
3.6 Gas Production and Use

The outcome of the study indicated that the main application of biogas was for cooking. Biogas was used only for cooking purpose in 60 (91%) of the households. Gas stoves (single burner stoves in 13 hhs, double burner stoves in 52 hhs and both types in 1 hh) were installed in all the biogas-households. Biogas lamps were installed only in six households. However, lamps were not in use in 4 households because of technical defects. Users reported that the lamps were used only during the time of power cut. While calculating the gas production, use of gas for cooking has only been considered as the share of lamp was reported to be negligible.

Total burning hours of stove in the sampled households was calculated to be 220.25 hours with an average of 3.34 hours/household per day. The gas demand in these households was reported to be 388 hours with an average of 5.88 hours per day per household. Gas was reported to be sufficient only in 16 (24%) households. When asked about the reasons for lesser gas production, the respondents felt that it was small-sized plant (5 hhs), under-fed plants (19 hhs), defective construction and technical failures (9 hhs), lack of timely repair and maintenance work (6 hhs), less gas production during cold season (2 hhs), and combination of any of the above (6 hhs). The remaining 3 households replied that they do not know the reason.

Interestingly, the amount of dung feed into the digester in totality is enough to meet the demand. The theoretical gas production from the dung fed into the digester per day has been calculated to be enough for the stove burning hours of 531 per day. The theoretical burning hours of stove based upon the size of plants under study has been 850, which is far more than the actual amount of gas being received.

Figure 3.1 shows the biogas use pattern in an average biogas household (actual and anticipated) calculated based upon the use of biogas stoves as reported by the users. The distribution of average stove burning hours of 5.88 (anticipated) and 3.34 (actual) have been shown in the figure.



The above graph (Figure 3.1) on biogas use pattern suggests that the produced gas, in totality, was not sufficient to meet the anticipated demand. The gas storage capacity of biogas plant therefore needs to be calculated based upon the peak demand of biogas at 7 to 7:30 am.

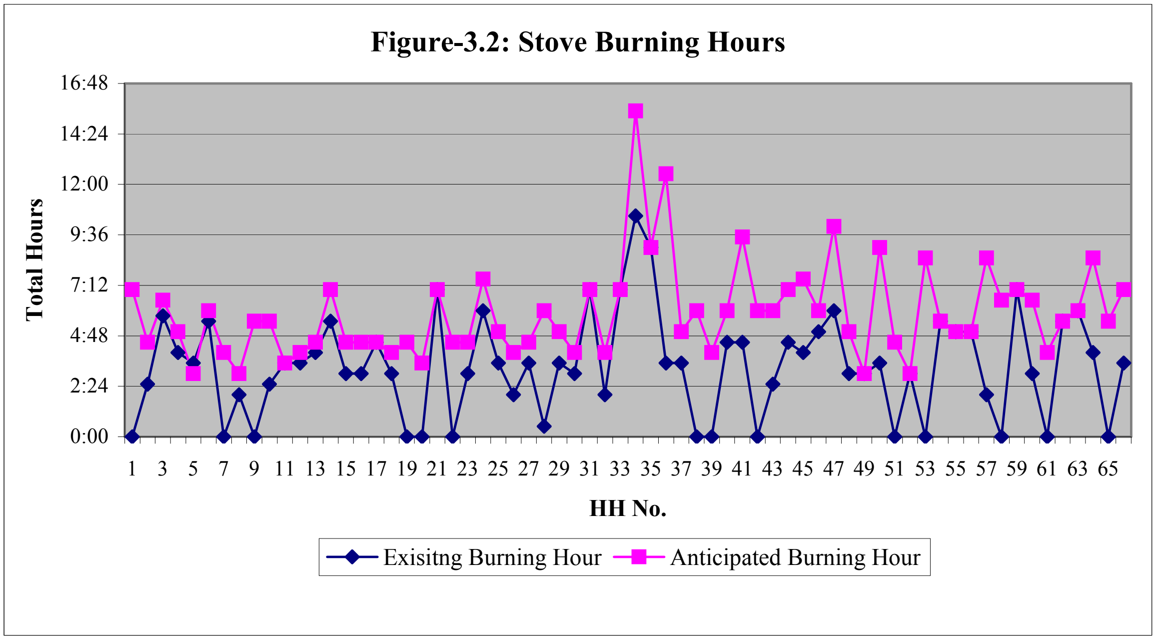


Figure 3.2 shows that there is wide gap between present use of biogas and the anticipated use (demand). The demand can be fulfilled if the average efficiency of existing plants is increased from 49.6% to about 86%.

4. PHYSICAL STATUS AND FUNCTIONING OF BIOGAS PLANT

The study attempted to evaluate the overall performance of biogas plant on the basis of: (a) existing physical status and functioning of its different components, (b) present level of benefits being achieved (the gas being produced), (c) response of respective plant users whether their expectation prior to the installation of biogas came true after the plants are operational (evaluated in terms of gas demand and supply), and (d) level of users' satisfaction on the impacts of biogas plants on them.

4.1 Plant Components

The fixed dome design of biogas plant generally consists of the different components for effective operation and trouble-free functioning. General findings of the field investigation on these components are briefly described hereafter:

4.1.1 Inlet Tank with Mixing Device and Inlet Pipe

In general, rectangular or square inlet tanks with one end truncated to accommodate the inlet pipe are constructed (refer to the plant drawings given in the annex) in Bangladesh. Bricks are used to construct base and walls, which are plastered with cement-sand mortar. Reinforced cement concrete pipes of diameter ranging from 10 cm to 20 cm are used to convey feeding materials to the digester. The quality of workmanship involved in construction is satisfactory with some rooms for further improvements. None of the plant is fitted with mixing device. Quality of workmanship meets the required standards in majority of the cases and the finishing touch is notably good. Users have, on their initiative, used a wedge with handle to block the flow of slurry during mixing.

One general defect observed in majority of the plant was the improper location of inlet pipe. Inlet opening was placed in such a manner that inserting of pole or rod is not possible to de-block the inlet pipe in case of some blockages. Another noted defect was the relative location of inlet tank. The inlet tank must be located at the opposite end of the outlet to orient inlet pipe exactly at the opposite of outlet opening, at the longitudinal centerline of the digester to ensure full digestion of slurry and comply with the designed retention time of 40-45 days. However, this standard was not followed in majority of the case. The shortened retention time might be the cause of escaping of slurry through outlet opening before releasing the whole amount of volatile substances. Slurry in outlet and slurry pit in majority of the cases was observed with bubbles and depressions, which indicated the escape of biogas. In some cases, inlet pipe is located very near to the outlet chamber endangering the functioning of plant significantly. The size of inlet tank was needs to be constructed to facilitate easy mixing of water and dung. In some cases the sizes were too big and in other cases these were too small.

4.1.2 Digester Attached with Dome (Gas Holder)

As all the plants under study were operational and filled with feeding materials, it was not possible for the study team to verify the quality of construction and compliance of the design at the field by direct observation. Efforts were made to collect information based upon interviews and observation on relative positions and finishing touches given to the plant. The shape of the floor of digester is spherical which is appropriate in the context of Bangladesh where water table is very high and some areas remain inundated during rainy season.

Plants are usually constructed at a higher or raised ground to avoid inundation during rainy season. Though some sort of stabilization/protection measures are adopted in majority of the biogas plants, some of the plants lack the provision and therefore, are at higher risk to be exposed. In majority of the cases the dome is exposed and it is not protected with compacted earth from above. The top filling over dome serves duel functions; the first being a protective cover against vandalism and the second acting as insulation during winter season to maintain constant temperature inside the digester.

The construction materials used to construct base are bricks and concrete. Bricks joined with cement sand mortar are used to construct walls. The gasholder is the extension of the digester wall at spherical (dome) shape in the top. The finishing touch in outer exposed surface is given by the use of cement plastering or concreting. Waxing in the finished surface of cement sand plastering inside the dome is used as method to make the gasholder airtight. The finished product of dome therefore consists of waxing, cement plastering, bricklayer and concreting or plastering in the case of BCSIR plant. Combination of both brick and concrete makes the product costlier. Similarly, waxing involves a labor intensive cumbersome effort which needs to be replaced by more simple and less labor intensive methods like the application of cement-slurry and plastic emulsion paints as widely practiced in Nepal for many years.

4.1.3 Main Gas Pipe and Turret

Gas produced in digester and stored in the dome (gas holder) is conveyed to the pipeline through a main gas valve placed exactly at the center point of the dome. This main gas pipe is protected with a masonry block called 'turret' constructed to encircle the pipe. In the case of plants under study, a 30-45 cm long GI pipe with diameter ranging from 25 to 35 mm is used as main gas pipe. Turret is not constructed and therefore, gas pipe remains constantly at higher risk of sabotage from human or animal activities. The size of gas pipe is not enough to compensate the reduced diameter because of flow of slurry due to some technical reasons and to ease cleaning of the pipe by inserting stick or rod.

4.1.4 Outlet (Displacement Chamber) System

The outlet system consists of an outlet opening known as manhole, a tank called outlet displacement chamber and outlet opening of suitable dimension at proper height in the outlet wall. The manhole is provided at a point diametrically opposite to the inlet pipe to avoid short-circuiting of feeding. This opening serves a number of purposes: as a manhole or gate for entry and exit of people during plant construction and maintenance, for emptying the digester for cleaning, for stirring the slurry using long pole or rod is case it forms floc in the top, and to facilitate the outward movement of displaced slurry due to gas accumulation in gas holder and inward movement of slurry from displacement chamber at the time of gas utilization so that there would be sufficient pressure for the gas to reach the points of utilization.

The quality of workmanship in general is satisfactory, however, there are lot of rooms for further improvements especially in terms of complying with quality standards. The design of BCSIR plant recommends rectangular and that of LGED suggests circular shape of displacement chamber. However, the actual shape of BCSIR varies from rectangular to square depending upon the condition of construction sites and will of mason without any valid reason.

The overflow opening discharges slurry at the ground level in some of the plants, which increases risk of entering the floodwater into the digester through overflow tank.

The main drawback observed at the site is the absence of protective cover for the displacement chamber. In majority of the cases, outlet tanks remain open, which facilitates accumulation of rainwater in the displacement tank. This added water impacts adversely to the water dung ratio in the digester. Moreover, leaving outlet chamber uncovered increases the risk of falling children, animals and poultry into the outlet and manhole. In some plants, users have constructed RCC cover or CGI sheet roofing or bamboo netting as covers.

Another construction defect in displacement chamber was observed to be the reorientation of the length and breadth of the tank without considering the consequences. Technically, the longer side of rectangular tank has to be constructed parallel to the longitudinal centerline of the biogas digester. In actual practice, majority of the plants were found to have shorter side of the rectangle to be parallel to the centerline. This increase short circuiting of feeding and creates dead-volumes inside the outlet tank especially in the both corners of longer walls.

In majority of the cases, outlet tank are constructed at a raised ground to avoid inundation during rainy season and creates outlet walls exposed over the ground. In such cases, outlet walls were not supported with compacted soils from outside to counter-balance the pressure of slurry exerted from inside at the wall. Outlet walls are found to be cracked or collapsed in such plants where such support was not provided.

4.1.5 Slurry Pits (Composing Pits)

The slurry coming out of the outlet displacement chamber discharges into the slurry pit which is also known as composting pit. This pit is very important to safeguard and add the nutrient value of the slurry coming out of the biogas digester. The size of such composting pit should at least be equal to the volume of the biogas digester. Two pits are preferable as it eases operation. The depth of pit should be kept minimal to avoid accidents.

In majority of the plants, compost pits were not constructed. The slurry coming out of the displacement chamber was either conveyed to the near by watercourse (pond or stream) or left to flow here and there. Even in cases where slurry pits were constructed, the volume of pit was very small and composting was not done properly.

4.1.6 Pipeline and Fittings

The gas conveyance system in a biogas plant usually consists of main gas valve placed at the top of dome immediately after the main gas pipe to control flow of gas to the point of application, a pipeline with required fittings, a water condensation system known as water outlet or water trap and gas taps to control flow of gas to gas stove.

Different types of main gas valves were in use as per their availability in the local market. In few plants imported Italian valves were installed. In majority of the cases, local valves were in use. Though gas valve is one of the important components in biogas plant, users in the surveyed plants were not aware of such importance. It is manifested by defects like gas leakage, broken knob, slipping handle etc. in the main valves. In some cases, valves are fitted very near to the point of application increasing the chances of gas leakage through the pipeline. Majority of the owners reported that these valves usually remained open all day long and were not operated regularly.

Gas from the dome was conveyed to the point of application through plastic pipe of ½” to ¾” diameter. However, some of the users have used GI pipe of ½” diameter. Plastic pipes in all the cases remained exposed over ground and are supported by wooden poles, houses or natural trees throughout its alignment like the electric or telephone cables. Pipes remained exposed to natural sunlight as they are hung from one tree to other. Continuous exposure to sunlight makes pipe more vulnerable to damage as pipe tends to become more brittle and tougher. There were higher risks of vandalism of pipeline in one hand and leakage of gas in the other. Most importantly, as the profile of pipe is not maintained in slope, condensed water tends to clog the pipeline and interrupt the flow of gas. One of the major drawbacks of pipe conveyance system is the absence of water trap in the alignment. None of the plant was observed to have water trap. Likewise, gas taps have not been used in any plant to regulate the flow of gas to gas-stove. In general, the conveyance system is poor and highly vulnerable to damages and vandalisms.

4.1.7 Gas Stove and Gas Lamps

Locally manufactured gas stoves and lamps popularly known as ‘hajak’ are in use in Bangladesh. In all the cases, these appliances were reported to be supplied by the service providers (BCSIR and LGED). Different types of gas stoves were in operation. Stove burners were fitted in a metal frame. Problematic stoves were reported to be the main difficulty for the biogas users. Wide-spread damage of gas-regulating knob, heavy corrosion of the frame, clogging of burner holes and low pressure yellow flame with less calorific value were observed to be the main problems. These stoves lack primary air intake.

Gas lamps, ‘Hajak’, with shape similar to the kerosene lantern were in use. As all the biogas plants under study were located in electrified areas, use of biogas lams was limited during the time of power-cut, which was reported to be quite a regular phenomenon in Bangladesh. The performances of such lamp, in general, were reported to be satisfactory. However, 4 out of the 6 biogas lamps were out of order during the time of survey.

