Biogas Energy- An Alternative Solutions for Sustainable Energy in Rural Areas of Bangladesh

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Abstract

A study was conducted to assess the possibilities of introducing biogas technology at rural household level in Bangladesh. At the same time the present energy scenario of Bangladesh was highlighted in order to see the comparative picture of present energy situation in rural areas and urban areas. Biomass fuels constitute the major energy sources for rural people. A major share of the fuel is consumed for cooking and enormous amount of labour is spent on fuel wood gathering and collecting fuel woods that reduce the productive time of women. Most of biomass comes from crop residues. Tremendous pressure on rural forest for fuel wood is increasing day by day. As a result, there is over cutting of rural forest results in environmental degradation. The health implication of women and child isn’t available for the use of biomass, wood, dung as fuel etc. Under present conditions, biogas is not economically viable for the poor people. Biogas itself would not be economically appropriate energy source for the rural people but it could be economically viable if integrated farming system will be practised. The necessary training and capital is needed for women to increase their household income.
CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

The energy sector in rural areas of Bangladesh is mainly subsistence, which means that people have less access to their household energy. Energy sources are still unmechanised and energy efficiency is very low. The supply of traditional renewable energy sources such as fuelwood, crop residues and animal dung is becoming difficult to obtain while demand is increasing rapidly. Most rural people rely on biomass as their main source of energy. About 63% of the total energy requirements are met by biomass whereas only 37% are used for commercial fuel (Bangladesh Bureau of Statistics, 93). Biomass is a traditional and low-density energy carrier with varied and low conservation efficiencies because it is used, as it’s primary form. As a result, people have less access to household energy for their household appliances that could ensure a life of comfort for the rural dwellers. Household energy requirements are restricted to cooking, lighting, moving fans and some entertainment as powering of radio or TV set.

Biomass is cheap but extensive and unplanned consumption pattern of biomass fuels led the consumption beyond regenerative limits with serious environmental consequences (Islam, 1990). Continuous use of leaves, twigs, agricultural and animal residues as fuel deprive the soil from valuable nutrients and causes soil erosion, especially in the coastal region of Bangladesh (Islam, 1993).

The whole picture could be clear through the mental concept given below.

Figure 1: Problems associated with household energy in Rural Bangladesh

The country has one of the highest population densities in the world i.e. 745 persons/square km with a growth rate of 2.2% per annum (Bangladesh Bureau of Statistics, 1992). The combination of high population and the growing needs for energy pays a great stress on available biomass resources. Moreover, low per capita income and slow economic growth are the tow major
constraints to shifting modern energy in the near future. The country, therefore, is heavily expected to depend on biomass resources for several decades to come. This over dependence on biomass causes numerous environmental problems like over cutting of forests, desertification, cyclone, soil erosion, loss of soil productivity etc. All of these hazards have negative impact on rural population. Every year, remarkable numbers of people are died by storm, cyclone that is the contribution of deforestation or desertification. The rural-urban migration rate is quite high due to these natural calamities and sometime people have to shift their occupation. Using biomass, wood or dung as fuel also affects women and child so badly in two ways. Firstly, it ruins their socio-economic life because women spend a lot of time for collecting fuels for cooking and low efficiency of these fuels takes too much time to cook food. Their children often give them company instead of going school. In one sense they lose their productive time when they can do some economic activities and other sense it makes difficult for their children to have sound education, which is one of the reasons for the low literacy rate in rural areas of Bangladesh. Secondly, biomass or other traditional energy sources creates smoke, dust that causes eye-irritation and other health problems as they inhale smoke while cooking with these stuffs. Though this is not considered in this model.

All of these problems contribute a lot to keep people at poverty level and that is why they pay a little attention about their socio-economic status. As a result, their social awareness about birth control, child mortality rate, child care, health care, living standard, hygiene, sanitation, environment etc is still absent. As a consequence, the population growth rate is quite higher than urban areas. This seems one kind of loop though there are so many reasons behind these problems and by providing them a solution deal with sustainable energy would be an effective way to resolve these problems.

An alternative efficient form of energy source that would be sustainable, as a whole is necessary for the rural people. One of the potential new sources of energy, which could provide household energy requirements for rural people, is biogas. Biogas system is an efficient way of dealing with organic wastes, dung and crop residues while making optimal use of their energetic as well as nutrient content. It is a clean source of energy. Biogas technology treats agricultural and animal wastes, in a sanitary manner that produces biogas, as a convenient source of energy in a decentralised way.
Faced with growing population and therefore diminishing agricultural land and forests, the fuel wood supply in both rural and urban areas is going to be very limited. Biogas production, therefore, can be considered as a part of integrated farming system where the effluent from digester can be used as fertiliser or fodder\(^1\). Thus this new system can provide fuel, fertiliser, food, and feed and solve problems of food, nutrition and rural development as well. Bangladesh, having a strong agricultural background, may be well suited for biogas production as an alternative sustainable energy source. In agricultural areas where organic feed stock is available, biogas production would appear to offer great potential.

**1.2 Objectives of the study**

These are the objectives that have guided the paper.

1. To find out the present sources of energy of rural areas in Bangladesh in relation with National energy sources.
2. To establish the possibilities of introducing biogas technology for rural household energy.

**1.3 Scope of the study**

The main area of this study is the rural area of Bangladesh where people are deprived from any kind of conventional energy supply. The poor people are the target group obviously. An alternative way for supplying energy for rural household in a sustainable manner is assessed here. A provision for providing only household energy in rural areas has been made throughout this paper and at the same time it has been examined the possibility of using family size digester and community size digester at socio-economic point of view. In case of raw materials, using human excreta is not included here because most of the houses have no sanitary latrine or even pit latrine and the collection of wastes would be a problem in this case. Also the acceptance of human feces as energy source for preparing food and the use of human excrements as fertiliser need special attention for dissemination of information. Water is an important element for biogas digester and in this study an attempt has been made to use grey water for this purpose, which will minimise the use of fresh water. In this way, misuse of fresh water and reuse of water have been focused.

\(^1\) As nutrient source for growing algae
Increasing the efficiency of fuelwood utilisation can increase through aforestation program or the supply of fuelwood. But this could help them little to cope with their shortage of fuelwood. First of all it will take time to let the trees grow enough to collect twigs and leaves, it will create smoke in kitchen, and the most important thing is it will occupy agricultural land. Due to rapid population growth, the demand for land for food production is increasing day by day. An investigation would be needed to find out what types of trees is suitable for this climate and which will fulfil the needs like commercial, social, recreational, fodder, fuel, etc. That is why, aforestation program is excluded in this study as an alternative source of energy supply.