4.2 Condition of Biogas Plants

The existing condition of different components of biogas plant was observed in detail during the field investigation to assess the quality of construction, effectiveness of maintenance activities carried out and the operational status prior to categorizing them. The existing physical status of different components of biogas plant have been categorized in three different headings viz. good (functioning without defects), fair (defective but functioning) and poor (defective and not functioning) in qualitative manner, dependent on the physical observation of the plant made by the members of the study team during field investigation. The categorization has been made based upon the following indicators:

Table-4.1: Indicators for Categorization of Biogas Plants

Category	Indicators
Condition of Plant as a whole	
Good (functioning without defects)	• All the plant-components are constructed with good workmanship complying with the basic minimum quality standards • All the plant-components are operational without any technical problem • Location and relative orientation of plant components meet the basic minimum standards of site lay-out • Location of plant is managed in such a way that it is at reasonable distances from kitchen (point of gas application), water source, cattle shed and main access way.
Fair (defective but functioning)	• Plant-components are constructed with moderate workmanship. Plants are constructed without giving due attentions to the quality norms and standards • Plant-components are operational with one or more technical problems • Location and relative orientation of plant components do not meet the basic minimum standard of site lay-out, however, the non-compliance do not affect gas production seriously • Location of plant is either very near or reasonably far from kitchen (point of gas application), water source, cattle shed and main access way.
Poor (defective and not functioning)	• Plant-components are constructed with poor workmanship. Plants are constructed without giving due attentions to the quality norms and standards and in many cases it violets basic minimum standards • Plant-components are not operational and there are one or more technical problems • Location and relative orientation of plant components do not meet the basic minimum standard of site lay-out, and the non-compliance affect gas production seriously • Location of plant is quite far from kitchen (point of gas application), water source and cattle shed and vary near to main access way.
Condition of Inlet	
Good (functioning without defects)	• Constructed in firm ground and quality of construction meet the basic norms and standards usually adopted. The finished product reflects the work of a qualified mason. • The location of inlet pit is managed in such a way that the opening of inlet pipe to the digester is exactly placed in opposite side (at 180 degrees) of the manhole. • Inlet opening is placed in such a manner that inserting of pole or rod is possible to de-block the inlet pipe in case of some blockages • Height of pit facilitates comfortable mixing of dung and water • No cracks or other construction defects are visible • No technical problems that affect the functioning of the inlet seriously are encountered
Fair (defective but functioning)	• Constructed in firm ground however, the quality of construction violets one or more basic norms and standards usually adopted. The finished product reflects the work of a mason who is not trained properly to construct biogas plant. • The location of inlet pit is placed in such a way that the opening of inlet pipe to digester is not exactly in opposite side (at 180 degrees) of the manhole. • Inlet opening is placed in such a manner that inserting of pole or rod is not possible to de-block the inlet pipe in case of some blockages • Height of pit is either high or low which obstruct comfortable mixing of dung and water • Some cracks or other construction defects are visible • Some technical problems that affect the functioning of the inlet to some extent are encountered
Poor (defective and not functioning)	• Constructed in damage-prone ground and the quality of construction violets basic norms and standards usually adopted. The finished product reflects the work of a mason who lacks skills and knowledge to construct biogas plant. • The location of inlet pit is placed in such a way that the opening of inlet pipe to digester is placed very near to the manhole opening • Inlet opening is placed in such a manner that inserting of pole or rod is not possible to

	de-block the inlet pipe in case of some blockages • Height of pit is either very high or very low which obstruct comfortable mixing of dung and water • Serious cracks or other construction defects are distinctly visible • Technical problems that affect the functioning of the inlet seriously are encountered
Condition of Digester and Dome: In the case of dome and digester, as the main structure remained underground, it was not possible to observe the quality of construction and construction defects in detail. Only physical observation of the exposed portion was possible. Indicators are selected which could be easily verified.	
Good (functioning without defects)	• Located in firm ground with no vulnerability of flood, land-erosion or other natural and manmade disasters • Enough top filling to safeguard the dome against damage. If plant is constructed above ground to minimize the risk of flood and higher water table, it is well protected from all side with stabilization measures.
Fair (defective but functioning)	• Located in firm ground with little vulnerability of flood, land-erosion or other natural and manmade disasters • Not enough top filling to safeguard the dome against damage, some portion of the dome is exposed and the exposed portion does not illustrates signs of poor workmanship (distorted shape, minute cracks etc.). If plant is constructed above ground to protect it form flood and higher water table, it is not properly protected from all side with stabilization measures.
Poor (defective and not functioning)	• Location of digester and dome is highly vulnerable to flood, land-erosion or other natural and manmade disasters • No top filling to safeguard the dome against damage, dome is exposed and the exposed portion illustrates signs of poor workmanship (distorted shape, minute cracks etc.). If plant is constructed above ground to protect it form flood and higher water table, it is not protected from all side with stabilization measures
Condition of Outlet (displacement chamber)	
Good (functioning without defects)	• Located in firm ground with no vulnerability of flood, land-erosion or other natural and manmade disasters • Outer sides of the walls are supported properly with compacted soil or stabilization measures to counter-balance the pressure of slurry and walls do not have any cracks or defects • Protected with good covering (CGI sheet or concrete covering) • Outlet opening is located in such a manner that there are no chances of flood water entering into the outlet chamber in case of water logging • Outlet opening facilitates the flow of slurry easily to the composting pit • The relative orientation of the plant suits with the engineering requirements
Fair (defective but functioning)	• Located in firm ground, however, it is vulnerable to flood, land-erosion or other natural and manmade disasters • Outer sides of the walls are not properly supported with compacted soil or stabilization measures to counter-balance the pressure of slurry and walls have minor cracks or defects • No covering is provided • Outlet opening is located in such a manner that there are chances of flood water entering into the outlet chamber in case of water logging • Outlet opening is partially blocked with dried slurry or other obstructions that hinders easy flow of slurry to the composting pit • The relative orientation of the plant do not suits with the engineering requirements, it is distorted or adjusted to suit with the site condition compromising the quality
Poor (defective and not functioning)	• Location is highly vulnerable to flood, land-erosion or other natural and manmade disasters • Outer sides of the walls are not supported with compacted soil or stabilization measures to counter-balance the pressure of slurry and walls have major cracks or defects • No covering is provided, there is high risk of animal and children to fall in the chamber • There are high chances of flood water entering into the outlet chamber in case of water logging • Outlet opening is blocked with dried slurry or other obstructions that interrupt flow of

	slurry to the composting pit • The relative orientation of the plant violets the engineering requirements, it is distorted or adjusted heavily to suit with the site condition compromising the quality
Condition of Main Gas Valve	
Good (functioning without defects)	• Good quality imported Italian gas valve is used, which is functioning trouble-free without any gas leakages • Gas valve is fitted at right place in the pipeline and is protected against further deterioration or damages • Gas valve is easy to operate and regular greasing/oiling is done
Fair (defective but functioning)	• Locally available gas valve is used, which is functioning without any gas leakages • Gas valve is not fitted at the right place in the pipeline and is not protected against further deterioration or damages • Gas valve is either tight or too loose to operate and regular greasing/oiling is not done
Poor (defective and not functioning)	• Locally available gas valve is used, which has one or more technical defects (gas leakage, broken knob, slipping handle etc.) • Gas valve is not fitted at the right place in the pipeline and is highly vulnerable to deterioration or damages • Gas valve is very difficult to operate and greasing/oiling is not done at all
Condition of Pipeline	
Good (functioning without defects)	• Gas pipeline is aligned in such a way that the length is minimized • Either GI pipe of 15mm diameter or good quality plastic pipe of diameter more than 20mm is used • Pipes are buried under ground at right depth to protect them from vandalism and further damages • Minimum fittings are used and the joints are properly sealed off
Fair (defective but functioning)	• Gas pipeline is not aligned through the shortest route rather another route is followed • Flexible plastic pipe with diameter less than 20mm is used. • Pipes are aligned over-ground and remain hanging from one tree to other or one pole to other or one house to other at considerable height from ground level • There are high risks of pipe vandalism and damages • There are numbers of joints along the pipe alignment • Even with one or more of these defects, pipeline is functioning
Poor (defective and not functioning)	• Gas pipeline is not aligned through the shortest route rather zigzag and longer route is followed • Flexible plastic pipe with diameter less than 20mm is used. • Pipes are aligned over-ground and remain hanging from one tree to other or one pole to other or one house to other at lower height from ground level. • Pipes are damaged or vandalized along its alignment • Leakages are observed along the pipeline • Pipeline is not in operation due to one or many of these defects
Condition of Gas Stove	
Good (functioning without defects)	• Gas stove is operating without any trouble and there are no pending maintenance works • The stove burns with blue flames and at adequate pressure • Burner rests on firm metal frame free from rust
Fair (defective but functioning)	• Gas stove is operating but there are one or few pending maintenance works • One of the burners in double burner stove does not work • The stove burns with blue flames and at low pressure • The burner holes are clogged and the metal frame has rust in it
Poor (defective and not functioning)	• Gas stove is not operating and there are few pending maintenance works • The stove burns with yellow flames and at low pressure • The burner holes are clogged and the metal frame has rust in it
Condition of Gas Lamp (Hajak)	
Good (functioning without defects)	• Gas lamp is operating without any trouble and there are no pending maintenance works • The lamp burns with bright light and at adequate pressure • The metal frame is free from rust
Fair (defective	• Gas lamp is operating without but there is one or more pending maintenance works

but functioning)	• The lamp burns with relatively deem light and at low pressure • The metal frame has rust
Poor (defective and not functioning)	• Gas lamp is not operating and there are one or more pending maintenance works • The lamp does not burn at all • The metal frame has heavy dust
Condition of Slurry Pit	
Good (functioning without defects)	• Two slurry pits with capacity at lease equal to the volume of digester are constructed at a reasonable distance from the outlet overflow • Slurry in the pit is mixed with other organic material as composts • Slurry pit is covered with shades to avoid direct sunlight over it
Fair (defective but functioning)	• Only one slurry pits with smaller dimensions is constructed at a reasonable distance from the outlet overflow • Slurry in the pit is not mixed with other organic material as composts • Slurry pit is not covered with shades to avoid direct sunlight over it
Poor (defective and not functioning)	• Either slurry pit is not constructed or the pit is too small to accommodate the quantity of slurry flowing into it • Slurry flows elsewhere around the pit

The following table shows the categorization of general condition of biogas plant and its components based upon the above-mentioned criteria.

Table-4.2: General Condition of Biogas Plants

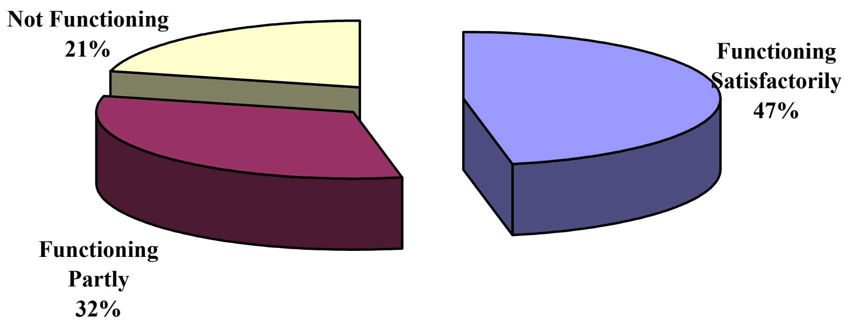
Plant Component	Plant under study different category					
	Good (functioning without defects)		Fair (defective but functioning)		Poor (defective and not functioning)	
	Nos.	%	Nos.	%	Nos.	%
Biogas Plant as a whole	2	3	50	76	14	21
Inlet tank	5	8	46	70	15	22
Digester and dome (gas holder)	5	8	47	71	14	21
Outlet (displacement chamber)	2	3	49	75	15	22
Pipeline	2	3	50	76	14	21
Main gas valve	2	3	48	73	16	24
Gas lamp (hajak)	1	17	1	17	4	66
Gas stove	1	1.5	51	77	14	21
Slurry pit	1	1.5	7	10.5	58	88

It is evident form Table-4.2 that there are lot of rooms for further improvements in biogas plants and their components. The poorest component was observed to be the slurry pit as 88% of the pit falls under poor category.

4.3 Functional Status

The outcome of the study indicated that despite number of defects and weaknesses, the functional status of biogas plants on an average was satisfactory. Out of the 66 plants under analysis, 31 (47%) plants were functioning satisfactorily, 21 (32%) plants were functioning partly and the remaining 14 (21%) plants were not functioning at all during the time of field investigation. The following pie-diagram illustrated the functional status of biogas plants under study:

Figure-4.1: Functional Status of Biogas Plants



Out of the 14 defunct plants, 3 were not functional for the last 4 months, 9 for one year, 1 for two years and the remaining 1 for one month only. The reasons for non-functioning as reported by the respondents were[1]:

- Non-availability of feeding materials especially due to selling of cattle after the installation of biogas plant (responded by 6 users)
- Poor workmanship during construction (responded by 5 users)
- Sub-standard quality of construction materials and appliances (responded by 3 users)
- Non-availability of repair and maintenance services (responded by 2 users)
- Clogging of pipeline due to accumulation of condensed water (responded by 2 users)
- Poor operational activities by the users (responded by 2 users)

The following table shows interrelationship between types of training received by the users on operation and maintenance, and functional status of biogas plants.

Table-4.3: Relationship between Training Received and Functional Status of Plant

Type of Training Received	Functional Status of Plant (No of Plants)			
	Not Functioning	Partly Functioning	Functioning Satisfactorily	Total
No training received	2	2	5	9
Training not provided but leaflet/booklet/manual provided	5	3	4	12
One day orientation training provided by service provider	0	5	4	9
Short term O & M training (7days or less)	0	0	1	1
Long term O & M training (more than 7 days)	0	0	2	2
On the spot instructions from mason/company supervisors etc.	7	11	14	32
Training provided by other NGOs (not the service provider)	0	0	1	1
Total	14	21	31	66

It is apparent from Table-4.3 that biogas plants of those users who received operation and maintenance training, either short or long term, are satisfactorily functioning. In other cases there seemed no direct relationship between the two variables.

[1] Some respondents whose plants do not function gave more than one reasons

Likewise relationship between quantity of feeding received and functional status of biogas plants has been shown in Table-4.4.

Table-4.4: Relationship between Quantity of Feeding and Functional Status of Biogas Plants

Quantity of Feeding Received (% of prescribed quantity)	Functional Status of Plant (No of Plants)			
	Not Functioning	Partly Functioning	Functioning Satisfactorily	Total
Less than 25%	8	2	2	12
<25% but >50%	1	8	12	21
<50% but >75%	2	6	4	12
<75% but >100%	2	1	7	10
More than 100%	1	4	6	11
Total	14	21	31	66

As shown in Table-4.4, 57% of the plants, which received feeding less than 25% of the prescribed quantity, were non-functional during the time of survey. In the other hand, 57% of the plants, which received feeding more than 75%, were functioning satisfactorily. These facts indicate that the quantity of feeding and functional status of plant have direct relationship.

4.4 Efficiency of Biogas Plant

Attempts have been made to assess the efficiency of biogas plants. Efficiency of biogas plant is the ratio of input to output. Cattle dung or other feeding materials added into the biogas plant have been considered as input and gas produced per day as a result of anaerobic digestion in the digester is the output. The amount of gas being produced was estimated from total burning hours of gas stove and lamp installed therein. While calculating the gas production, it is estimated that one kg of dung produces 40 litres (1.41 cft) of gas and one biogas stove consumes about 300 to 350 litres (10-12 cft) of gas per hour[2]. In totality, the theoretical amount of gas production from all the biogas plants under study based upon the daily feeding is 150.61 cum of biogas per day. Total biogas production based upon the gas being used is 74.71 cum per day. The calculated efficiency of biogas plants collectively is, therefore, 49.6%. The lower input to output ratio suggested one or more of the following facts:

a. **The feeding material fed into the digesters was not fully digested and escaped out of the plant prior to its full digestion either because of short-circuiting (as a results of dead volumes in digester or displacement chamber) or higher water-dung ratio in the feeding.** The likelihood of this fact is high viewing lot of bubbles in displacement chamber and depressions in the slurry, which indicate the existence of gas in slurry. Moreover the undigested smell of slurry in some plants also supports this argument.

b. **The produced gas did not store in the gasholder, rather escaped in the atmosphere either because of undersized volume of gasholder or cracks in the dome.** The probability of this statement is high, given the size of the gasholders as suggested by the plant design of BCSIR. For example, the volume of digester of plant capacity of 100 cft (2.8 cum) gas production per day is 7.95 cum. The volume of outlet of the same plant is 1.382 cum. The volume of gasholder in this plant is only 0.607 cum which is capable of storing only about

[2] BCSIR stoves is designed to consume 10 cft of biogas per hour

22% of the daily gas production. Hence, the likely happening of this hypothesis could not be ruled-out.

c. **The volume of displacement chamber was small as a result the produced gas could not be pushed to the point of application**. The probability of this hypothesis is quite low as it was observed that in most of the cases outlet chambers were oversized.

d. Biogas produced in the digester was not conveyed to the point of application efficiently because of the technical and operational defects in various components of biogas plant. The possibility of this assumption is high given the condition of biogas plant and its components in majority of the cases. There are lots of rooms for further improvements in the gas conveyance and utilization systems of the plant especially in pipelines and appliances. Problem with main gas valve, leakages in pipeline, water accumulation in pipe due to absence of water outlet, leakages from stove, absence of gas tap to control and regulate flow of gas to gas stove, and low efficiency of stove especially due to defective operating knobs, absence of primary air-intake and clogging of burner-holes; are some of the issues that might have resulted in lesser burning hours of gas stove.

e. **The total burning hours of gas stove and lamp were reported wrongly by the users.** This statement, though probable, will have not much significance on affecting the efficiency of plant as the variation on burning hours would not be much given different triangulation methods used to verify the responses of the users.

The following table illustrates the efficiency of various sizes of biogas under study based upon the amount of gas production based upon actual feeding and actual quantity of gas being used.

Table-4.5: Efficiency of Biogas Plants

Efficiency of Plant	No of Plants in each category of Plant Size (Cft gas production per day)						
	100	125	150	200	250	300	Total
Nil (No gas production)	7	1	3	2		1	14
Less than 20%	2		2				4
>20% but < 40%	9	2	2	2	2		17
>40% but < 60%	7	1	2	1			11
>60% but < 80%	9		1		1		11
>80% but < 100%	4		1	1			6
More than 100%	3						3
Total	41	4	11	6	3	1	66

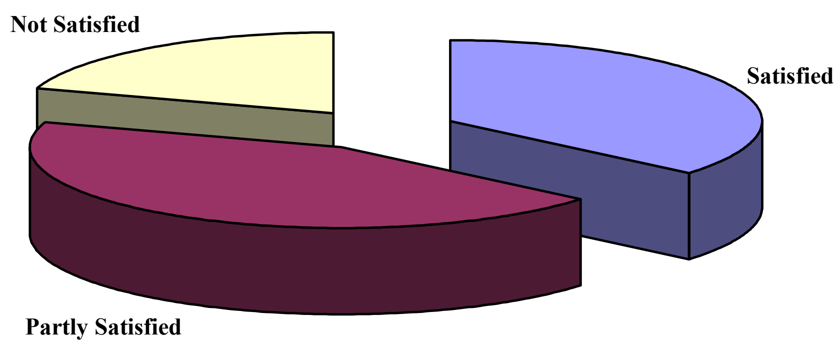
It can be seen from Table-4.5 that in most of the cases (57 plants out of 66) actual amount of gas production is less than the expected, which indicates lower efficiency of plants. Although 21 plant users were reported to have fed dung to meet at least 80% of the prescribed rate, only 9 plants were producing gas at the rate of 80% or more of the expected quantity. Noteworthy is the bigger the plant the less its efficiency. Interestingly, 3 plants are producing gas more than the theoretical expectation. The reasons of the higher efficiency might be the night soil feeding (latrine attachment to biogas digester) in two cases (plant nos. 62 and 64) and inflated burning hours in one case (plant no.6).

4.5 Users' Perception

4.5.1 Perception on Plant Performance

The respondents were encouraged to evaluate the performance of their plants by putting various direct and indirect questions. There responses have been analyzed carefully to come to a conclusion on whether the respective users' were satisfied with the output from and impacts of their plants on them. On being asked if they were satisfied with the functioning of their biogas plants, 24 (36%) responded that they were satisfied, 29 (44%) responded that they were partly satisfied and the remaining 13 (20%) respondents responded that they were not satisfied.

Figure 4.2: User's Level of Satisfaction



The reasons for full satisfaction were reported to be:

a. Enough gas for cook/lighting (9 hhs)
b. Easy cooking/lighting (7 hhs)
c. Nutrient fertilizer (5 hhs)
d. Economic benefit (4 hhs)
e. Health benefits (2 hhs)
f. Environmental Benefits (2 hhs)
g. Trouble free functioning of plant (1 hh)
h. Workload reduction (1 hh)

The reasons for not satisfying were:

a. No gas production from the plant (13 hhs)
b. Non-availability of feeding materials (10hhs)
c. Poor quality of construction (3 hhs)
d. Not enough gas (3 hhs)
e. Often encounter technical problems (2 hhs)
f. More added works (2 hhs)
g. Substandard quality of construction materials and appliances (1 hh)
h. Non-availability of maintenance services (1 hh)

It was attempted to examine if there was any correlation between the efficiency of biogas plant based upon the actual gas being received as described in heading 4.4 above, and the level of users' satisfaction as responded by them. The results of analysis have been illustrated in Table-4.6 below:

Table-4.6: Relationship between User's Satisfaction and Plant Efficiency

Efficiency of Plant	Users' Level of Satisfaction			Total
	Not Satisfied	Partly satisfied	Satisfied	
Nil (No gas production)	13	1		14
Less than 20%		3	1	4
>20% but < 40%		9	8	17
>40% but < 60%		6	5	11
>60% but < 80%		7	4	11
>80% but < 100%		2	4	6
More than 100%		1	2	3
Total	13	29	24	66

It is clear from Table-4.6 that users directly relate their level of satisfaction with the efficiency of biogas plant. 13 out of the 14 plants whose efficiency is nil responded that they are not at all satisfied with the functioning of their plants. Interestingly, one of the users is partly satisfied with the performance of his plant despite its malfunctioning. It is because of the realization of the users that the plant is not functioning for the reason that they have not fed the plant correctly.

Users' satisfaction is also reflected in their answers to the question on whether they will advice others to install biogas plants in which 61 users (92%) have replied in positive. Only 5 users told that they will not advice others to install biogas plant. The main reason mentioned for not advising others to install biogas plant was reported to be the difficulty in fulfilling the feeding requirements. One of the plant owners despite being satisfied with the performance of his plant responded that he will not advice others to install biogas plant probably because he does not want other villagers to install biogas plants to maintain his prestige in the community.

People used to call me a madman when I first invested my precious money to construct biogas plant. Now all of them have totally different feelings. Most of them appreciate my decision, some of them are too jealous to see me benefiting from biogas plant, which is sometimes manifested by their ill behaviors – they cut my gas pipeline. Now, my wife's hands are so soft and clean because of the liberty from hard rubbing to remove black-soot from the cooking utensils. I am earning good income from selling bio-slurry and using it to cultivate fish-feeds. Biogas has totally changed my quality of life. I started biogas plant with only one cow and now I have 16 cows in my stable.
- Mr. Azizur Rahaman, a plant owner from Bogra expressing his full satisfaction

Interestingly, 10 out of the 14 users whose biogas plant was not functioning during the time of field survey reported that they would like to adapt the technology again.

4.5.2 Perception on Merits and Demerits of Biogas

Users were also asked to mention three main merits and demerits of biogas plants based upon their experience with the technology. Weights were then allocated according to the number of responses. The highest was given 20 points while subsequent answers were allocated 19,18,17… points each. The result of analysis has been summarized in the following table.

Table-4.7: User's Perception on Merits of Biogas Plant

Merits	Mean	Std. Deviation	Minimum	Maximum	Kurtosis	Skewness
Easy and comfortable cooking	19.66	2.45	12	20	0.06	(0.16)
Environment friendly/Protection of forest	17.46	3.85	10	20	0.18	(0.54)
Saves time and workload	17.30	4.24	9	20	0.16	(0.42)
Nutrient rich fertilizer	12.14	5.32	8	20	(0.27)	(0.22)
Economically beneficial	11.78	5.24	8	20	(0.56)	0.18
Health benefits	8.58	4.37	6	20	(0.24)	(0.12)
Fuel saving	8.46	5.76	6	20	0.42	0.64
Comfort in cleaning cooking vessels	8.34	4.98	6	20	0.14	(0.87)
Utilizes waste materials	8.02	5.95	4	20	0.64	0.76
Readily available cooking fuel	7.24	5.12	2	20	1.10	1.20
Eliminates the problem due to wet-firewood during rainy season	5.26	4.16	1	20	0.23	0.98
Encourages livestock development	4.72	5.68	1	20	1.10	(0.98)
Easy to handle/operate	4.14	4.34	1	20	0.76	1.2
Enhances prestige in society	4.00	6.55	1	20	(0.08)	0.89
Clean kitchen and cooking environment	4.00	5.23	1	20	0.48	0.74
Safe to use	3.98	5.80	1	20	0.34	(0.06)
Helps to enhance quality of rural life	3.98	5.31	1	20	1.1	0.65
No need of storage place for firewood	3.98	5.26	1	20	1.20	0.45
Reduces foul odor from poultry farm	3.80	6.12	1	20	0.86	0.97

Scores ranging from 1-5 was given to the demerits of a biogas plants. The following table shows that result of analysis.

Table-4.8: User's Perception on Demerits of Biogas Plant

Demerits	Mean	Std. Deviation	Minimum	Maximum	Kurtosis	Skewness
Tension due to problematic components	3.8	1.14	1	5	0.17	(0.42)
Smells bad	3.1	1.42	0	5	(0.98)	(0.38)
Complicated to operate	2.45	1.86	0	3	(0.01)	0.87
Maintenance difficult	1.54	1.26	0	3	1.2	0.56
Socially not acceptable	2.56	1.54	0	5	0.88	(0.12)
High investment cost	0.90	0.87	0	3	3.0	2.42

The respondents rated easy and comfortable cooking, environment friendly technology, time saving and workload reduction, nutrient rich fertilizer, economic benefits; and health improvement as main merits, while tension due to problematic components of biogas plants, foul smelling in kitchen when gas leaks, difficulty in maintenance to be the main demerits of biogas technology.

Even if the government's gas pipeline is conveyed to my community, I will not take the gas connection. I have biogas plant of my own which is producing gas free of cost – without any monthly payment.
- Md. Abu Taleb from Malgram, Bogra on being asked the main benefit of biogas plant

The kurtosis is the measure of the extent to which distribution is "tail heavy", compared to normal distribution. Positive kurtosis indicates more cases in extreme tails than in normal distribution with same variance. Similarly, the skewness is a measure of asymmetry of distribution. Positive skewness indicates that more values are less than the mean. In other words, lower the kurtosis value more the responses are scattered around the mean.

The options ranked high by the respondents have lesser kurtosis value compared to low ranked options, which means that the users in general have positive attitude towards the high ranked options. In addition, these options have negative skewness, which means more values are less than the mean. Negative skewness with lesser kurtosis of the high ranked options means that most of the responses are very close to mean, even though it is lesser than mean.

Negative kurtosis value along with negative skewness values for the merits and demerits show that the distribution of the responses is more clustered to the center and the tail of the distribution curve is not heavy. This also shows the consistency in responses of the users.

4.5.3 Suggestions for Future Program

The respondents were encouraged to give suggestions for the effective implementation of future biogas program in the country based upon their experience with biogas technology. The responses received from them were:

a. Increase subsidy to benefit the poorer section of communities (16)
b. Improve the quality of biogas stove (8)
c. Establish service centers/formulate effective maintenance mechanisms (7)
d. Increase the size of plant/gasholder (6)
e. Produce electricity from biogas (5)
f. Avail credit facilities for the potential users (4)
g. Launch effective motivational/promotional activities to aware the people on importance and benefits of biogas plant (4)
h. Make provision of mixture device in inlet tank (2)
i. Commercialize the biogas plant with the introduction of community/institutional plant (2)
j. Provide training and orientation to users on operation and maintenance of biogas plant (2)
k. Design and construct plant in such a way that other feeding materials besides cattle dung could be used (2)
l. Encourage users to construct two slurry pits compulsorily (2)
m. Decide installation and size of plant based upon available feeding materials (1)
n. Reduce the cost of installation (1)
o. Increase the diameter of the gas pipe (1)
p. Activate media for promotional activities (1)
q. Make arrangements to store biogas in cylinder (1)
r. Install plants according to family size (1)
s. Improve construction quality and workmanship (1)
t. Improve the quality of main gas valve/use good-quality valves (1)

The responses as summarized above indicated that the users perceive subsidy as one of the motivating factors for the promotion and extension of biogas technology. They also strongly pointed out the need for effective after-sale services.

5. IMPACTS OF BIOGAS ON USERS

5.1 Impacts on Time Saving and Workload Reduction

5.1.1 Cooking

The finding of the field investigation indicated that biogas plants have positive impact on reduction of time for cooking household meals. Maximum, average and minimum timesavings after the installation of biogas plant were reported to be 2 hours, 40 minutes and 15 minutes per day respectively. Interestingly, four households were found to have incurred more time for cooking after they started using biogas. The reason for added time was reported to be the cooking in single burner stove that took longer hour than the twin-mouth conventional firewood kiln previously in use. 19 households reported that they did not experience any time saving. However, 15 households saved time in the range of 15 min to 59 minutes, 21 households saved 1-2 hours and the remaining 7 households saved more than 2 hours per day.

5.1.2 Collection of Water

It was observed that collection of additional quantity of water to mix dung and water to feed into biogas plant was not a problem for all the households as water sources especially the hand pumps were readily available in the courtyards of the biogas households. The maximum distance of water source from the biogas plant was not more than 60 meter. Water source was available within 10 m in 44 households, within 10-20 m in 15 households and within 20-60 m in the remaining 7 households. However, 47 households experienced a slight increase in total time allocated to collect water after the installation of biogas plant. The added average time has been calculated to be 6 minutes/households/day, which is not that significant.

5.1.3 Plant Feeding

Mixing of dung and water is an added work to be carried out each day. In an average, one household was reported to need 10 more minutes to carry out this task.

5.1.4 Collection of Fuel

Firewood, dried dung cakes and agricultural wastes were reported to be the main conventional fuel sources used in the biogas households for cooking. Some households used LPG (9 hhs) and natural gas (2 hhs) for this purpose. 40 households collected fuel wood from nearby jungle and their own lands. 11 hh bought it from market or mobile vendors, 15 hh collect it from both the sources. When asked if they have experienced any changes in allocated time to collect fuel before and after the installation of biogas plants, 19 of them replied that there was no difference while the remaining experienced decrease in time. The total time saving per household per day ranges from 25 min to 1 hour, with an average of 32 minutes.

5.1.5 Cleaning of Cooking Vessels/Utensils

54 of the respondents, especially the women, reported that they have experienced a significant duration of time saving to clean cooking vessels in absence of black soot that used to be a major

problem with the vessels used to cook food with fuel wood. The time saved to carry out this task ranged from 15 minutes to 1.5 hours depending upon the number of family members and types of food being cooked. The average time saving in this case was reported to be 27 minutes/household/day.

5.1.6 Caring of Animals

When asked if the users have felt any difference in time allocated for cattle care before and after the installation of biogas plants, majority of the respondents (89%) replied that they did not experienced any changes. According to the remaining respondents (11%), more time was needed to care cattle because they are now forced to stall-feed the cattle to produce more dung to feed into the digester. Such added time ranged from 10 minutes to 30 minutes, the average being 2 minutes/hh/day, which is quite insignificant.

Besides the above-mentioned six activities related to biogas plant, users did not feel any difference in allocated time before and after the installation of biogas plants. The total time saving after the installation of biogas plants as responded by the users has been summarized in the following table.

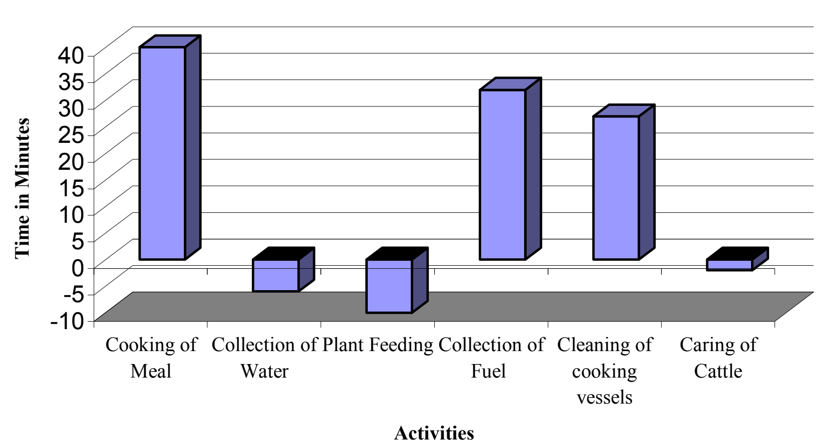
Table-5.1: Time Saved after the Installation of Biogas Plant

Activity	Average time saving/min/day*
Cooking of Meal	40
Collection of Water	(6)
Plant Feeding	(10)
Collection of Fuel	32
Cleaning of cooking vessels	27
Caring of Cattle	(2)
Average time saving	81 minutes (1 hour 21 minutes)

** Numbers inside bracket indicated time added*

The following figure illustrates the graphical representation of the time being used in various biogas related activities by the biogas households under study.

Figure-5.1: TIme Used for Biogas Related Activites



The findings of the study therefore revealed that, in general, a family saved an average of 1 hour 21 minutes per day as a result of biogas plant. The study also discovered that rural women who are mainly responsible to carry out much of the biogas related activities as mentioned above, rarely have an opportunity to decide themselves what to do with the saved time. In subsistence agricultural economics like in Bangladesh, time was reported to be reallocated to other activities that benefited the family unit and it is within this unit that those choices are made. Whether biogas reduced the drudgery, therefore, is debatable. What is done is that they substituted the drudgery of firewood collection, cooking in smoke-filled environment and cleaning vessels with black soot, for activities that helped in producing economic gain for the family. Even though majority of the respondents agreed that there was considerable time saving from biogas plant installation, none of them was in a position to say exactly how much additional financial earnings they made out of that or how much drudgery they reduced.

5.2 Impact on Saving of Conventional Fuel Sources

Saving in the quantity of cooking and/or lighting fuel is directly an economic benefit of biogas plant to the concerned household. Theoretically, based on effective heat produced, a plant producing 2 cum of biogas each day can replace about 210-150 kilograms of firewood per month depending upon its quality. In monetary values, if the quantity of gas is used to replace fuel wood in Bangladesh, it saves BDT 400 to BDT 475. The field finding revealed that 74.71 cum of biogas is produced by the plants under study per day. This saves about 300 kgs of firewood per day. The average saving of firewood was therefore 1660 kg/year/hh.