Technical aspects of biogas production are not explained here in detail. Social and cultural aspects are more important for the acceptance of biogas for rural people rather than the technical side. Therefore, community participation has been taken as an important ingredient of dissemination of information and growing awareness among people about health, education, women empowerment, environment etc. Biogas is not economically viable for the poorer strata of the rural populations who need it badly. But in Bangladesh, the Government has already taken initiatives to promote biogas energy at household level. At the same time some NGO’s (Non Governmental Organisations) and LGED (Local Government Engineering Department), and other organisations have been operating a number of biogas plants both at household level and community level, getting fuel and fertiliser. Thus, there is a hope for rural people that biogas promotion will not be a serious problem in Bangladesh.

1.4 Methodology

The existing energy situation of Bangladesh has been discussed here with the possibilities of other alternative energy sources. The reason why other sources of energy have been discussed here is that these energy sources could be viable sources of energy in near future along with biomass. Even in some areas where the implementation of biogas technology is impossible, solar/water/wind power may take place. The full paper is basically prepared with secondary data from books, journals, reports, thesis and internet. The study would be benefited from field data with household survey to know the opinion of the people who are going to use this technique. This was, however not possible in this case. In this paper, both family size and community size plants has been discussed with relative possibilities and constraints. No specific decision has been made here, about
which design (Indian, Chinese) or types of digesters that are suitable for rural people since specific data would be required. In case of cost-benefit analysis, it is difficult to obtain a real picture without actual data. No cost benefit analysis of the biogas project has been done and the shortcomings and weak points of cost benefit analysis, which has been done before in other study are discussed. Some solutions are discussed to get rid of the problems associated with biogas project and it has been shown that the project would be viable economically, socially and environmentally at both macro and micro level. In this regard a cost benefit analysis from a previous study has been followed here as an example (Biswas & Lucas, 1996). The real energy scenario of rural Bangladesh and the problems associated with traditional sources of fuel has been discussed with a causal loop diagram (CLD). The use of human excreta is not included in this study as in rural areas maximum household has no sanitary latrine that will be a problem in case of transportation.

1.5 Limitations of the Study

The main problem of this study is that only secondary information has been used here, where relevant household survey and primary data could be more useful for this study. But due to economic reasons, a field survey could not be conducted.

Another limitation is the availability of relevant data, (where as, it is very difficult to come by from secondary sources) and this is a major constraint of this study. So, in some cases, analysis has to rely on data and statistics from other developing countries. This is because most of the developing countries and the data for population growth and increasing demand for energy don’t vary considerably.

CHAPTER TWO: THE STUDY AREA

Rural area has been considered as the study area of this paper. Agriculture employs approximately 70% of each village and this varies from village to village. Homogeneity is the most unique characteristics of villages. People practices agriculture, which is mainly labor intensive and based animal drought power.

The literacy rate in rural areas, is still very low, birth rate is relatively higher then the urban areas. There is a big gap between urban and rural areas in terms of utility services, facilities, education and health facilities, living standard, occupational pattern etc.
Generally people live houses made of mud, straw, wood, bamboo, tin etc. maximum houses have not any proper sanitation system or waste disposal system. People pay very few attentions to their kitchen, as it is the most neglecting part of house. Sometimes they use kitchen as animal shed at night. In rural areas, people have very less opportunity or options to earn enough, as they don’t have diversification of work. Lacks of proper infrastructure, marketing facilities, labor market, education etc prevent them of from doing various types of work. Women are usually habituated to stay in home, take care of family, children and household activities. But they don’t know, simple technical devices can change their live more easier and comfortable. They are spending maximum time a day doing their household activities as the disguised unemployment. But they may utilise these times, if they will get training, small credit and technical support to reduce their working load. Children are the deprive part of rural society. They have been getting very little attention from their childhood and they have to give support in field for farming and also to collect fuel wood, rather than go to school. This is the reason, why the illiteracy rate in rural areas is still high. Division of labor is quite high there, where as people expect son rather then daughter.

Bangladesh enjoys tropical climate and as for tropical climate it has very fertile land and also water availability. And this is one of the main reasons, why people of rural area basically choose agriculture as the basic occupation. Biomass fuels constitute the major energy sources for rural people, but rapid population growth created tremendous pressure on rural forests for fuel wood. As a result, deforestation and environmental degradation have taken place in rural environment. In order to get rid of this problem an efficient and alternative source of energy is needed that can address the problems of household energy, waste management, sanitation, drop out of children from school, better way of living for women etc.

CHAPTER THREE: PRESENT ENERGY SITUATION OF BANGLADESH

3.1 The National Energy Situation

The energy sector of Bangladesh has been suffering for years like the rest of the economy. The main problem lies on the high cost of imported coal, gas and liquid fuel
Along with this problem, shortage of electric capacity for medium and long-term development and low efficiency for using fuelwood and other types of fuels are also responsible. Weak, fragmented and poorly co-ordinated institutional structure is considered as a prime obstacle in the development of the energy sector.

However, the Government has made efforts to improve the co-ordination in the energy sector. A fully-fledged ministry of Energy and Mineral Resources has been created to deal with all matters within this sector. Special attention has been given on natural gas to make sure its fair distribution within the country and abroad with good value.

Bangladesh has small reserves of oil and coal, but very large natural gas resources. Commercial energy consumption is around 69% of gas, with the remainder almost entirely oil (and limited amounts of hydropower and coal). Only around 18% of the population (mainly in urban areas) have access to electricity, and per capita commercial energy consumption is almost the lowest in the world. (Drillbits and Trailings, May 16, 2000, vol-5). The fuel consumption of per capita per year is only 57-kg oil equivalent. (Hoque, 1989) The supply of electricity by Bangladesh Power Development Board (BPDB) is mainly confined to cities and towns. According to the recent statistics, 64.8% of the fuel is used for domestic purposes, 19.5% for small industrial purposes and 8.6% for non-energy use (Hoque, 1989).

### 3.1.1 Commercial Energy

The first gas extraction in this country began in 1955 (Bangladesh Bureau of Statistics, 1992). According to the oil and Gas Journal, Bangladesh has currently estimated the proven natural gas reserves (of ground) to 11 trillion cubic feet (Tcf) in approximately 20 fields (mainly onshore) (Drillbits and Trailings, May 16, 2000, vol-5). At present, Bangladesh, has to spend the major portion of it's export earnings for importing about 1.078 million tons of crude oil with a value of US $ 203 million (1990-91) (World Bank Report, 1992). The electric generation capacity was 3.3 giga watts in 1998 (with only around 2.4 giga watts considered available) (Drillbits and Trailings, May 16, 2000, vol-5).

Some coal deposits have been discovered in the western part of Bangladesh, but international assistance is needed to exploit these resources.
3.1.2 Traditional Energy

Traditional energy plays a vital role in the energy sector in Bangladesh e.g. muscle-power: both animal and human, used for traditional ploughing and other related work in agriculture, irrigation, road and water transportation, biomass fuels: tree biomass, agricultural residues and animal waste are used for domestic cooking and small rural industries.

In the rural areas, about 93% of the total fuel energy is used for domestic cooking and 7% for lighting (World Bank Report, 1992). Of this fuel, 7.8% comes from animal residue, 27.8% agricultural residue and 65.2% from tree biomass. Tree biomass is one of the main sources of energy for rural domestic cooking whereas kerosene is used for lighting as well as cooking.

Bangladesh Energy Planning Project (BEPP) conducted a survey to account for rural energy consumption in 1995. The data indicate that around 88% of the rural energy comes from local traditional biomass, of which 71% are used for domestic cooking. Commercial fuels (e.g. diesel, electricity and fertiliser) are 9.8% of the total energy and are used for increasing agricultural production. Kerosene used for lighting is only 2.2% of the total rural energy.

3.1.3 Alternative Energy

Solar energy

Solar heat has been used in Bangladesh for years in various activities like drying of clothes, food-grains, fish, vegetables, raw jute, etc, and evaporation of saline water to produce salt. In rural areas, various activities are performed by solar heat and completely depend on it. By using some simple devices, these activities could be performed quickly and efficiently, which would increase the productivity without any share from the commercial energy sector.

Biogas

In 1972, the first biogas plant was installed in Bangladesh at Bangladesh Agricultural University (Eusuf, 1997). Research on low cost and efficient biogas plants has been undertaken since then at various institutions.
Low head-hydropower
In Bangladesh, the potentiality of low head hydropower has been assessed in recent years. Twenty-three hydropower plants with capacities ranging from 10Kw to 5Mw have been located in the flat plains and this capacity is available, during June to October (Bangladesh Energy Planning Project, 1985).

Tidal energy
In 1984, an attempt was made by Bangladesh University of Engineering and Technology (BUET) to assess the possibilities of tidal energy in the coastal region of Bangladesh, especially at Cox’s Bazar and at the islands of Moheshkhali and Kutubdia (Hoque, 1989). They found that there are a number of places at Cox’s Bazar, Moheshkhali and Kutubdia and also other places where a permanent basin with pumping arrangement might be constructed (BPDB, 1992).

Wave Energy
Wave power could be a significant alternative source of energy in Bangladesh with favourable wave conditions, especially during the period beginning from late March to early October (Hoque, 1989). Waves are generally prominent and show a distinct relation with the wind. But unfortunately no attempt has been made by Government or any Non-Government Organisation to assess the prospects for harnessing energy from sea wave in the Bay of Bengal.

The gas sector of Bangladesh is the only commercial energy supplier that could meet the demands of new consumers until 2010 and provide sufficient supplies to meet the total requirements for the next 60 years (Iman, 1992). But up to now gas is still costly and the poorer section has no access to it.

Natural Gas
The rural and remote parts in Bangladesh where about 65% people live, is characterised by poor land-man ratio, disguised unemployment, landless farmers, low living standards, poverty and deprivation in general. In order to meet the demand of energy greater energy efficiency and larger energy supply are necessary. Thus it is necessary to tap all sources of energy and their fair distribution at cheapest prices in either natural or converted form.
to the people. In this respect, the above sources of energy need further research and at the same time others renewable sectors like wind energy, river current etc, need proper attention. All of these energy sources can meet the demand of rural people with cheap price and will save imported fuel cost.

### 3.1.4 Rural Energy Situation

In the rural energy sector, biomass has taken a major place for a long time because people had access to wood as a free commodity. Wood is acquiring a monetary value in rural areas as its scarcity (Singoro, 1988). As a consequence, people start to depend on biomass fuel for cooking purpose. But due to rapid increase of rural population and increasing demand of fuelwood, a severe shortage of fuelwood has been noticed in a number of places. The long time involvement of both women and children in fuel collection is a sign of increasing fuel supply shortages. Even in some areas the eating pattern has changed and people have only two meal a day instead of three. (Rahman, 1998) This causes negative health effect on people, especially the children are suffering a lot. Sign of under-nourishment are observed among them despite of available food. (Rahman, 1998)

A representation of the rural energy system is shown in figure 2.

**Figure 2: Present Rural Energy Uses in Agricultural and Household Sector**
CHAPTER FOUR: BIOGAS PRODUCTION

4.1 What is biogas?

Biogas is produced by bacteria in the bio-degradation process of organic materials under anaerobic (without air) conditions. Methanogens (methane producing bacteria) are the last in a chain of microorganisms, which degrade organic material and return the decomposition matters to the environment. In this process biogas is generated, a source of renewable energy (Rehm & Reed, 1986).

Any waste or residue, as a matter of fact almost any organic matter, whether a slurry or a wastewater, left by itself under biologically open (septic) conditions, will undergo spontaneous biological degradation either aerobically or anaerobically.

The breakdown of organic material by anaerobic bacteria to produce methane is a naturally occurring process. This process constitutes one of the primary mechanisms of decay in the nature and also performs an important role in the digestive systems of nutrient animals. Referred to as anaerobic digestion, the process was first harnessed for waste treatment purposes. Current interest, however, has shifted towards its potential application as a means of deriving energy from biomass materials, particularly those with a high moisture contents (Rehm & Reed, 1986). Using various substrates, the mechanism of bio-methanation system has been shown in figure 3.

Figure 3: General outline of anaerobic bio-methanation system
4.2 Composition of the Organic Substrate

Any organic waste, which is biodegradable, can be digested. As organic matter is biodegraded by bacteria, a portion of the materials is converted methane and carbon dioxide, while part of the material is converted into bacterial cells (Ward, 1984).

Anaerobic digesters can use a number of materials as substrate. These include dung, poultry dropping, human wastes, crop residues, food processing and other wastes including kitchen wastes, or mixture of one or more of the residues and wastes. Manures have been using as a feedstock for a long time for its availability. Also it has good nutrient balances, is easily slurried and is relatively biodegradable (Ward, 1984). It is noticeable that fresh manure is more degradable than dried one. A dairy cow that weighs about 450 kg will produce about 39 kg of manure and urine per day contains about 4.8 kg of dry organic solids (Ward, 1984). Estimated manure and gas production rate from different animals has shown in table 4.1.