The study attempted to assess the quantity of conventional fuel used in the biogas households before and after the installation of biogas plant. The findings have been summarized in the following tables.

Table-5.2: Saving of Conventional Fuel after the Installation of Biogas Plant

Particulars	Quantity used before the installation of biogas plant (in Kg/month)	Quantity used after the installation of biogas plant (in Kg/month)	Saving/deficit (in Kg/month)
Firewood			
Total quantity used	18000	7675	10325
Average quantity used per hh	272.73	116.29	156.44
Liquid Petroleum Gas			
Total quantity used (assuming 1 cylinder = 13 kgs)	156	119	37
Average quantity used per hh	2.36	1.80	0.56
Dried Dung Cake			
Total quantity used	6340	3525	2815
Average quantity used per hh	96.06	53.4	42.66
Agricultural residues			
Total quantity used	7625	4125	3500
Average quantity used per hh	115.5	62.5	53

Based upon the quantity of saving of conventional fuel sources, yearly monetary saving because of the use of biogas has been given in the following table.

Table-5.3: Financial Gain from Saving of Conventional Fuel

Conventional Fuel	Quantity use and saving (unit/year/hh)			Average cost in BDT/kg	Total Saving in BDT/hh/year
	Before	After	Saving		
Firewood (kg)	3273	1395	1877	1.90	3566.3
LPG (cylinder)	2.02	1.54	0.48	533	255.84
Dried Dung (kg)	1153	641	512	1.23	629.76
Agricultural residues (kg)	1386	750	636	0.7	445.20
Natural Gas (BDT)	-	-	-	-	50.00
				Total	**4947.10**

Average financial saving from biogas plant was calculated to be BDT 4947.10 per year/household, which a significant amount. The maximum saving was reported to be BDT 21330, where as the minimum was BDT (-6120). The negative value indicates that the cost was increased. The increase in cost was reported to be the switching of fuel sources from firewood before the installation of biogas plant to biogas when the biogas plant was functional and again to LPG after the failure of biogas plant. The reason for switching to LPG was reported to be the reluctance of housewives to use firewood once they became habituated to cook in smoke free environment when they used biogas. The following table shows the financial saving in the biogas households under the study.

Table-5.4: Financial Saving in Biogas Households

Amount saved (in BDT)/month	No of HHs	% of HHs
More amount needed	1	1.5
Zero saving	9	14
Saving less than BDT 200	5	7.5
Saving BDT 200 to 500	29	44
Saving BDT 501 to 1000	18	27
Saving More than 1000	4	6
Total	66	100

Table-5.4 clearly points out that 84.5% of the biogas households are experiencing financial benefit from biogas plants. When asked if they felt any decrease in expenditures incurred in fuel collection because of biogas plant, 35% replied it has gone down to some extent, 47% felt it has decreased significantly, 3% had no idea whether it has gone down and the remaining 15% told it has not gone down. Responses of 82% of the respondents mentioning that they experienced tangible financial benefit from biogas plants is encouraging in a situation that people often tend to overlook such gain because of the fact that biogas plants do not earn cash rather it only saves cash. This response also justifies validity of the calculation on financial benefits as shown in Table-5.3.

The responses of users on being asked if they have experienced any advantages of biogas over other conventional fuel sources have been summarized in the following table:

Table-5.5: Advantages of Biogas over Conventional Fuel Sources

Response	No of response (hhs)	% of respondents
Comfortable and easy cooking	47	71
Environment friendly (no smoke)	45	68
Less costly	16	24
Time saving/fast to cook	14	21
No need of constant care during cooking (other works can be done while cooking)	7	11
More advanced and energy efficient	3	4.5
Less heat while cooking (temperature in kitchen is not increased)	2	3
Suitable in rainy season when firewood gets wet	2	3
Anybody can cook/no need of constant blowing and less risk of burns	2	3
No ash and firewood in kitchen	1	1.5

Table-5.5 indicated that the users considered comfortable cooking, smoke-free cooking environment, reduction in expenditure and time saving to be the most advantageous things of cooking in biogas.

Among the few disadvantages mentioned by the users, problematic stove that adds tension during cooking (24%), bad smell in the kitchen when gas escapes (12%) and reluctance of people to accept food cooked in biogas (1.5%) were the major ones.

5.3 Impact of Bio-slurry

Biogas slurry when composed, stored, handled and applied properly is considered to be of high nutrient value. It is well-recognized fact that the economic benefit of biogas technology is greatly increased if the slurry bi-product is used effectively on farms. During field investigation process, it was observed that 44 (67%) users were using bio-slurry in one or other ways; where as the remaining 33% were not using it. Majority of the users (78%) who did not use the slurry drain it directly to watercourses. Draining slurry to the watercourse means the farmers are loosing nutrient fertilizer in one hand and in the other excessive accumulation of slurry in watercourse expedites the process of eutrification, which is environmentally hazardous. Among those who did not use slurry, 68% did not owe arable land to use it, 18.5% felt it is difficult to use, 4.5% sensed it to have lesser nutrient value and another 4.5% stopped using it as people were reluctant to carry slurry from toilet attached plant. Slurry is not coming out of the plant in the case of the remaining 4.5% of the users.

Users who used slurry on farm reported that it is of high nutrient value than the farmyard manure. The use according to them were: as organic fertilizer without composing (48%), as organic fertilizer after composting (7%), as fish feed (11%), sale to others as organic fertilizer (2%), and as organics fertilizer as well as fish feed (32%). Though the users expressed their views that the production of crop and fish has increased after the use of bio-slurry, they could not exactly quantify the increment.

Previously hens used to eat or destroy cattle dung (farm-yard-manure) making the surrounding filthy and unhygienic. After the installation of biogas plant, the slurry coming out of the plant is not even touched by the hens; probably because there are no insects to eat.
- Md. Sahir Uddin from Chakkatoli in Bogra expressing his feelings on the benefit of biogas plant

Bio-slurry has been found to be beneficial in decreasing the use of chemical fertilizers. As responded by the user, the saving of fertilizer varies from 10 kg per year to 800 kg per year; the average being BDT 61 per household/year. Reduction in fertilizer not only saves money spent to purchase it but also helps to safeguard soil fertility. Among 66, households under study, 39 (59%) did not experience any saving of chemical fertilizer and the remaining 27 (41%) reported that they collectively saved 4015 kg of chemical fertilizer, the monetary value of which is about BDT 56,210. The average saving per household thus is BDT 852 per year.

During the time of field survey one of the plant owners was hesitating to express his feelings on the usefulness of biogas to replace some quantity of chemical fertilizer being used before the installation of plant. A neighbor who was present in the house when survey team was administering questionnaire, disclosed the fact and told, 'how can he accept the fact that bio-slurry can replace the chemical fertilizer? He sells chemical fertilizer.'

6. FINANCIAL AND ECONOMIC ANALYSIS

6.1 Financial Analysis

Financial analysis is the most commonly used tool that helps to decide whether a user benefits from installation of a biogas plant and, if so, by how much. The basic underlying assumption of financial analysis is that people will adopt a new technology only if they expect to have a positive impact in their financial situation. In financial analysis for biogas plants in the present case, all costs and benefits are valued from the point of view of the users.

Benefits and costs of biogas plant will vary depending upon the use of inputs and outputs be the particular user. For the present purpose rather than analysis the costs and benefits at the individual user's level an average values as calculated based upon the outcome of field investigation have been used.

The financial analysis of different sized biogas plant under study has been done with the following major assumptions:

- Though a fixed dome type of biogas plant lasts for more than 30 years depending on the quality of construction materials and workmanship, the economic life span period of biogas plant is taken as 10 years mainly because any cost and benefit accrued after 10 years will have insignificant value when discounted to the present worth.
- Cost of construction of different sizes of biogas plant is based upon the responses from the users under study and different costs for the same sizes are summed up to calculate the average cost per plant
- Operation and maintenance cost has been taken as per the actual amount spent by the users as responded during the field investigation. Operation and maintenance costs are taken to be BDT 1080 and BDT 340 as per the calculation based upon the responses from the users.
- Annual income from plant includes saving on conventional fuel sources and saving on chemical fertilizer because of the use of bio-slurry. The saving of time because of the installation of biogas plant is not considered as no evidence was found to justify that the time is used in other income generating activities. However, it does not include added nutrient value of slurry and other health, social or environmental benefits. The relationships between the quantity of gas produced, the amount of conventional fuels saved and the value of such savings for different plant sizes are based on the following assumptions:
    - 0.040 cum of gas is produced per kg of fresh dung
    - 1 cum of gas is equivalent to 4 kgs of firewood given the good quality of firewood used in Bangladesh
    - The cost of fuel is the average of all the cost as responded by the users which is BDT 4947.10 per plant per year for average plant capacity of 129 cft gas production per day as calculated based upon size of sampled plants. The corresponding values for 100, 200 and 300 cft plants are therefore, BDT 3834.96, BDT 7669.92 and BDT 11504.88 respectively.
    - Saving in chemical fertilizer because of the use of slurry is BDT 851.66 per household per year

- The salvage value of biogas plant is not included in the benefit stream of financial analysis because after 10 years of operation, the plant or its parts will not be re-salable.

In such calculation, quantity of conventional fuels saved has been taken into consideration not the value of total gas produced as equivalent to the cost of fuels. The following tables show the financial analysis of different sized plants.

Table-6.1 (a): Financial Analysis (At cost of Installation)

Cost and Benefits	**Year of Operation**										
	0	1	2	3	4	5	6	7	8	9	10
100 cft plant without subsidy											
Benefits											
Saving of fuels		3835	3835	3835	3835	3835	3835	3835	3835	3835	3835
Saving of Chemical fertilizer		852	852	852	852	852	852	852	852	852	852
	0	4687	4687	4687	4687	4687	4687	4687	4687	4687	4687
Costs											
Installation	13575	0	0	0	0	0	0	0	0	0	0
Operation		1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance		0	340	340	340	340	340	340	340	340	340
	13575	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-13575	3607	3267	3267	3267	3267	3267	3267	3267	3267	3267
	B/C Ratio = 1.95			**FIRR=**	**21%**						
100 cft plant with subsidy											
Benefits											
Saving of fuels		3835	3835	3835	3835	3835	3835	3835	3835	3835	3835
Saving of Chemical fertilizer		852	852	852	852	852	852	852	852	852	852
Subsidy	7000	0	0	0	0	0	0	0	0	0	0
	7000	4687	4687	4687	4687	4687	4687	4687	4687	4687	4687
Costs											
Installation	13575										
Operation		1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance		0	340	340	340	340	340	340	340	340	340
	13575	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-6575	3607	3267	3267	3267	3267	3267	3267	3267	3267	3267
	B/C Ratio =4.03			**FIRR=**	**51%**						
200 cft plant without subsidy											
Benefits											
Saving of fuels		7670	7670	7670	7670	7670	7670	7670	7670	7670	7670
Saving of Chemical fertilizer	0	852	852	852	852	852	852	852	852	852	852
	0	8522	8522	8522	8522	8522	8522	8522	8522	8522	8522
Costs											
Installation	20100	0	0	0	0	0	0	0	0	0	0
Operation	0	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance	0	0	340	340	340	340	340	340	340	340	340
	20100	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-20100	7442	7102	7102	7102	7102	7102	7102	7102	7102	7102
	B/C Ratio=2.40			**FIRR=**	**34%**						
200 cft plant with subsidy											
Benefits											
Saving of fuels		7670	7670	7670	7670	7670	7670	7670	7670	7670	7670
Saving of Chemical fertilizer		852	852	852	852	852	852	852	852	852	852
Subsidy	7000	0	0	0	0	0	0	0	0	0	0
	7000	8522	8522	8522	8522	8522	8522	8522	8522	8522	8522
Costs											
Installation	20100	0	0	0	0	0	0	0	0	0	0
Operation	0	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance	0	0	340	340	340	340	340	340	340	340	340
	20100	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-13100	7442	7102	7102	7102	7102	7102	7102	7102	7102	7102
	B/C Ratio = 3.68			**FIRR=**	**54%**						

300 cft plant without subsidy											
Benefits											
Saving of fuels	0	11505	11505	11505	11505	11505	11505	11505	11505	11505	11505
Saving of Chemical fertilizer	0	852	852	852	852	852	852	852	852	852	852
	0	12357	12357	12357	12357	12357	12357	12357	12357	12357	12357
Costs											
Installation	30500	0	0	0	0	0	0	0	0	0	0
Operation	0	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance	0	0	340	340	340	340	340	340	340	340	340
	30500	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-30500	11277	10937	10937	10937	10937	10937	10937	10937	10937	10937
	B/C Ratio = 2.29			**FIRR=**	**34%**						
300 cft plant with subsidy											
Benefits											
Saving of fuels	0	11505	11505	11505	11505	11505	11505	11505	11505	11505	11505
Saving of Chemical fertilizer	0	852	852	852	852	852	852	852	852	852	852
Subsidy	7000	0	0	0	0	0	0	0	0	0	0
	7000	12357	12357	12357	12357	12357	12357	12357	12357	12357	12357
Costs											
Installation	30500	0	0	0	0	0	0	0	0	0	0
Operation	0	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance	0	0	340	340	340	340	340	340	340	340	340
	30500	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-23500	11277	10937	10937	10937	10937	10937	10937	10937	10937	10937
	B/C Ratio = 2.97			**FIRR=**	**46%**						

The financial analysis done above was based on the existing cost of installation of biogas plants incurred at the year when these plants were installed. As mentioned earlier, some of the plants are eight years old. The cost of installation, therefore, will increase to a significant amount if it is to be considered at present value. Moreover, the cost of installation is expected to increase if plants are constructed to meet the anticipated quality of construction. For example, concrete cover in displacement chamber, gas taps, water trap and systematization of pipelines etc. will add certain cost. It is therefore anticipated that the increase in cost of plant will be 30 to 40%. The following table shows the result of financial analysis based on the increments is cost of installation.

Table-6.1 (b): Financial Analysis (At Added cost for Quality Improvement Options)

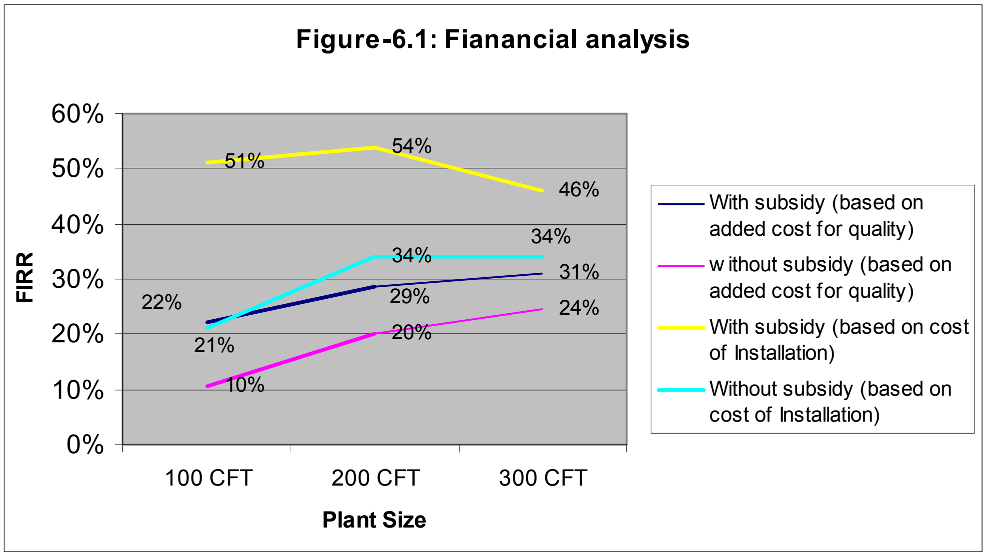
Cost and Benefits	Year of Operation										
	0	1	2	3	4	5	6	7	8	9	10
100 cft plant without subsidy											
Benefits											
Saving of fuels		3835	3835	3835	3835	3835	3835	3835	3835	3835	3835
Saving of Chemical fertilizer		852	852	852	852	852	852	852	852	852	852
	0	4687	4687	4687	4687	4687	4687	4687	4687	4687	4687
Costs											
Installation	20000	0	0	0	0	0	0	0	0	0	0
Operation		1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance		0	340	340	340	340	340	340	340	340	340
	20000	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-20000	3607	3267	3267	3267	3267	3267	3267	3267	3267	3267
	B/C Ratio = 1.32			**FIRR=**	**10%**						
100 cft plant with subsidy											
Benefits											
Saving of fuels		3835	3835	3835	3835	3835	3835	3835	3835	3835	3835
Saving of Chemical fertilizer		852	852	852	852	852	852	852	852	852	852
Subsidy	7000	0	0	0	0	0	0	0	0	0	0
	7000	4687	4687	4687	4687	4687	4687	4687	4687	4687	4687
Costs											
Installation	20000										
Operation		1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance		0	340	340	340	340	340	340	340	340	340
	20000	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-13000	3607	3267	3267	3267	3267	3267	3267	3267	3267	3267
	B/C Ratio =2.04			**FIRR=**	**22%**						

200 cft plant without subsidy											
Benefits											
Saving of fuels		7670	7670	7670	7670	7670	7670	7670	7670	7670	7670
Saving of Chemical fertilizer	0	852	852	852	852	852	852	852	852	852	852
	0	8522	8522	8522	8522	8522	8522	8522	8522	8522	8522
Costs											
Installation	30000	0	0	0	0	0	0	0	0	0	0
Operation	0	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance	0	0	340	340	340	340	340	340	340	340	340
	30000	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-30000	7442	7102	7102	7102	7102	7102	7102	7102	7102	7102
	B/C Ratio=1.60			**FIRR=**	**20%**						
200 cft plant with subsidy											
Benefits											
Saving of fuels		7670	7670	7670	7670	7670	7670	7670	7670	7670	7670
Saving of Chemical fertilizer		852	852	852	852	852	852	852	852	852	852
Subsidy	7000	0	0	0	0	0	0	0	0	0	0
	7000	8522	8522	8522	8522	8522	8522	8522	8522	8522	8522
Costs											
Installation	30000	0	0	0	0	0	0	0	0	0	0
Operation	0	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance	0	0	340	340	340	340	340	340	340	340	340
	30000	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-23000	7442	7102	7102	7102	7102	7102	7102	7102	7102	7102
	B/C Ratio = 2.09			**FIRR=**	**29%**						
300 cft plant without subsidy											
Benefits											
Saving of fuels	0	11505	11505	11505	11505	11505	11505	11505	11505	11505	11505
Saving of Chemical fertilizer	0	852	852	852	852	852	852	852	852	852	852
	0	12357	12357	12357	12357	12357	12357	12357	12357	12357	12357
Costs											
Installation	40000	0	0	0	0	0	0	0	0	0	0
Operation	0	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance	0	0	340	340	340	340	340	340	340	340	340
	40000	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-40000	11277	10937	10937	10937	10937	10937	10937	10937	10937	10937
	B/C Ratio = 1.75			**FIRR=**	**24%**						
300 cft plant with subsidy											
Benefits											
Saving of fuels	0	11505	11505	11505	11505	11505	11505	11505	11505	11505	11505
Saving of Chemical fertilizer	0	852	852	852	852	852	852	852	852	852	852
Subsidy	7000	0	0	0	0	0	0	0	0	0	0
	7000	12357	12357	12357	12357	12357	12357	12357	12357	12357	12357
Costs											
Installation	40000	0	0	0	0	0	0	0	0	0	0
Operation	0	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Maintenance	0	0	340	340	340	340	340	340	340	340	340
	40000	1080	1420	1420	1420	1420	1420	1420	1420	1420	1420
Total	-33000	11277	10937	10937	10937	10937	10937	10937	10937	10937	10937
	B/C Ratio = 2.12			**FIRR=**	**31%**						

The FIRR of biogas plants calculated based upon the cost of installation was above 30% in all the cases except for 100cft gas producing plant without subsidy. This indicated that the return on investment made for the installation of biogas plant was above the opportunity cost in the capital market, which is about 12-15%.

Likewise, in the second case, the FIRR without subsidy are 10%, 20% and 24% respectively for 100, 200, and 300 cft gas producing plants. Corresponding values with subsidy of Rs.7000 are 22%, 29% and 31% which indicated that biogas plants are financial viable even without subsidy especially in the case of bigger sized plants.

The results have been summarized in the following figure:



The benefit-cost ratio in the first case is more than 2 for all sizes of biogas plants except the smallest one (100 cft), even without subsidy. In the second case, it ranges from a minimum of 1.32 for 100-cft plants without subsidy to 2.12 for the largest plant (300 cft) with subsidy. Conclusively, in all the cases the B/C ratio exceeds one, which indicates the financial viability of all the biogas plants in the given conditions.

6.2 Economic Analysis

Some of the benefits and cost of biogas plants are not limited to the users. For example, if a large number of biogas plants are installed in a community, the non-users will also be benefited due to a cleaner community and conservation of forest in the area. Such benefits and costs that accrue even outside of the user's household is a subject matter of economic analysis. A single biogas plant does not significantly affect the economy as a whole. Therefore, economic analysis may not be relevant for a single plant but is of an immense importance at the community program level where the impact of the program on the economy is assessed.

In analyzing the economic viability of biogas program some intangible benefits like environmental impacts such as protection of forest, land-productivity improvement, reduction in carbon emissions etc; reduction in smoke-borne diseases and improvement in general health; improvement in economic condition due to employment opportunities and proper use of saved time; increased yield of crop with the use of nutrient-rich bio-slurry; social prestige and satisfaction etc. should be valued. Difficulties involves in identifying all these items of benefits and adjusting their market prices to reflect social preferences have been the major limitation of the economic analysis. The situation requires some level of generalization, simplifications, and even some restrictive assumption.

In the case of biogas plants under study, a detailed economic analysis has not been done because of the fact that most of the factors as mentioned above add the value in the benefit stream. It is therefore, assumed that biogas plants economically viable as in the case of financial analysis.

7. CONCLUSION AND RECOMMENDATION

7.1 Conclusion

The general outcome of this study suggested that the existing biogas plants are functioning at a satisfactory level though there are lots of rooms for further improvement. Installation of about 25,000 biogas digester across the country has been instrumental in popularization of the technology at the grassroots level. Moreover, the functional plants have been found to be effective tools for the promotion and extension of the technology.

The following are some of the major achievements noted in the biogas sector in Bangladesh:

- Installation of some 25000 biogas digesters
- Production of more than 1600 trained technical manpower (junior engineers, masons, supervisors, plumbers) through continuous training programs and refresher courses
- Mobilization of more than 50 NGOs in promotion and extension of biogas technologies
- Popularizing of the technology in the rural areas in the country
- Benefiting directly about 150000 people

Though biogas technology has already created a ground at the rural communities in the country, this has happened with isolated efforts in an uncoordinated manner by some sector institutions especially BCSIR. To effectively harness the high potential of 950,000 domestic biogas plants across the country (Wim J. van Nes, et.al.) a base has been created and there is need of coordinated approach and collaborative efforts of the sector institutions.

The majority of the plants under study were under-fed. The average feeding rate was 17 kg per 1 cum gas production per day biogas plant, which is only 68% of the required quantity. Operation and maintenance status of biogas plants in the sampled district indicated that there is ample room for further improvements. There is high need to optimization of biogas plants. Out of the 66 plants under study, 31 (47%) plants were functioning at full capacity, 21 (32%) plants were functioning partly and the remaining 14 (21%) plants were not functioning at all during the time of field investigation. This data clearly illustrate that there are rooms for further improvements. The number of functional plants was lower in number than that reported by a study carried out in 2004 by DPC Group, which suggested that 88.5% of the plants constructed by BCSIR during Phase I and 97.2% of the plants constructed during Phase II were functional. However, the functional rate is higher than the functional plants in Pabna District where the functional plants were reported to be just 50% (Ali, 2005).

7.2 Recommendations

In general, the outcome of the study indicated that there are certain issues that need special considerations for speedy promotion and extension of biogas technology in Bangladesh. These are summarized below:

7.2.1 Linking Biogas Program with Government Initiatives

The National Strategy for Economic Growth, Poverty Reduction and Social Development prepared by the Ministry of Finance has put emphasis on 'crating a policy environment that is capable of providing right incentives to adopt new technologies' (page-37). It has also emphasized on the integration of environmental conservation strategy into national poverty alleviation strategies (page-52). Likewise, the strategy document also emphasizes on 'increasing output of animal products by improving animal health and introducing modern methods of production, expanding technical skills of farmers, and building supportive policy framework and infrastructure' for livestock development (page-88). On the whole the biogas plans and policies in Bangladesh are yet to come in stronger form in the national planning framework so that the impact of consequent related activities could be felt in lives of targeted communities and the country as a whole. In a situation where there is high need of strengthening and streamlining the Government policy regarding the development of biogas technology, government's commitment to provide incentive to new technologies, strengthen environmental management initiatives and promote livestock development brings some rays of hope that will beneficial to the National Biogas Program. The proposed program should build on these positive rays of hope.

7.2.2 Ensuring Availability of Feeding Material

The trend in declining of number of cattle in Bangladesh is a serious threat to biogas program. The situation is further alarming in absence of immediate government program on livestock development. In one hand the grazing land are declining to accommodate the need of the rapidly increasing population, and in the other globalization and modernization process has encouraged people to switch on to another alternatives/profession jeopardizing livestock raising initiative which is getting lesser attention. However, the bright side is that the demand for meat and milk product has been increasing in Bangladesh in the recent years. There is high need to aware people on modernized methods of livestock management so that feeding materials are constantly available.

7.2.3 Improvement in the Quality of Construction

The success of biogas program depends much on the functioning of the installed plant which is directly associated with the quality of construction, besides some other variables like quality of after-sale-services, operation and maintenance mechanisms etc. The outcome of the study indicated that there is lot of rooms for improvement in installing quality plants to receive anticipated benefits. The following factors need due care:

- There is high need for the modification of the design of biogas plants to suit the gas use pattern in Bangladesh. This will help in optimization of the plant and there by reduction in cost of installation.
- Equally important is the formulation of quality standards on construction, operation and maintenance of biogas plant giving special attention to the local conditions.
- Inlet needs to be standardized. The volume and height of the tank have to be constructed to facilitate the mixing process. It should not be considered simply as a mixing tank without

giving due attention to its relative position with other components of biogas plant. Improvements in inlet is needed with installation of mixing device and proper placing of inlet pipe to ease inserting of pole or rod during the time of blockage and to discharge feed exactly opposite to manhole opening at the longitudinal center line of the digester and outlet tank to maintain designed HRT.

- The relative capacity of digester and dome in all the designs of biogas plant under study needs to be optimized so that biogas is stored in the gasholder to meet the demand during peak hours. Likewise the method of construction of gasholder needs to be standardized. Use of bricks and concrete lining increases the cost of installation. More user-friendly technology such as cement punning and application of acrylic emulsion paint should be considered to replace the cumbersome task of waxing. Dome has to be properly backfilled to avoid damages and to maintain the temperature of feedstock inside the digester especially in the cold season.

- The size of outlet should be designed based upon the total pressure needed to push the biogas stored in the gasholder to the point of application optimally. Oversized and elevated outlet increases the chance of slurry being pushed into the pipeline. Undersized outlet tank decreases the quantity of usable gas, leaving more gas than required in the gasholder. To function effectively, outlet tank should be maintained with right relative positioning and orientation. The longer side of the tank should be parallel to the longitudinal axis of digester and manhole opening to avoid short-circuiting of slurry. The tank needs to be covered with reinforced concrete slab to avoid accidents and excessive rainwater entering into it. The outer sides of the wall of outlet have to be supported with enough backfilling to prevent cracks in wall due to excessive slurry pressure.

- Gas conveyance system needs to be systematized. To ensure safety and avoid gas leakages, main gas valves of proven quality have to be installed and operated before and after the use of gas. Water trap has to be provided in the pipeline to drain condensed water inside the pipe which if not drain will obstruct the flow of gas. The pipeline should be profiled in such a way that the water trap is capable of draining the whole quantity of water accumulated inside. It is recommended to use ½" GI pipe for a shorter length of pipeline and ¾" for the longer length exceeding 100m. The dome gas pipe needs to be increased from ¾" to 1.5" to safeguard the clogging of pipe by slurry and facilitate the inserting of rod to clean during the time of blockage. This main gas pipe has to be protected with the construction of suitably sized masonry block called turret. Awareness raising training initiatives are needed to orient users on the importance of quality conveyance system.

- The problem with gas stove needs to be solved with proper research and development on the modification. There is need to orient and certify manufacturers to produce biogas appliances including gas stove. Primary air intake in stove is very important to regulate the flow and ensure effective burning. Gas taps need to be installed to regulate the flow of gas to the stove. Research on hajak lamps is also recommended to make it more cost-effective, durable and trouble-free.

- Slurry pit(s) should be considered as an integral part of biogas plant. To protect the nutrient value in the digested slurry it need to be collected in a pit and mixed with other household wastes. Composting of other household wastes with biogas slurry expedite the process of digestion. Compost pit should have volume at least equal to volume of digester. Two pits are highly recommended. The pits should be provided with shading.

7.2.4 Formulation of Repair and Maintenance Mechanism

Timely repair and maintenance help biogas plants to function effectively for a longer duration. The plant owners in most of the cases are not able to carry out required maintenance of all defective parts on time due to technical and financial constraints. After-sale-service provisions therefore should be viewed as major tool to preserve the interest of the users and safeguard the fate of the plant against any further deterioration. It is obvious that early failure of biogas plant results adversely in the future extension program and business of the service providers too. All these necessitate effective post-construction services so that the efficiency, sustainability and reputation of the plants are guaranteed. It is therefore recommended that the initial phase of the biogas program in Bangladesh include interventions to repair and maintain the already existing plants in different parts of the country. Such endeavors to retain and sustain the serviceability of the non-functional plants will be instrumental in getting appreciations from the users, which in turn will be beneficial for speedy promotion and extension of the technology. The existing pools of technical manpower that were trained by BCSIR under the framework of Biogas Pilot Plant Projects (Phase I and II) could be mobilized for this purpose.

There is high need of user's training on operation and maintenance of biogas plant to ensure the continual functioning of biogas plant. As the main cause of failure of majority of the plant was observed to be the defective operation and maintenance practices such as under-feeding, higher water-dung ratio, ignorance of users on feeding-requirements, improper use of main gas valve, zero maintenance of defective parts etc. Users need to be made aware more seriously in these regards.

7.2.5 Private Sector Development

The first and second phases of biogas program implemented under the framework BCSIR have been instrumental in producing qualified biogas technicians in the market. According to the concerned authority, more than 1600 technical persons have been trained on the technical aspects of biogas plants. The proposed National Biogas Program should tap this manpower and identify additional capacity building needs to effectively involve them in the sector. This pool of manpower will be instrumental for private sector development in Bangladesh for speedy promotion and extension of biogas technology. The experiences of Nepal suggest that private sector starts operating from grassroots technicians and expands upon with the continuous capacity building and business development orientation. It is recommended that selected technicians available in the market be encouraged to start biogas construction companies of their own and provide strengthening as well as institutionalization supports to these companies.

Private sector development should be viewed as a means to develop a more productive and efficient economy and to increase the economic participation of the population. In the case of production and use of biogas, the objective should be to let the sector develop by using the internal forces of demand and supply and by reducing external driving forces such as centrally planned production targets and subsidization in the long run. However, the immediate or short term driving force should be external driving force like subsidy. A condition for a successful privatization process should be that there are checks and balances between countervailing powers, because that dismisses the government sector from the need to intervene.

The objective of national policy on biogas program should be to provide a conducive environment for the private sector entrepreneurs to function effectively. Strengthening and capacity building of provide sector is the main pre-requisite for the promotion and extension of biogas technologies. Private sectors are the main vehicle to penetrate the program to the needy communities.

The private sector should be provided with a clear-cut mandate to participate in biogas programs. The implementation strategy of private sector should incorporate the following components:

- The strategy adopted for motivating potential beneficiaries
- Assuring the quality of installation, building the capacities of grassroots-level functionaries and the users
- Strategies on after-sale-services and operation and maintenance
- Integration of biogas programs with other development activities
- Involvement of women and other stakeholders in the program at various levels

7.2.6 Program Integration

Biogas technology has a number of synergies with other development sectors like health, women's development, agriculture, forestry and livestock management. In addition to energy supply, biogas technology can be viewed as a time saving and environmental conservation technique. It can also be promoted to improve the quality of life for women by reducing the drudgery of fuel wood collection and cooking in smoke-filled kitchen. The synergies can be utilized effectively if biogas integrated functionally with other programs. Integration essentially means identifying these synergies and incorporating them in the process of implementation.