Table 4.1: Estimated manure and gas production rate (Based on 450kg live-weight)

<table>
<thead>
<tr>
<th>Source: Ward, 1984</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values may vary due to differences in feed ratio and management practices.</td>
</tr>
<tr>
<td>*- Based on theoretical gas production rate of 831 L/kg of volatile solids (VS) destroyed and assumes the CH₄: CO₂ ratio is 60:40 (Jewel, 1981).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Dairy Cattle</th>
<th>Beef Cattle</th>
<th>Pig</th>
<th>Chicken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure Production (kg/day)</td>
<td>39</td>
<td>26</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Total Solids(kg/day)</td>
<td>4.8</td>
<td>3.4</td>
<td>3.3</td>
<td>7.9</td>
</tr>
<tr>
<td>Volatile solids(kg/day)</td>
<td>3.9</td>
<td>2.7</td>
<td>2.7</td>
<td>5.8</td>
</tr>
<tr>
<td>Dig. Efficiency</td>
<td>35</td>
<td>50</td>
<td>55</td>
<td>65</td>
</tr>
<tr>
<td>Gas Production 1/kg VS*</td>
<td>219</td>
<td>325</td>
<td>381</td>
<td>490</td>
</tr>
<tr>
<td>Liter/450 kg animal per day</td>
<td>860</td>
<td>870</td>
<td>1020</td>
<td>2860</td>
</tr>
</tbody>
</table>

Poultry dropping are much more concentrated than cattle or pig dung. It contains about 25% to 35% solids. For chicken with 1000kg of live weight (Jewel, 1976) estimated the methane gas production to be 2.3 cubic meter (Ward, 1984). It is better to dilute or mix with other wastes for poultry dropping.

There are some factors that need considerations if any one want to use manure as feedstock.

a) Number of animals (poultry) and their weight.
b) Under what conditions are the animals kept?
c) If they are confined then what types of pans are used and how and when is the manure collected?
d) What quantities of manure are collected?
e) If it is sold after conversion, what will be the price?
f) What are the transportation costs of the manure from the production place to the conversion facility?

Agricultural residues have been used for feedstock for biogas production also but usually they are mixed with manure. The most desirable materials are the high moisture herbaceous materials for a completely mixed system (Ward, 1984). There are other specific materials that have been used for substrate like water hyacinths, algae, corn, rice and wheat straw.

Though there is an argument against the use of crop residues because they are also used as animal feeds and fuel. In some countries, animals (Cows, Buffalos, goats) are kept on crop residues and then these are fed for digester. These materials are stable but produce less gas and leave more solids in the effluent (Ward, 1984). Gas production rate (Methane) varies from animal to animal feedstock has been shown in table 4.2.

Table 4.2: Typical gas yields from different feedstock:

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Gas yield (cm/ton of organic matter fed)</th>
<th>Gas Composition (%Methane)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow dung</td>
<td>90-300</td>
<td>65</td>
</tr>
<tr>
<td>Chicken manure</td>
<td>300-600</td>
<td>60</td>
</tr>
<tr>
<td>Pig manure</td>
<td>350-480</td>
<td>65-70</td>
</tr>
<tr>
<td>Farm Wastes</td>
<td>300-420</td>
<td>60-70</td>
</tr>
<tr>
<td>Elephant grass</td>
<td>420-540</td>
<td>60</td>
</tr>
<tr>
<td>Chicken manure/paper pulp</td>
<td>420-480</td>
<td>60</td>
</tr>
<tr>
<td>Chicken manure/grass clippings</td>
<td>350</td>
<td>68</td>
</tr>
<tr>
<td>Sewage sludge</td>
<td>600</td>
<td>68</td>
</tr>
</tbody>
</table>

Source: Rehm, & Reed, 1986
4.3 Temperature and Retention Time

Operating temperature is an important factor that can influence digester efficiency. There are three temperature ranges within which anaerobic digestion can take place (Mattocks, 1984).

- The low temperature, which is less than 35°C/90°F;
- The medium temperature, which is 29° to 40° C/85° to 105° F; and
- The high temperature, which is 50° to 55° C/135° to 140° F.

Organic materials degrade more rapidly at higher temperature because the full ranges of bacteria are at work. Thus at a higher temperature, the productivity of a digester will be high and can be expected to produce greater quantities of biogas. But there is a disadvantage of an elevated-temperature digester, which is that even a little changes in system conditions, could set off digester efficiency or even productivity. Moreover, an additional source of energy will be required to maintain the digester contents at a constant higher temperature.

Though it seems that operating temperature is important but stabilising the temperature and keeping it stabilised are even more critical and important. Variations of plus or minus 1°C in a day may force the methane-producing organisms into periods of dormancy. One way to overcome the problem of low temperature is to dilute the daily waste materials (inputs of biogas digester) with preheated (solar heated) water (Mattocks, 1984).

4.4 Solids Concentration

The moisture content of the digestion liquor (waste that is diluted) should be in the range of 5 to 12% of the total solids. The percentage of total solids should avoid inorganic sands and soils. The waste materials (input materials) may have to be diluted to a consistency of slightly thick cream. A rule of thumb for diluting cattle waste is 2.5 parts water for every one part of relatively dry waste or one part water for every one part of fresh manure (Mattocks, 1984).

Another necessary thing is to get a more rapid digestion is to stir or agitate the digester contents by paddle, scraper, piston, or in more sophisticated settings, by gas recirculation. The reason behind doing this is the micro-organisms that degrade the waste materials are
living, metabolising creatures that also produce their own metabolic by-products. In order to prevent these bacteria from stagnating in their own waste products stirring the digester contents is necessary (Mattocks, 1984).

4.5 Biogas Digester and Design Considerations

A biogas digester is the device in which the digestion process occurs. The organic feedstock, which is called the substrate, may consist of agricultural or animal wastes or similar materials. These are diluted with water, and are thoroughly mixed into slurry. Crop residues and vegetation are cut or chopped into small and fairly uniform pieces. Substrate are then fed into the digester and permitted to undergo degradation in a sealed oxygen-free chamber. After completing the degradation, the material is removed from the digester. The biogas is collected continuously for direct usage and the discharged material is called effluent or sludge.

Digesters vary widely with regard to their complexity and layout (Singoro, 1988). No simple design can be considered as an ideal design, since various factors affect their arrangement and construction. The design of a digester mainly depends on the type and volume of wastes it requires associated with other factors like climatic condition, social and environmental aspects, etc applicable to the particular situation.

Digesters can be grouped into the following categories: (Singoro, 1988)

a. Batch digester
b. Continually fed digester
c. Plug flow digester
d. High rate digester
e. Anaerobic contact process
f. Multi stage digester

The variety of digester designs that are used as anaerobic digestion covers a wide spectrum. They range from basic holes in the ground fitted with some kind of gas collection and removal device, to sophisticated reactors equipped with heating, stirring and continuous feed facilities. The most sophisticated digesters are sewage sludge digesters in current use (Rehm, & Reed, 1986). They consist of large concrete tanks, typically 1000-10,000 cubic metres in capacity (Mosey, 1980). Large-scale anaerobic digestion systems have also been developed for the conversion of municipal solid waste.
A number of large-scale anaerobic digesters have also been built for the conversion of animal manure to methane. On the other hand, for a small digester, the feasibility of anaerobic digestion of wastes is hampered by the high equipment costs and the operation and maintenance requirements of sophisticated systems. But with systems designed for developing country applications, simplicity and low costs are key considerations. The two most widely used types are Indian KVIC digesters and Chinese-type, fixed roof systems. Well-operated Indian digesters can be very efficient, a major problem is that they are expensive to build (Roy, 1980). To get rid of these problems a new type of digester called “Janata” biogas plant has been introduced. This is basically based on Chinese design with fixed roof. This new design is able to reduce the costing 40-70% of similarly sized KVIC plants.

Chinese digesters are typically designed for a family of five members, having a capacity of around 10 cubic meters and producing 1 to 2 cubic meters of biogas per day. Their basic design is very simple and consists of an underground chamber, which serves as both the digester and gas collector.

4.6 Location of a Digester

The location of a digester system is important because it should be located near the supply place to minimise the labour it needs. As an example, in China the digesters are often located near the house so that the pig wastes and human wastes can flow directly to the digester. In Turkey, the digester has been built under the floor of the cattle shed. This is another example to use less labour. Also this system provides additional insulation at cold period to run the digester smoothly without any change in gas production.

CHAPTER FIVE: PURPOSES OF BIOGAS USE

In Asia, about 95% of all biogas plants are of family size type and the output is used for cooking and lighting purposes mainly (Singoro, 1988). China has approximately 7 million digesters, most of which are family sized type used to provide gas for cooking and lighting. However, a large number of digesters medium and large sized are used for generating electricity (EL-Halwagi, 1986). In India, approximately 100,000 digesters provide gas for cooking and lighting in rural areas. But the gas can be used for other
purposes also like refrigeration, generation of electricity, transportation of vehicles, for running irrigation pumps etc. For some of these purposes it becomes necessary to compress and store the gas in a portable container and carry it to the place of application. For cooking and lighting, it does not need to be purified. Hydrogen sulphide has to be removed in order to prevent corrosion of storage containers, if the gas is to be stored or transported. By using iron fillings, this can be accomplished. Another by product from biogas digesters is sludge, that is a high quality fertiliser. Table 5.1 shows the alternative uses of biogas from a typical Chinese family size digester produced 1-2 cubic meters of biogas per day.

Table 5.1: Various uses of biogas from a family size digester.

<table>
<thead>
<tr>
<th>Application</th>
<th>Output from 1 cubic meter of biogas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>Illumination equivalent to a 60-100 Watt bulb for 6 hrs</td>
</tr>
<tr>
<td>Cooking</td>
<td>3 meals for a family of 5-6 people</td>
</tr>
<tr>
<td>Stationary Power</td>
<td>Runs a 1 Hp motor for 2 hrs</td>
</tr>
<tr>
<td>Road vehicles</td>
<td>Runs a 3 ton truck for 2.8 Kms</td>
</tr>
<tr>
<td>Electricity generation</td>
<td>Generates 1.25 KWh of electricity</td>
</tr>
</tbody>
</table>

Source: Rehm, & Reed, 1986

5.1 Cooking and Lighting

In rural areas of Bangladesh fuel for cooking and lighting are the prime needs and biogas could be able to meet the demands. Biogas requires good burning vessels to allow complete combustion and hence good results. Also simple and cheap devices made from locally available materials can be used to burn biogas. If the gas is burned in open air, the flame will be forceful, pale-blue in colour and also will make a hissing sound. If it waves and is pale-blue in colour, then there is too little air (oxygen) and hence incomplete combustion. On the other hand, if the flame is short, yellow and unsteady, then it would be clear that there is insufficient biogas and too much air. Both of these two conditions will produce low temperatures and bad results (Singoro, 1988).

5.2 Heating

One of the prominent uses of biogas is heating of houses in cold regions. Bangladesh having a tropical country does not need heating system in houses even in winter season except some areas of Northern part of the country. On the contrary, cooling
systems in houses are required. But in case of rural areas, full of trees and greens, cooling systems are not required. However, there are many areas, like industrial heating, where biogas can be utilised. Methane, being a non-polluting agent, can be used in food industries where a high cleanliness is an important condition. In case of drying food products, one can just blow the exhaust gases from methane combustion through the material without any danger of contamination and therefore, help to reduce the cost (Singoro, 1988).

5.3 Driving Engines and Generation of Electricity

Gas driven engines is not a new idea, since in 1907, one engine was driven with biogas in India. In Europe and USA, biogas from sewage treatment plants has been used to run stationary engines. These engines drive alternators, which generate electricity to provide power, light and heat to the plants.

Uncleaned gas is not suitable for use in engine because it contains water vapour, hydrogen sulphide, carbon dioxide, methane and suspended particles that are carried along during gas production (Singoro, 1988). Large amount of carbon dioxide may have an effect of reducing the power output from the engines. Hydrogen sulphide is another component of biogas that can create problems when it comes to use in engines. Methods are available to remove these two gases from biogas. Low concentration of hydrogen sulphide can be removed by passing the gas over heated iron oxide.

Generation of electricity from biogas is an important use of biogas along with water pumping, drying of farm products, etc. Electricity that is produced from biogas is easier, convenient and economic for lighting rather than direct use of biogas for the same purpose. The electricity generated from 0.75 cubic meter biogas is able to light 25-40 watt lamps for one hour whereas the same amount of gas can only light 7 gas lamps for one hour by direct burning. Electricity generation from biogas also help to reduce fire risks. Biogas can be used to run a health clinic in rural areas where some important medicine, even life saving drugs and vaccines can not be stored for lack of electricity.