Most of the people interviewed during field investigation have expressed the need of integration of biogas programs to other programs. The main motivation for the installation of biogas facilities in Bangladesh could be the improvement on the quality of life of the families, especially that of women. The second motivation could be the use of slurry bi-product as organic fertilizer. It is therefore recommended that the biogas program be integrated with the women's development, agriculture, health and other rural development programs. There are rooms, at present, to integrate biogas program with firewood saving and forest conservation programs though some of the areas have still easy access to biomass like agricultural residues and remains of fodders.

Importantly, there is a need to develop and establish linkages between potential stakeholders for program integration at the policy level as well.

7.2.7 Linking Biogas Program with Poverty Alleviation

Biogas program should also be linked with the poverty alleviation efforts of the government. The analysis indicated that the following features are important in the success of biogas program to address the issue of poverty alleviation.

- For direct effects, they should be small scale, affordable and accessible to the poor.

- Increasing access to energy through dissemination of biogas plants can provide the means for freeing time and empowering the people. Where possible the biogas related services being delivered should allow either a manual drudgery task to be replaced, or provide an improvement in efficiency, which results in freed time. This allows an increase in earned income or other quality if life benefits. This also maximizes local benefits from biogas project in terms of education and health.
- Subsidy should continue as driving/motivating factor to penetrate the poorer strata of the society until a demand-driven market is propelled.
- Poor and marginalized people with strong willingness and commitment to be involved in biogas plant construction needs to be given opportunity while imparting training and capacity building initiatives.

The field findings on socio-economic indicators such as educational status, land holdings, income from agricultural production and other sources indicated that biogas plants has been installed by well off farmers. To penetrate into small and marginal farmers and to make biogas technology more affordable, one of the major efforts would be to provide credit to spread loan period over a longer period of time, there by reducing the size of each payment. Given the relative newness of the technology in the rural areas, low level of awareness on the benefits of the technology and the lack of credit history of the majority of the target population financing institutions may be hesitant to provide biogas loans. A massive awareness campaign to disseminate the usefulness of the technology is needed. Group loans without collateral would be beneficial to include more small and marginal farmers under the framework of the biogas program.

7.2.8 Developing Effective Partnership

The proposed biogas program should formulate the modality of partnership agreement with other potential partners, based upon their areas of expertise and capacity of undertake specific assignments, with the assumption that it is the morally and sometimes legally binding documents to illustrate that two or more parties are working towards achieving shared and/or compatible objectives in which the parties:

- Share authority and responsibilities
- Invest time and resources for synergy
- Share risks and benefits
- Help each other to grow and institutionalize
- Enter into an explicit agreement or contracts that sets out terms

The participation of stakeholders varies from consultative, contributory, operational and collaborative depending upon the nature of tasks to be performed. Biogas program is recommended to encourage operational and collaborative partnership as far as possible. This will help in institutionalization of partners and building true ownership feeling of the interventions by the stakeholders.

7.2.9 Study on Performance of Existing Plants

49.6% efficiency of biogas plants under study is one of the serious concerns that need further investigation. The lower than the anticipated efficiency might be the result of constructional defect, operational problems, faulty designs and other unseen reasons. As mentioned in heading 4.4, the main reasons envisaged are short-circuiting of slurry in the digester or under-sized gasholder. A quick look on the design drawing of the existing plants suggested that there are lot of rooms for further optimization of plant and its components. It is strongly recommended to undertake a detailed research study to assess efficiency and suitability of the present models of biogas plants, prior to taking decision on the type and size of plant to be disseminated under the framework of Bangladesh Biogas Program.

7.2.10 Orientation on Toilet Attachment and Effective Use of Slurry

One of the factors noted during the field investigation is the improper use of slurry in most of the biogas households mostly because of ignorance of users on the correct methods of application. It is therefore recommended that a training course for users be prepared and implemented on effective composting, handling and application slurry in the farms. There is need to make people aware of the benefits of attaching toilet to biogas plants by highlighting the major benefits such as improvement in environmental sanitation in and around the house, production of more gas, elimination of harmful pathogens after digestion of excreta into the digester and enrichment of bio-slurry by added nutrient value.

7.2.11 Research & Development

It was reported by many professionals consulted during the study that less than desired is being done in the sector of R&D related to biogas technology promotion and dissemination. The present thrust of emphasis on research and development in biogas sector needs to be rationalized. Research has to focus more on finding out immediate solutions for day-to-day problems and the results there on should have practical applications.

7.2.12 Motivation and Technology Promotion

Motivation is a vital component of any program like biogas that is aimed at a wider section of the population. The exact nature of motivation strategy must, however, be responsive to the specific needs of the area and situation. In the context of biogas program in Bangladesh, motivation plays an important role when the technology is being introduced in some areas for the first time. Developing an effective motivation strategy becomes even more critical in areas where people developed unfavorable attitudes towards the technology because of various reasons especially the failure of the existing plants. Similarly, in areas where the general awareness among the people on biogas technology is low or not existent, there is a strong need to actively publicize it. The following could be some strategies for motivation in the context of Bangladesh:

Reliance on 'demonstration effects'

A successful biogas plant is assumed to be a sufficient stimulus for motivating others to install biogas plants. Demonstration effect can be an effective means to promote biogas technology in progressive areas close to urban or semi urban centers with well-developed communication systems. The existing biogas plants have some positive impacts on the promotion and development of the technology which can be utilized for future promotional strategy. Technology demonstration becomes essential especially in these areas where there is a need to change the existing negative attitude about biogas.

Motivation through governmental and non-governmental officials

It is rather awkward to recommend that the biogas program office hire motivation staff focusing solely on biogas. However, various governmental and non-governmental agencies working in the fields of agriculture, women development, social sensitization, health, education and other functional areas could be effective vehicle to work as motivation agents. The forestry division, agriculture and livestock divisions, energy division etc of the government and NGOs like BRAC, TMSS, GS, ASA etc. could be effective partners of SNV/IDCOL in this case. Although biogas is not their core activity, these agencies can integrate biogas with their routine programs. For example, biogas could be integrated with land productivity improvement project of agricultural division.

Use of Local Resource Persons

Another prominent strategy for motivation is the utilization of local resource persons by providing fixed incentives. The existing pools of technicians involved during BCSIR Biogas Projects could be instrumental in this case. These persons in the communities could be mobilized as agents to inform implementing agencies regarding potential beneficiaries. Awareness generation and motivation could then be undertaken by implementing agencies.

Use of local leaders

Local leaders could be mobilized in biogas program as motivation agents. Such leaders could either exist already in the village or may be identified and trained by IDCOL. The village heads, schoolteachers and other influential persons in the community could play an important role in selecting and motivating beneficiaries.

Use of Village Institutions/Networks

Existing village institutions, such as poultry association, NGO Network, farmers' cooperatives, women's group, youth union, and labor union could effectively be used as motivation agents. IDCOL should create such structure at the village level to organize and sustain the participation of the people, especially women, in the program. These groups should not focus on biogas exclusively but for all programs the communities.

Use of Educational Institutions

The use of educational institutions for promoting biogas technology is one of the best possible options. School children could play the role of motivation worker. Schools can include course on biogas technology to familiarize the technology. Effective coordination and networking with educational institutional is required.

7.2.13 Miscellaneous

Besides the above mentioned major recommendations, the following issues also need to be given due care:

- Coordination between sector institutions on program interventions, implementing and monitoring needs to be made more efficient. Biogas activities need to be coordinated and monitored effectively.
- RET sector has experienced many 'ups and downs' in the course of its growth. Varieties of information and knowledge exist in the market. However, effective mechanisms to manage such information and knowledge for the benefits of the sector are still lacking.
- Subsidy has been proven to be driving factor for speedy dissemination of biogas technology. However, after the phasing out of the biogas programs under the framework of BCSIR, subsidy has not been provided to the farmers willing to install biogas plants. This has jeopardized the biogas market. A flat rate subsidy needs to be continued to attract more farmers to install biogas plant.

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ANNEXES

Annex-1: Information on Sampled Plants

ID	Name of Plant Owner	District	Village	Male	Female	Total	P. Size	P.Age	Installed by	Date of Visit
1	Nasir Ahmed	Comilla	Banasua Bazaar	4	6	10	100cft	3 yrs	BCSIR	5-Sep-2005
2	Md. Ruhul Amin	Comilla	Charanal	7	5	12	100	1 yr	BCSIR	5-Sep-2005
3	Eklasur Rahaman	Comilla	Gazipur	2	6	8	150	2 yrs	BCSIR	5-Sep-2005
4	Dr. Anwar Hussain	Comilla	Zamamura	6	2	8	150	2 yrs	BCSIR	6-Sep-2005
5	Ahidur Rahaman	Comilla	Zamamura	2	3	5	100	2	BCSIR	6-Sep-2005
6	Abul Kasim	Comilla	Zamamura	3	5	8	100	2	BCSIR	6-Sep-2005
7	Md. Makbul Hussain	Comilla	Chouyarsa	3	2	5	150	7	BCSIR	6-Sep-2005
8	Md. Tazul Islam Mazumdar	Comilla	Damoria	4	4	8	100	2	BCSIR	6-Sep-2005
9	Md. Latfur Rahaman	Comilla	Daulatpur	15	10	25	200	3	BCSIR	6-Sep-2005
10	Late Chittaranjan Majumdar	Comilla	Lodhuwa	2	2	4	150	8	BCSIR	6-Sep-2005
11	Abdul Jaffer	Manikgunj	Dargram	4	2	6	100	2	BCSIR	7-Sep-2005
12	Md. Rafiquel Islam	Manikgunj	Dholla, Shaturia	3	2	5	100	3	BCSIR	7-Sep-2005
13	Mehar Ali	Manikgunj	Panjonkham	3	1	4	100	3	BCSIR	7-Sep-2005
14	Md. Karam Ali	Manikgunj	Panjonkham	2	2	4	150	2	BCSIR	7-Sep-2005
15	Rabiya Begum	Manikgunj	Dargram	2	1	3	125	2	BCSIR	7-Sep-2005
16	Md. Ali Zinnah	Manikgunj	Kamta	2	1	3	100	6	BCSIR	8-Sep-2005
17	Mehabub Alam	Manikgunj	Golora	4	4	8	125	4	BCSIR	8-Sep-2005
18	Abdul Vadir	Manikgunj	Kamardia	2	2	4	100	3	BCSIR	8-Sep-2005
19	Hayat Ali Mallik	Manikgunj	Jamalpur	1	2	3	150	4	BCSIR	8-Sep-2005
21	Abdul Aziz	Manikgunj	Basta	3	3	6	150	3	BCSIR	8-Sep-2005
22	Azizur Rahaman	Bogra	Barpur Bastibaria	4	3	7	100	2	BCSIR	9-Sep-2005
23	Md. Fazlur Bulbul	Bogra	Aguniatar	2	4	6	100	1	BCSIR	9-Sep-2005
24	Abdul Manan	Bogra	Malipara	4	6	10	100	3	BCSIR	9-Sep-2005
25	Md. Zibrail Hassan	Bogra	Helenchupara	10	7	17	100	3	BCSIR	9-Sep-2005
26	Md. Sahir Uddin	Bogra	Chakkatoli	2	3	5	100	3	BCSIR	10-Sep-2005
27	Masudur Rahaman	Bogra	Rabibariya	3	6	9	100	5	BCSIR	10-Sep-2005
28	Md. Abu Taleb	Bogra	Malgram	2	3	5	100	2	BCSIR	10-Sep-2005
29	S. M. Safiul Karim	Bogra	Mahipur	4	3	7	150	2	BCSIR	10-Sep-2005
30	Md. Au Kasim Sardar	Bogra	Sripur	2	4	6	100	2	BCSIR	10-Sep-2005
31	Md. Mazharul Islam	Bogra	Barokhira	1	3	4	250	7	BCSIR	10-Sep-2005
32	Hazi Md. Iad Ali	Gazipur	South Salna	5	4	9	100	3	LGED	12-Sep-2005
33	Md. Alam Akanda	Gazipur	Durbati	4	4	8	100	7	LGED	12-Sep-2005
34	Hussen Ahmed Siddiqi	Sylhet	Raynagar	0	0	0	150	2	BCSIR	15-Sep-2005
35	Jahangir Hussain	Sylhet	North Bhaluchaur	7	7	14	300	4	BCSIR	15-Sep-2005
36	Mustafa Kamal	Sylhet	Nayagaon	2	4	6	250	2	BCSIR	15-Sep-2005
37	Maulana Haris Uddin	Sylhet	Shampur	9	8	17	200	3	BCSIR	16-Sep-2005
38	Abul Minya	Sylhet	Dolaipara	4	4	8	100	2	BCSIR	16-Sep-2005
39	Md. Nazim Uddin	Sylhet	Nizpat Bazaar	4	3	7	100	8	BCSIR	16-Sep-2005
40	Babu Fani Day	Sylhet	Uzaninagar	6	4	10	100	4	LGED	16-Sep-2005
41	Md. Rubel Minya	Sylhet	Tamabil	4	6	10	150	3	BCSIR	16-Sep-2005
42	Md. Nazrul Islam	Sylhet	Naljuri	1	3	4	150	3	BCSIR	16-Sep-2005
43	Md. Abu Bakar	Sylhet	Biraimara	8	4	12	100	2	BCSIR	17-Sep-2005
44	Mufid Ahmad Master	Sylhet	Darbost	5	3	8	100	8	BCSIR	17-Sep-2005
45	Md. Moznur Rahaman	Jassore	Barandi	2	3	5	100	2	BCSIR	19-Sep-2005
46	Mustafa F.A. Chaudhary	Jassore	Loan Office Para	2	5	7	100	1	BCSIR	19-Sep-2005
47	Sushil Kumar Das	Jassore	Sarapole	2	4	6	120	2	BCSIR	19-Sep-2005
48	Md. Faruq	Jassore	Chandipur	5	2	7	100	1	BCSIR	19-Sep-2005
49	Md. Tazul Islam	Jassore	Bakra	7	5	12	100	1	BCSIR	19-Sep-2005
50	Md. Assad-uz-Zamal	Jassore	Teghoria	3	1	4	100	2	BCSIR	19-Sep-2005
51	Md. Shukat Ali	Jassore	Talbariya	3	3	6	100	2	BCSIR	20-Sep-2005
52	Md. Soharab Uddin	Jassore	Kamargana	5	8	13	300	7	LGED	20-Sep-2005
53	Milan Dafadar	Jassore	Bhagalpur	3	2	5	100	1	BCSIR	20-Sep-2005
54	Md. Abdul Mannan	Jassore	Jatrapur	3	9	12	200	5	BCSIR	20-Sep-2005
55	Dilip Singh Ray	Jassore	Paratan Kashba	3	2	5	200	5	BCSIR	20-Sep-2005
56	Abdl Khaled Khandukar	Borisal	Pangsha	2	3	5	100	2	BCSIR	23-Sep-2005
57	Md. Sikandar Ali Khan	Borisal	Gol Bathan	3	2	5	100	3	BCSIR	23-Sep-2005
58	Bijaya Krishna Day	Borisal	Pangsha	0	0	0	200	2	BCSIR	23-Sep-2005
59	Md. Habibur Rahaman	Borisal	Pratappur	5	4	9	125	7	BCSIR	23-Sep-2005
60	Md. Zia-Ul-Haq	Borisal	Khudrakathi	4	3	7	110	2	BCSIR	23-Sep-2005
61	Md. Riazul Haq Khan	Borisal	Pangsha	3	2	5	100	1	BCSIR	23-Sep-2005
62	Khandakar Saiful Huda	Borisal	Muslim Gorosan	3	2	5	100	2	BCSIR	24-Sep-2005
63	Md. Belal Hussain	Borisal	Sagardi	5	4	9	100	3	BCSIR	24-Sep-2005
64	Jaharul Haq Khan	Borisal	South Alekanda	5	3	8	100	5	BCSIR	24-Sep-2005
65	Asadur Rahaman	Borisal	North Sagardi	6	3	9	100	2	BCSIR	24-Sep-2005
66	Mohamad Hiron	Borisal	Rupatali	5	5	10	100	1	BCSIR	24-Sep-2005
67	Johara Khatun	Gazipur	Chapulia	3	1	4	250	5	LGED	29-Sep-2005
Plant surveyed but not included in Analysis										
20	Ashish Kumar Saha	Manikgunj	Shohorali	4	4	8	3 m^3	1 mon	GS	8-Sept-2005
68	Nuruddin Khan (Poultry Firm)	Gazipur	Dogri	20	-	20	2500 cft	7 yr	LGED	29-Sept-2005
69	Md. Nazrul Islam	Dhaka	Horindhara	8	6	14	5 m^3	5 mon	GS	6-Oct-2005
70	Md. Fazor Ali	Dhaka	Pandhoa	8	4	12	6 m^3	5 mon	GS	6-Oct-2005
71	Miah Abdul Mannan	Gazipur	Boropota	5	6	11	2 m^3	2 mon	GS	9-Oct-2005
72	Korshed Ali Mollah	Gazipur	Boropota	4	6	10	2 m^3	1 mon	GS	9-Oct-2005

Annex-2: 1st meeting on Household Biogas Project in Bangladesh held in IDCOL on September 3, 2005.