5.4 Safety Precaution

Methane is an odourless gas and 5 to 15% methane in air forms an explosive mixture (Singoro, 1988). Biogas contains small amount of impurities will smell and then
its existence can be detected easily. If it is placed outside the building somewhere, the normal wind will dilute and disperse any gas leaking from the digester. A floating gasholder can act as a safety valve but in case of fixed dome digester, a combination of a manometer and a safety valve should be installed.

During the operation of the digester precaution should be taken, when gas produced will mix up with air in the gasholder, forming an explosive mixture at some stage. By discharging the first gas into the air when enough wind to blow it away, can make the situation safe. Anybody going down the pit stands the danger of being poisoned as for carbon dioxide and hydrogen sulphide. When the pit will be checked enough safety precaution is necessary. The flame arresters are another source of explosion and it is better and safer to have one in each place like before a gas stove or lamp or near the digester.

Chapter Six: Conditions for the Introductions of Biogas in Rural Bangladesh

6.1 Energy Demand

Bangladesh is a predominantly agrarian country, which has made extraordinary strides to assure basic health and survival, but it’s literacy rate and per capita energy use still lag behind its neighbouring countries. Until now, the demand for rural electrification has been met by the extension of the central grid or not at all in many places. However, in rural areas, the provision of grid electricity is the most expensive form of energy supply and it would be unaffordable to the users. Therefore, an integrated approach combining the provision of rural electrification and economic development is necessary.

Present scenario reveals that rural Bangladesh, for the most part, depended on drought animal power and traditional biomass fuels that have very low rate of energy efficiency to convert the chemical energy of such materials to heat. This in effect means that a more than proportional amount of energy is spent to get less energy. Generally, income level is the most important driver that governs the usage of all these fuels. This consumption pattern of fuelwood in rural areas has contributed to the progressive deforestation of rural regions and a worsening shortage of energy raw materials. It is remarkable that
Bangladesh is one of the countries with smallest area of natural forest (5.4% of total land area in 1995) (Rahman, 1998). Needless to say, poverty has received scant attention from an energy perspective.

People living in poverty primarily use wood, dung and other biomass for their energy services. Enormous amount of human energy is spent on fuel wood gathering for domestic cooking and other supplies. It has been estimated that the average amount of time spent on gathering and transporting fuelwood in rural areas are 2-6 hours and 4-6 kilometres per day per family to collect 10 kilograms of wood for cooking (UNDP, 1997). Children are also engaged in providing these services (gathering and collecting firewood) and contribute with a significant amount of time, which thereby prevents them from participating in education.

In-door air pollution is a major by-product of the traditional use of biomass, which diminishes the quality of life, especially for women and young children. The health implication of the use of fuel wood, dung etc includes the emission of particles, which pose respiratory problems, eye irritation etc. It is more acute in the use of fuel wood. The use of low forms of petroleum likes kerosene, which is mainly used for lighting pose severe environmental and health risk including the emission of nitrogen oxides, carbon monoxide (Stockholm Environmental Institute, 1993).

The emissions of carbon dioxide for rural energy consumption are increasing with time and contribute to global warming. This contribution is small in the global context but unsustainable use of biomass contributes to environmental degradation. As a result, the humidity of air decreases relatively and desertification starts at the western part of Bangladesh (Bala, 1996). For a country like Bangladesh, the contribution of energy related a carbon dioxide emission is still low in global context but there is a chance for further reduction through efficient use of energy.

For these reasons, the need of a cleaner source of energy is a prime demand for rural people, which can make their lives easier and will meet up all the problems discussed above. Biogas production may play a part in meeting energy requirements in rural households and also will help to solve the problems of health, environment and children education associated with traditional household energy use. Biogas means social benefits for women and children. A smoke free kitchen means women are no longer prone to lung
and throat infections and can look forward to a longer life expectancy. In rural areas, where there is generally no electricity supply, the introduction of biogas will give women a sense of self-worth and time to engage in more activities outside home. It will help to minimise loss of fertiliser from burning cow-dung and can help to earn money for rural people either by selling sludge as fertiliser or they can save money from not having to buy fertiliser.

6.2 Availability of Technical Devices/Infrastructure

The practice of biogas technology has been known since the eighteen century but still it is too expensive and therefore, does not render itself to widespread adaptation. More research is required to develop cheap technology for digester so that poor people who are still deprived from their basic energy needs can afford it easily.

In order to provide biogas digesters for household energy, technical know how is a basic requirement. The collection of digester inputs, crop residues, cow-dung can be a problem. Simple wood wheelbarrows could be used for this purpose. This type of vehicle is available in Bangladesh and can be suitable for material collection. Also this vehicle can be used to carry the sludge to the field or even to the market to sell it.

Initially the gas will mostly be used for cooking and lighting that does not need high-tech appliances. There are already locally made metallic gas cookers or kerosene cookers for cooking purpose in the country though the question of price might limit it uses among the rural poor. But cookers made of clay could be a viable alternative in this case since the raw materials is available free of cost. The women are expert to make these cookers whereas many of them have learned how to make improved cookers with clay from different NGO’s. For lighting the use of metallic lamps are frequent and can be used with biogas. It seems that rural people in Bangladesh do not need any high-tech appliances for the use of biogas and for the collection of biogas inputs except skilled labour force.

6.3 Availability of Technical Know how

Biogas technology requires high levels of skills, from the planner as well as from the constructor and user. With a high training input, skill gaps can be overcome. At the same time, masonry skills are major elements for a biogas digester construction. The
question is what types of skill and labour Bangladesh has for providing biogas at rural household.

In answering this question, it can be noted that Bangladesh entered into the arena of biogas technology in 1972. Until 1980, a number of organisations were working with biogas technology and then a separate department was established to extend biogas technology. This department has experts, and they very often arrange seminars/workshops where they offer training of interested person including NGO’s, engineers, local people etc, on how to construct biogas digesters and how to take care of it. At the same time, 24 district level officers of Council of Scientific and Industrial Research (BCSIR) were trained and through these trained personnel, BCSIR introduced a number of plants and they give training to the users about operation and maintenance technique. There are some NGO’s and other organisations that has started study, research, development and extension of biogas technology. Some NGO’s are working with local people and artisans. At Thana level\(^2\), they have a co-operation with Thana authority and they select artisans/interested persons and send them for training. Persons engaged in training are encouraged through an offer of an amount of money. These people then help to set-up biogas plants in the household premises and provide them with the technical back-up services they need.