Agenda:

Discussion on questionnaire prepared for household survey on status of biogas plants in Bangladesh to receive comments and feedback from experts in the sector.

List of Participants:

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8. Prakash C. Ghimire
   Technical Consultant/RET Expert
   Development Partners-Nepal

9. Md. Jahidul Islam
   Investment Officer (Technical)
   Infrastructure Development Company Ltd.

10. Md. Zahidul Islam
    Investment Officer (Technical)
    Infrastructure Development Company Ltd.

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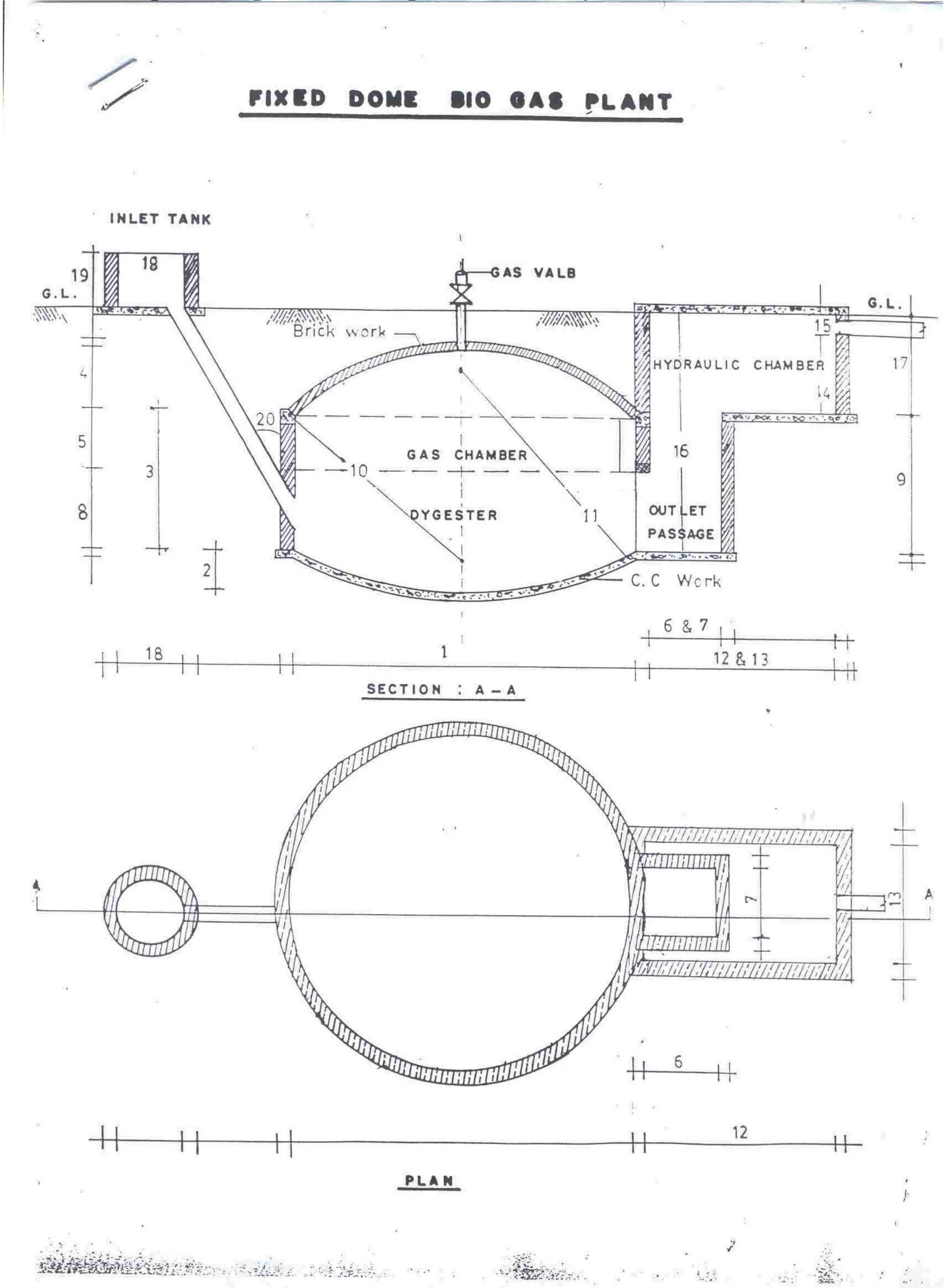
Annex-3: Designs of Biogas Plants being Disseminated by BCSIR and GS



Specification for 2 – 6 m3 Fixed Dome Biogas Plant

Hydraulic retention time= 40 days

Sl. No.	Item	Unit					
	Plant Size (Gas production)	m3	2	3	4	5	6
	Volume of Digester	m3	5	7	10	12	14
	Cow dung req./day	kg	50	75	100	125	150
Amount							
1	Diameter of Digester, D	ft	7’-3”	8’-2”	9’-2”	9’-10”	10’-6”
2	Depth of bottom dome, f2	inch	11	12	14	15	16
3	Total height of the digester wall, H	inch	36	39	45	48	54
4	Height of top dome, f1	inch	17	20	22	24	25
5	Height of gas chamber, h1	inch	12	12	13	14	15
6	Length of outlet passage	inch	D30	30	30	36	36
7	Width of outlet passage	inch	30	30	36	36	36
8	Door height of outlet passage	inch	24	27	32	34	39
9	Height of outlet passage	inch	36	39	45	48	54
10	Radius of top dome	inch	64	71	80	85	91
11	Radius of bottom dome	inch	91	105	117	127	134
12	Length of hydraulic chamber, L	inch	69	79	87	91	105
13	Width of hydraulic chamber, B	inch	42	48	54	60	60
14	Hydraulic chamber’s floor-base over flow	inch	21	24	26	28	29
15	Base over flow- top hydraulic	inch	6	6	6	6	6
16	Floor outlet passage- top hydraulic	inch	63	69	77	82	89
17	Hydraulic chamber’s floor-top hydraulic	inch	27	30	32	34	35
18	Diameter of inlet chamber	inch	24	24	30	30	30
19	Height of inlet chamber	inch	24	24	24	24	24
20	Inlet pipe	°C	30°	30°	30°	30°	30°

Annex-4: List of Participants to discuss on Draft Final Report of the Technical Study of Biogas Plants Installed in Bangladesh

Date: October 27, 2005.
Venue: IDCOL, UTC Building (16th Floor), 8 Panthapath, Kawranbazar, Dhaka-1215.

Sl. No.	Name	Organization	Designation	Contact
01	Abser Kamal	Grameen Shakti	G.M.	0171-567042
02	M. A. Gofran	Grameen Shakti	Biogas Consultant	011-146933
03	K. M. Nazmul Hoque	Grameen Shakti	Asstt. Eng.	0171-943846
04	Shamaresh Ch. Ghosh	LGED	Biogas Specialist	011-138603
05	Kazi Aktaruzzaman	BCSIR	Director	0171-405637
06	Mr. Sundar Bajgain	SNV	Consultant	
07	Md. Ruhul Quddus	-	-	0173049415
08	Christoph Isenmann	KFW	Director of Office	0175059839
09	Habibur Rahman	KFW	Local Expert	0173001317
10	Prakash C. Ghimire	SNV/IDCOL	Consultant	
11	Dr. M. Fouzul Kabir Khan	IDCOL	CEO	0173004388
12	S. M. Formanul Islam	IDCOL	Company Secretary	
13	Md. Jahidul Islam	IDCOL	I.O.	
14	Md. Zahidul Islam	IDCOL	I.O.	

Annex:5

SNV/IDCOL

Questionnaire for Household Survey on
Status of Biogas Plants in Bangladesh

Informed consent & cover page

Greetings! My name is ______________________________. I am here on behalf of the Netherlands Development Organization (SNV) which is conducting detailed feasibility of biogas plants in Bangladesh. In order to get more information about your biogas plant and its functioning, SNV is conducting a survey of households in the area. Your household has been selected by chance from all households in the area. I would like to ask you some questions related to the installation, operation, maintenance and other aspects of your biogas plants.

The information you provide will be useful to find out the status of biogas plants in your community, and will be used to plan future development programs on biogas in this area and also in the country.

Participation in the survey is voluntary, and you can choose not to take part.

All the information you give will be confidential. The information will be used to prepare general reports, but will not include any specific names. There will be no way to identify that you are the one who gave this information.

If you have any questions about the survey, you can ask me, my survey field supervisor who is here with the survey team. At this time do you have any questions about the survey?

Signature of interviewer	
Date:	
Respondent agreed to be interviewed	1. YES 2. NO

1. HOUSEHOLD IDENTIFICATION

This section is to be completed for each household visited.

101. Name of the Plant Owner	
102. District name	
103. Village Name	
104. Sample number	
105. Size of Plant (on basis of gas production)	
106. Installed by	BCSIR/ LGED/ GS
107. Date of Installation	Month | Year
108. Type of House	Kuchcha/ Semi Pucca/ Pucca
109. Electrified	Yes / No
110. Respondent's name	
111. Date of interview	**Day:** | **Month:** September | **Year:** 2005
112. Time interview commenced	
113. Time interview ended	

Interviewers — **Remember to obtain consent from each household. Write answers directly in the tables and mark the boxes on the right side of each form**

Field Supervisors — **Check ALL answers recorded in each section, ensuring gaps or missing answers are obtained BEFORE leaving the household. Mark tick in the right hand side for checked answers after correction and validation.**

Please complete this part of the form

	Interviewer	**Data entry personnel**
Name		
Date		

Record Number [ ]

2. HOUSEHOLD CHARACTERISTICS

Can you please tell me the names of all the members of your household who usually live here, sleep here and eat from the same kitchen, including yourself. Please include children, relatives or orphans, but do not count temporary visitors. First names are sufficient. This information is confidential and will not be shared with anyone. Names are only used in the interview and will not be related to data in the report. **Make a list of ALL names before asking other questions.**

After getting the full list of family members, continue with the other questions in the table for each person in the list.

201	**202**	**203**	**204**	**205**	**206**	**207**
Name of all the members	Gender	Age	Highest-level education completed?	Main Occupation 1.Agriculture 2.Small Business 3. Teaching 4.Govt Service 5. Other Services 6. Politics/Social Work 7. Student 8. Others (specify)	Secondary Occupation 1.Agriculture 2.Small Business 3. Teaching 4.Govt Service 5. Other Services 6. Politics/Social Work 7. Others (specify)	Approximate Income
Coding For Answers → Name ↓	1. Male 2. Female	For children < 5 years write the number of months	Write the number for the grade level passed. Put 0 = never 13=BA 14=MA 15=PhD			Monthly Income (Estimated) in Tk
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
Gross family income from individuals per YEAR(208)						
Income from other sources such as selling of agricultural productions per YEAR(209)						
Total expenditure in food, health, education etc. per YEAR (210)						
Net surplus/deficit per YEAR(211)						

Land Holdings

212	*213*	*214*
Arable Land (Ha/Acres)	**Non-arable Land (Ha/Acres)**	**Total Land Area (Ha/Acres)**

Agricultural Production

Agri. Production	**Production in Kg**	**Consumption in Kg**	**Saving/Deficit in Kg**	**Current market price (Taka) per Kg**
Paddy (215-218)				
Wheat (219-222)				
Potato (223-226)				
Oilseeds (227-230)				
Pulses (231-234)				
Vegetables (235-238)				
Fruits (239-242)				
Jute (243-246)				
Others (247-250)				

Livestock Ownership

Livestock	Numbers (current)						Numbers (before 3 years)
	Adult		Calf		Total		Total
	Stall-fed	Open-grazed	Stall-fed	Open-grazed	Stall-fed	Open-grazed	
Cow/Oxen (251-257)							
Buffalo (258-264)							
Goats (265-271)							
Pigs (272-278)							
Horse/Donkey (279-285)							
Poultry (286-287)							
Other (288-294)							
Total quantity of dung production (295)							

Have there any changes in family size after the installation of biogas plant? (296)

No Yes, increased Yes, decreased

Have there any changes in cattle size after the installation of biogas plant? (297)

No Yes, increased Yes, decreased

3. INSTALLATION AND FUNCTIONING OF BIOGAS PLANT

Supervisor's use only

How did you come to know about biogas plant?

☐ 1. Through publicity media
☐ 2. Through government officials — 301. ☐
☐ 3. Through service providers
☐ 4. Through NGO/CBO
☐ 5. Through community leaders
☐ 6. Through friends/relatives
☐ 7. Through other biogas owners
☐ 8. Other (specify)

Were there any criteria to select you to install biogas plants? Or Why were you selected to install biogas plants - not your neighbor?

☐ 1. You know the influential person from service provider
☐ 2. You had enough raw materials to construct a plant — 302. ☐
☐ 3. You fulfilled all the criteria set out by the service provider, if any
☐ 4. You are prestigious person in the community
☐ 5. You were well aware of the benefits from the biogas plant
☐ 6. Other (specify)

Who in your family took decision to install a biogas plant?

☐ 1.The head of household, male member
☐ 2. The head of household, female member — 303. ☐
☐ 3. Your son/daughter
☐ 4. After discussions in the family
☐ 5. Service provider
☐ 6. Other (specify)

What is the motivating reason(s) behind installing a biogas plant? (answers can be more than one)

☐ 1. Subsidy
☐ 2. Non-availability of other fuel sources — 304. ☐
☐ 3. Social benefits/Prestige
☐ 4. Health benefits
☐ 5. Environmental benefits
☐ 6. Economic benefits
☐ 7. Motivation from service provider
☐ 8. Motivation from existing plant owners
☐ 9. Compulsion from neighbors (in the case of poultry)
☐ 10. Saves time and energy
☐ 11. Other (specify)

What was the total cost of your biogas plants including subsidy and your contribution including loans, if any?

☐ 1. Less than Taka 10,000
☐ 2. Taka 10,000-12000 — 305. ☐
☐ 3. Taka 12000-15000

4. Taka 15,000-18000
5. Taka 18,000-20000
6. More than Taka 20,000
7. Do not know

What was the subsidy amount received from service providers?

1. Taka 5,000
2. Taka 7,500 — 306.
3. No subsidy
4. Do not know

How much cash contribution you made from your part?

1. Less than Taka 5,000
2. Taka 5,000 to 10,000 — 307.
3. Taka 10,000 to 20,000
4. More than Taka 20,000

Did you take loan to install biogas plants?

1. No — if no, go to 312 →
2. Yes, less than Taka 10,000
3. Yes, Taka 10,000 to 15,000 — 308.
4. Yes, Taka 15,000 to 20,000
5. More than Taka 20,000

If yes, from where you take loans?

1. Bank
2. Local Cooperatives
3. Local Money lenders — 309.
4. Friends and relatives
5. Grameen Shakti
6. Others

What is the interest rate?

1. Less than 10%
2. 10-15%
3. 15-20% — 310.
4. More than 20%
5. Do not know

Have you paid the loan?

1. No
2. Yes, partly — 311.
3. Yes, whole

If loan not taken why?

1. You are well off
2. You are against the philosophy of taking loans
3. Interest rate is too high — 312.

☐ 4. Processing for the loan is cumbersome
☐ 5. Loan was not available/bank is far
☐ 6. Taking loans degrade your social status
☐ 7. Collateral asked, which you could not fulfill
☐ 8. Other (specify)

Who constructed your biogas plant?
☐ 1. Unskilled Mason
☐ 2. Skilled Mason without knowledge on biogas plant
☐ 3. Skilled Mason with good knowledge on biogas plant 313. ☐
☐ 4. Do not know

Were any standards set by the service provider as regards the quality of construction materials and mason to construct biogas plants?
☐ 1. No
☐ 2. Yes
☐ 3. Do not know 314. ☐

If yes, what types of quality standards were set (answers can be more than one)?
☐ 1. Trained masons should be used
☐ 2. Standards on construction materials
☐ 3. Standards on pipe and appliances 315. ☐
☐ 4. Standards on plant design
☐ 5. Do not know

Is your biogas plant functioning?
☐ 1. No if no, go to 321 →
☐ 2. Yes, partly 316. ☐
☐ 3. Yes, fully

If yes, are you satisfied with the functioning of the plant?
☐ 1. No if no, go to 320 →
☐ 2. Yes, partly 317. ☐
☐ 3. Yes, fully

If partly satisfied, what are the reasons for not fully satisfying?
☐ 1. Less gas for cooking/lighting
☐ 2. Difficult to operate 318. ☐
☐ 3. Often encounter technical problems
☐ 4. More added work
☐ 5. Food cooked in gas is not tasty
☐ 6. Others (specify)

If fully satisfied, what are the reasons for fully satisfying? (answers can be more than one)
☐ 1. Enough gas for cook/lighting
☐ 2. Trouble free functioning of plant 319. ☐
☐ 3. Easy cooking/lighting

☐ 4. Economic benefit
☐ 4. Health benefits
☐ 5. Social benefits such as prestige
☐ 6. Environmental Benefits
☐ 4. Workload reduction
☐ 5. Food cooked in gas is more tasty
☐ 6. Others (specify)

If not satisfied, what are the reasons for not satisfying?

☐ 1. Plant has failed, it does not work at all
☐ 2. Very less gas for cooking/lighting
☐ 2. Very difficult to operate — 320. ☐
☐ 3. Often encounter technical problems
☐ 4. More added work
☐ 5. Food cooked in gas is not tasty
☐ 6. Others (specify)

If plant has failed, how long is the plant defunct?

☐ 1. Less than a month
☐ 2. 1 to 4 months
☐ 2. 4 to 12 months — 321. ☐
☐ 3. More than a year

If plant has failed, what are the reasons for such failure?

☐ 1. Poor workmanship during construction
☐ 2. Sub-standard quality of construction materials and appliances
☐ 3. Poor operation (over fed, under-feed, more water, less water)
☐ 4. Poor maintenance/ No maintenance service available — 322. ☐
☐ 5. Non-availability of spare parts
☐ 6. Natural/manmade disasters
☐ 7. Toilet attachment in plant was considered to be un-sacred
☐ 8. Slurry entered into the gas pipe
☐ 9. Water collected in pipe clogged it
☐ 10. Higher water table/flooding during rainy season
☐ 11. Others (specify)

What is the frequency of feeding the plant?

☐ 1. Daily
☐ 2. Once in two days
☐ 3. Once in three days — 323. ☐
☐ 4. Once in four days
☐ 5. Others (specify)

How much dung is feed at one feeding?

☐ 1. All available plus extra collected/purchased from outside
☐ 2. Whole quantity of dung available in the stable
☐ 3. 75-99% of the available dung — 324. ☐

4. 50% to 74% of the available dung
5. Less than 50% of the available dung

Do you feed other feeding materials besides dung?

1. No
2. Kitchen and household wastes
3. Human excreta — 325.
4. Poultry droppings
5. Agricultural wastes
6. Other (specify)

How much water is used to mix dung/poultry dropping?

1. More than the volume of dung/ poultry dropping
2. Equal to the volume of dung/ poultry dropping
3. Less than the volume of dung/ poultry dropping — 326.

Do you know how much dung is required to be feed into your plant daily?

1. No
2. Yes, -------- kg — 327.

Has anyone in your family received training on operation and maintenance of biogas plants?

1. No training received
2. Training not provided but leaflet/booklet/manual provided
3. One day orientation training provided by service provider — 328.
4. Short term O & M training (7days or less)
5. Long term O & M training (more than 7 days)
6. On the spot instructions from mason/company supervisors etc.
7. Others (specify)

Have you received any follow up services from the service provider?

1. No, not even when requested
2. No, not at all — 329.
3. Yes, on call
4.Yes, regularly

Is there any service center nearby?

1. No
2. Yes, very near (with in 5 km reach) — 330.
3. Yes, quite far (5-10 km reach)
4.Yes, very far (more than 10 km reach)

Is toilet attached to biogas plant?

1. No, we do not have toilet
2. We have toilet but not attached to biogas plant — 331.
3. Toilet is attached to biogas plant

If toilet attached to plant, who encouraged you to attach toilet to biogas plant?

1. Self
2. The service providers
3. Friends and relatives
4. Others (specify)

332.

Are there any social taboos in attaching toilets to biogas plants?

1. No
2. Gas from toilet attached plants are considered to be un-sacred
3. People are hesitant to handle the bio-slurry from toilet attached plants
4. Others (specify)

333.

How much Taka you need per year for operation and maintenance of your plant?

1. Less than Tk.100
2. Tk.100 - 300
3. Tk.400 - 600
4. Tk. 700-1000
5. More than Tk. 1000

334.

For those whose biogas plant is not working,

Will you like to adapt the technology again with some modifications?

1. No
2. Yes

335.

4. SAVING OF CONVENTIONAL FUEL SOURCES

401 For what purpose is biogas used?

1. Cooking only
2. Lighting only
3. Cooking and lighting both
4. Other (specify)

401.

402 How many stoves/gas lamps do you have installed?

1. 1/2/3/4 stoves (… single burner, …… double burners)
2. 1/2/3/4 gas lamps

402. a-h

403 How long the stove is burnt in a day (calculate the timing of al the stoves)?

Stove
1. …….am to …….am (…..Hrs in the morning)
2. …… pm to ……pm (…..Hrs in the afternoon)
3. …… pm to ……pm (…..Hrs in the evening)

Lamp
1. …….am to …….am (…..Hrs in the morning)
2. …… pm to ……pm (…..Hrs in the afternoon)
3. …… pm to ……pm (…..Hrs in the evening)

403 a-r.

404 Is gas enough for cooking and/or lighting?

1. Not enough
2. Enough for cooking and/or lighting
3. Enough for cooking but not enough for lighting 404.
4. Enough for lighting but not enough for cooking

405 How much gas do you need for cooking and/or lighting?

Stove
1. …….am to …….am (…..Hrs in the morning)
2. …… pm to ……pm (…..Hrs in the afternoon)
3. …… pm to ……pm (…..Hrs in the evening)

Lamp
1. …….am to …….am (…..Hrs in the morning)
2. …… pm to ……pm (…..Hrs in the afternoon) 405 a-r
3. …… pm to ……pm (…..Hrs in the evening)

406 If gas is not enough, what is the reason(s)?
1. Small plant size
2. Under-fed plants
3. Over-fed plants 406.
4. Plants not regularly fed
5. Less gas production due to defective construction
6. Less gas due to defective operation and maintenance
7. Others (specify)
8. Do not know

407 How much fuel was required for cooking **BEFORE** the installation of biogas plant per month?
1. Fuel wood ------- kg @ Tk ………. per Kg
2. Kerosene --------- litre @ Tk……… per litre
3. LPG ---------- cylinder @ Tk ………. per cylinder 407 a-n.
4. Electricity -------- unit @ Tk ……….. per unit
5. Died dung --------- Kg @ Tk ……… per Kg
6. Agricultural wastes --------- Kg @ Tk…….. per Kg
7. Others (specify) …………….

408 How much fuel is required for cooking **AFTER** the installation of biogas plant per month?
1. Fuel wood ------- kg @ Tk ………. per Kg
2. Kerosene --------- litre @ Tk……… per litre
3. LPG ---------- cylinder @ Tk ………. per cylinder 408 a-n.
4. Electricity -------- unit @ Tk ……….. per unit
5. Dried dung --------- Kg @ Tk ……… per Kg
6. Agricultural wastes --------- Kg @ Tk…….. per Kg
7. Others (specify) …………….

409 How much fuel was required for lighting **BEFORE** the installation of biogas plant per month?
1. Kerosene --------- litre @ Tk……… per litre
2. Electricity -------- unit @ Tk ……….. per unit 409. a-h
3. Candle …… nos. @ Tk ……… per no.
7. Others (specify) …………….

410 How much fuel is required for lighting **AFTER** the installation of biogas plant per month? 410. a-h

- 1. Kerosene --------- litre @ Tk……… per litre
- 2. Electricity -------- unit @ Tk ……….. per unit
- 3. Candle …… nos. @ Tk ……… per no.
- 7. Others (specify) …………….

411 Do you buy fuel wood, dried dung or agricultural wastes or collect it from Jungle/source?

- 1. Buy fuel wood @ Tk……….. kg, dried dung @ Tk……….. kg and agricultural wastes @ Tk……….. kg from vendors
- 2. Collect from jungle/own land/other sources
- 3. Both 1 and 2

411.

412 How much fuel wood can you collected from Jungle/source in one day?

- 1. less than 25 kg
- 2. 25-35 kg
- 3. 35-50 kg
- 4. 50-75 kg
- 5. More than 75 kg

412.

413 What id the average time required to transport kerosene from market to the house?

- 1. Less than 0.5 hrs
- 2. 0.5 to 1 hr
- 3. 1-2 hr
- 4. 2-4 hrs
- 5. 4-7 hrs
- 6. More than 7 hrs

413.

414 Do you feel that your expenditure in fuel collection has gone down because of the biogas plant?

- 1. No, not at all
- 2. Yes, to some extent
- 3. Yes, significantly
- 4. It has gone up
- 5. Do not know

414.

415 Have you experienced any advantages of biogas over the other conventional fuel sources?

- 1. No
- 2. Less costly
- 3. Comfortable and easy to operate
- 4. Environment friendly
- 5. More advanced and energy efficient
- 6. Others (specify)

415.

416 Have you experienced any time saving after the installation of biogas plant?

- 1. No; time is not saved
- 2. Cooking, -------- hrs saved per day
- 3. Collection of water, -------- hrs added

416

☐ a-h. ☐
☐ 4. Mixing of dung and water, --------------hrs added
☐ 5. Collection of fuels, ------------- hrs saved
☐ 6. Cleaning of cooking utensils, ------------ saved
☐ 7. Caring of cattle, -------- hrs saved/added
☐ 8. Other (specify), -------- hrs saved/added

5. USE OF SLURRY

501 Do you use biogas slurry on farm
☐ 1. No
☐ 2. Yes, if yes, go to 504 → 501. ☐

502 If no, what do you do to the slurry?
☐ 1. Sale to others
☐ 2. Give out to others 502. ☐
☐ 3. Make dung cakes to burn
☐ 4. Drain to water courses or drains
☐ 5. Others (specify)

503 Why do not you use slurry?
☐ 1. It has lesser nutrient value
☐ 2. It is difficult to use 503. ☐
☐ 3. People are reluctant to use the slurry from latrine attached plants
☐ 4. No land to use
☐ 4. Others (specify)

504 If yes, what do you do to the slurry?
☐ 1. Use as organic fertilizer without composting
☐ 2. Use as organic fertilizer after composting 504. ☐
☐ 3. Use as fish feed
☐ 5. Use slurry through irrigation canal directly
☐ 6. Others (specify)

505 How much chemical fertilizer (all N,P,K) you used to use before the installation of plant?
☐ 1. Never use chemical fertilizers
☐ 2. Less than 10kg per year 505. ☐
☐ 3. 10-25 kg per year
☐ 4. 25 to 50 kg per year
☐ 5. More than 50 kgs per year
☐ 6. Do not know

506 Have you experienced any saving in chemical fertilizer after the use of bio-slurry?
☐ 1. No
☐ 2. Less than 10kg per year (Tk ……… per kg) 506. ☐
☐ 3. 10-25 kg per year

4. 25 to 50 kg per year
5. More than 50 kgs per year
6. Do not know

Finally,

507 Do you advice others to install biogas plants?

1. No
2. Yes — 507. [ ]

508 Would you have installed biogas plant if subsidy was not provided?

1. No
2. Yes — 508 [ ]

509 What is your opinion on the cost of installation of your biogas plant?

1. It is cheap
2. It is reasonable — 509 [ ]
3. It is quite expensive
4. It is very expensive

510 What are the three major benefits of biogas plants?

1.
2. — 510 a-c. [ ]
3.

511 What are the three major disadvantages of biogas plants?

1.
2. — 511 a-c. [ ]
3.

512 Do you have any suggestions for future biogas program?

1.
2. — 512 a-c [ ]
3.

6. OBSERVATION CHECKLIST

Component	Observation (a,b,c)			Quality of Workmanship (d,e,f)	Quality of Construction materials (g,h,i)	Any maintenance done? (j,k)	Who did the maintenance? (l, m, n)	What was the cost for maintenance (o)	Remarks (p,q)
Location of Plant (601)	Sunny	Partly sunny	Shadow						
Distance of plant from Kitchen (602)	Less than 10 m	10-20 m	More than 20 m						
Condition of the surrounding of plants (603)	Well maintained	Fair	Poor						
Distance of plant from water sources (604)	Less than 10 m	10-20 m	More than 20 m						
Condition of cattle shed/ poultry firm (605)	Distance Less than 10 m from Plant	Distance 10-20 m from Plant	Distance more than 20 m from plant	Good/fair/poor	Good/fair/poor				
Condition of plant as a whole (606)	Good	Defective but working	Not working at all	Good/fair/poor	Good/fair/poor	Yes/No			
Condition of inlet and mixer (607)	Good	Defective but working	Not working at all	Good/fair/poor	Good/fair/poor	Yes/No			
Condition of digester and dome (608)	Good	Defective but working	Not working at all	Good/fair/poor	Good/fair/poor	Yes/No			

Condition of outlet/displacement chamber (609)	Good	Defective but working	Not working at all	Good/fair/poor	Good/fair/poor	Yes/No			
Condition of water trap (610)	Good	Defective but working	Not working at all	Good/fair/poor	Good/fair/poor	Yes/No			
Condition of gas-pipeline (611)	Good	Defective but working	Not working at all	Good/fair/poor	Good/fair/poor	Yes/No			
Condition of main-gas valve (612)	Good	Defective but working	Not working at all	Good/fair/poor	Good/fair/poor	Yes/No			
Condition of Gas Tap (613)	Good	Defective but working	Not working at all	Good/fair/poor	Good/fair/poor	Yes/No			
Condition of gas-lamp (Hajak) (614)	Good	Defective but working	Not working at all	Good/fair/poor	Good/fair/poor	Yes/No			
Condition of Stove (615) Type of stove (616)	Good Single burner	Defective but working Double burner	Not working at all Multiple burner	Good/fair/poor	Good/fair/poor	Yes/No			
Cleanliness of kitchen (617)	Clean	Fair	Poor						
Condition of Slurry pits (s)… nos (618)	Well maintained	Fair	Poor (no pit)						

7. HOUSEHOLD NOT HAVING BIOGAS PLANTS

701. Are you aware of the biogas technology?

- ☐ 1. Yes
- ☐ 2. No
- ☐ 3. Partly

701 ☐

702. If yes, how did you know about this technology?

- ☐ 1. Through publicity media
- ☐ 2. Through government officials
- ☐ 3. Through service providers
- ☐ 4. Through friends/relatives
- ☐ 5. Through other biogas owners
- ☐ 6. Through NGO/CBO
- ☐ 6. Other (specify)

702 ☐

703. What are the reasons for not installing a biogas plant?

- ☐ 1. Do not know about the technology
- ☐ 2. No trust in the technology
- ☐ 3. Family members/community do not like it
- ☐ 4. High investment cost
- ☐ 5. Not enough livestock/feeding materials
- ☐ 6. Others (specify)

703 ☐

704. What are the three main advantages of biogas plants?

- ☐ 1.
- ☐ 2.
- ☐ 3.

704 ☐

705. What are three main disadvantages of biogas plants?

- ☐ 1.
- ☐ 2.
- ☐ 3.

705 ☐

706. Would you like to adopt the biogas technology?

- ☐ 1. No
- ☐ 2. Yes
- ☐ 3. Can not say now

706 ☐

707. If yes, why?

- ☐ 1.
- ☐ 2.
- ☐ 3.

707 ☐

708. If no, why?

- ☐ 1.
- ☐ 2.
- ☐ 3.

708 ☐

709. What incentives would you expect from government to install biogas plant?

- ☐ 1.
- ☐ 2.
- ☐ 3.

709 ☐