From the above statement it is clear that Bangladesh has skilled manpower though very few amount. But NGO’s, working at Thana level may be able to create more skilled manpower in the near future regarding biogas technology. Strong monitoring and co-operation is essential between all the organisations working for the same interest. At the same time, involvement of local women is necessary. As discussed before they will be the most benefited group after introducing biogas technology. So their participation is important and they can take care of the digester easily after getting training. Though there is no clear statement available for their involvement in this field yet.

\[\text{6.4 Availability of Digester Materials}\]

\(^2\) Bangladesh has four-tier administrative level, where Thana level is occupied third position according to its top-down hierarchy. (Division-District-Thana-Union)
In Bangladesh, like many other developing countries, basically animal wastes and agricultural residues are the main available sources suitable for gas generation at village level. Taboos stand in the way of using night soil in some places. Though there are some organisations working with night soil for biogas input and basically it is confined at urban areas. Livestock has been an integral part of the mixed farming system for centuries in Bangladesh. It has been estimated that one needs five livestock for a family unit biogas digester (Singoro, 1988). According to Bangladesh Council of Scientific and Industrial Research (BCSIR), the number of domestic cattle (like cow, buffalo etc) is about 22 million that gives about 220 million kg animal excreta. According to an estimation of 30LITER/KG-wet cow dung, where as 6.6 million cubic meter of biogas can be obtained that is equivalent to 4300 tons of kerosene (which is the principal fuel in the rural areas) (AT information, 1997).

Crop residues are very important inputs for biogas production. By using crop residues, the production of biogas can be increased (Singoro, 1988). Assuming that annual crops can yield 24 tonnes of dry matter per hectare, per year, approximately, in small holder farming, of which 10% is consumed as human food, leaves about 20 tonnes per hectare per year that can be used in digesters for gas production (Singoro, 1988). The use of crop residues can help to reduce dependence on cow-dung and therefore make it possible for those who have less than five livestock to run a digester. Moreover, water hyacinth can be used with these materials and in rural areas small pond is found more frequently. So people having pond can use water hyacinth. It can be said that crop residues, vegetable wastes, water hyacinth, poultry droppings will help to reduce the dependence on cow dung especially for the people who have no cow at all.

Water is another element crucial for fermentation and must be available. Bangladesh is called a riverain country and water is available everywhere except some places of northern part. In this regard, provision of use of grey water can be a solution. Even in rainy season, the water can be stored and could be used. All these things need proper structure to disseminate information to the people. But the best approach would be the integration the development of biogas, pumped water and the development in other fields of rural life.

6.5 Availability of Construction Materials
Usual building materials can be used for digesters and associated masonry works. Choice is normally a matter of what materials is available at the lowest price. Materials usually needed for Chinese fixed-dome type of digester are the following items: fired bricks, sand, cement, and water. Metallic material is needed for the Indian floating gasholder. Now in Bangladesh the following materials are used both for fixed dome and floating dome. The materials are Brick, cement, sands, RCC pipe, gas bulb, wax, and pipe. But one thing needs to be considered that the use of cheap material can cause serious problems like frequent operational failures and short lifetime.

In China, bamboo tubes are used in some places. They are normally coated with some protective material and connected with pieces of rubber hoses. A casing of bamboo tubing or any other suitable material available protects outdoor hoses. Junctions are normally made of glass, metal or plastic tubes. This technique can be tried out in rural areas of Bangladesh where bamboo is available or other tubing materials available locally.

In case of floating gasholder type of digesters, expensive construction materials for gasholder are necessary. The materials generally used are mild steel, galvanised iron, ferrocement, bamboocement and plastic. Mild steel is used in most countries and also in Bangladesh because of its low cost. However, it rusts, especially on the outside, where it dips in and out of the digester content. Usually using sandpaper and painting over is a handy way to remove rust. The life of a gasholder would extend greatly if paint is used regularly wherever rust appears.

Galvanised iron can be used if it achievable at reasonable price. Life expectancy for this kind of gasholder is said to be about five years unless coated with paint. If it is properly painted and maintained, it should give good service for many years.

Ferrocement and bamboocement are another category of gasholder material. Ferrocement is a composite material consisting of thin wire mesh impregnated with rich cement mortar. Ferrocement can be cast into sections as thin as 1cm. And it is suitable for precast products for the lightweight of the components.

In case of bamboocement holders, bamboo mesh is used instead of wire mesh. This is even lighter, cheaper and more easily available in rural areas of Bangladesh. For both
types of gasholder, suitable coating is required to the inside and outside surface to improve their impermeability to gas. These gasholders are cheaper than mild steel gasholder, have lower thermal conductivity and high resistance to corrosion (Singoro, 1988). This would be a good material for rural people and at the same time it will help to reduce the construction cost.

Many types of plastics like polythene, high-density polythene and PVC are used for this purpose. But they are not recommended here since their exposure to the sun causes crack and consequently gas leaks.

The fundamental problem with the Indian floating digester is that they are 50% or more costly than the Chinese one, though the size is same. Taiwan has developed a long plug-flow digester which is proved that it is inexpensive may be an alternative digestion plant for rural people in Bangladesh (Ward F, 1984).

**CHAPTER SEVEN: LIKELY EFFECTS OF BIOGAS IN RURAL BANGLADESH**

### 7.1 Integrated Biogas Farming

Biogas technology means not only gas for energy, it means more than that because of it's multifold benefits. It has some long-term positive effects on society like health aspects, employment opportunity, conservation of environment etc. Beside these, the benefits from an integrated biogas system are very important for rural societies in developing countries like Bangladesh. But all the necessary elements need careful management and considerations.

Integrated farming means poly/cultures, completed by livestock, fish breeding and waste recycling process. Biogas technologies play a vital role of providing '5F'; fuel, fertiliser, feed-staff, feedstock and food (Chen et al, 1983). Digested slurries can be used as feed staff for livestock fish and plant nutrition (Rehm, & Reed, 1986).

The main components for integrated biogas farming are:

- Agricultural fields
- Algae ponds
- Fish and duck ponds
• Animals
In this system, animal excreta can be used for biogas production. Biogas can be used as fuel to fulfill man’s basic need. Again, sludge can be used as fertiliser for algae production whereas algae can be used as feedstock for animals. Algae can also be used in fishpond and in crop field as fertiliser. All these elements are linked with each other has been shown in figure 4.

Figure 4: Shows a recycling process through integrated farming by implementing biogas technology
Source: (Rehm. & Reed. 1986).

Biogas can open a wide scope for rural people through integrated farming system. This may help the poor people to get economic stability and they may be get rid of malnutrition, health problem, environmental problem etc.

The outputs from this system are:
• Biogas: 0.03 m/kg of wet cattle dung
• Fertiliser: 10% increase in crop production
• Algae: 25,000 kg/hectare per year
• Fish: 3,000 kg/hectare per year
• Duck: 3,000 kg/hectare per year (Halwagi, 1984).

Each of these components will depend on various factors and will vary from time to time.
7.2 Long term benefits from biogas digester

There are some long-term benefits that have various positive impacts on rural economy, society, and environment as a whole.

7.2.1 Employment

In rural areas of Bangladesh, unemployment poses a severe problem with a large proportion of people moving away from traditional agricultural practice and migrating to urban areas. After introducing biogas technology, manufacture of bricks, sand collection, production of gas-utilising equipment etc will provide some alternative employment opportunity for them. On the other hand, animal husbandry will offer further diversifying employment opportunity especially for women. By saving time from cooking and collecting fuelwood, they may able to be involved in some income generating activities, which make them economically strong and solvent. This will be a good practice for empowering them. If biogas is used to run petrol or diesel engines, then some technical requirements associated with maintenance will provide more extensive employment opportunity.

7.2.2 Labour Distribution

Sexual distribution of labours is very well defined in Bangladesh. In rural areas, this distribution is quite sharp. So, it can be said that the introduction of any new technology is bound to have some effects on both men and women in terms of increase or decrease their working loads.

7.2.2.1 Men

This new technology will obviously increase some workload on men like construction of the digesters, major repair and maintenance etc. Usually in Bangladesh they do these types of works. The construction work needs technical know-how, but sometime it is seen that the owners of the digester do some non-technical works (e.g. digging well, transportation of materials etc) to save money. In this sense, this will be an extra temporary load for them. Again, there are some possibilities to increase their workload if the water source is located far from the digester. Generally water source (small pond) is
located near their house and women can collect water from it. Beside these, they will get a clean source of energy for cooking and lighting for their houses.

This does not mean that women can not do the construction and repair works, but the way things are now going, it will take a bit time to involve women labours in the field of masonry and building. This situation will be strengthened even more when these works are to be under taken at professional level with monetary exchanges involved.

### 7.2.2.2 Women

Any new technology has either a negative or positive effect on women as an important member of a society and family. In a lot of cases, the introduction of new technology has a negative impact on them in particular. As for example, the introduction of ox-plough and tractors have enabled men to plough large amount of fields but on the other hand the work load has increased by planting, weeding, harvesting which are mostly women’s job.

In case of biogas technology, the workload on women will be decreased when it is about collecting and gathering firewood and cooking meals for family members. And by saving time, they can spend some time for economic activities like poultry, homestead gardening etc. But this new technology could increase their workload if it is not incorporated into other works like the water supply system. A well coordinated introduction of biotechnology in rural areas especially where there is a shortage of domestic fuel would reduce the workload on women. There is another way, which will help them to reduce workload. They can use grey water to feed the digester. They can store this water in a big mud pot, which is available in rural areas. It will help them to save time and energy and at the same time preventing them to misuse of water. There is another possibility to break the traditional sexual division of labour with this new technology. For instance, in Bangladesh men do not need to cook because this is the field traditionally left for women. So, it can be said that men can easily get involved themselves in kitchen because it would be more easy and convenient to use gas cookers than traditional three stone open fire for cooking to help their wives.

### 7.2.3 Health Conditions

There is a direct link between domestic energy use and health condition. The shortage of domestic energy is quite often accompanied by a deterioration of health conditions of the
members in the society. There are various explanations for this. One is that it is not possible to prepare meat as frequently as it could be otherwise and children has to suffer a lot of health problem by eating cold food especially in winter and rainy season.

The introduction of biogas technology could help in getting rid of health problems associated with cooking. The gas is particularly convenient in the cooking of children’s food because it is easy to cook faster. So, the risk of feeding children cold contaminated food will be reduced. Again, it provides women a smoke and dust free safe kitchen, which will reduce their health risk and also it provides them with an efficient cooking system.

Biogas technology allows a positive contribution towards improved health and sanitation and social life.

The net effect of digester is not only health and sanitation but also create a new sense of social status and pride in overall family management. This helps to improve living standard of the family and helps to reduce the distinction between urban and rural life. This also contributes to a sense of aesthetic emotions and sensation to the family.

7.2.4 Environmental Conservation

Traditionally the cooking fuel in rural Bangladesh has consisted of cow dung cakes, firewood and crop resides. However, with increasing population and depletion of forests, firewood is becoming scarce and the most needed organic matter for enriching Bangladeshi soils is being burnt in the form of dung cakes for cooking fuel.

A lot of agricultural land is threatened with soil erosion as the result of increased population and live stock pressure leading to land clearing for agricultural, over grazing and over cutting forest for fuel wood. Deforestation also exposes the soil to wind erosion and high vapour transpiration, which lowers the water table.

Biogas production may help to save the forest and soil and its productivity by reducing dependency on them. It can also reduce the use of coal, kerosene, which will reduce nitrogen oxide and carbon monoxide emission. By using sludge, as fertiliser the use of chemical fertiliser would be reduced that will help to reduce water contamination through chemical fertiliser. It will help to manage waste, recycling of organic wastes, that will be
a solution to handle wastes in an environmental way, where there is no waste disposal and collection system existing in rural areas.

Again women could start practising homestead gardening by cleaning around their house, which is now full of bushes or marshy land, this will help to keep clean around their houses and reduce mosquito breeding. So, biogas technology has lots of direct and indirect environmental advantages through protection of soil, air, water, vegetation etc.

This technology addresses a number of things ranging from the health and well being of the families. The life cycles of parasitic and pathogenic organisms under proper conditions break down and reduce diseases transmission. The lack of proper sanitation is an important factor in spreading of diseases dangerous to infants and younger people. The fact that, waste materials placed inside the digester are rendered odourless and less attractive to flies, rodents and insects is another positive contribution to sanitary conditions. In other word, sanitary conditions in the household are made for safer food preparation, processing and storage. The availability of hot water also improves the overall laundry tasks as well as household cleaning.

### 7.3 Constraints with a biogas program

Obstacles can arise from religious or social taboos in the following respects;
- a. Prohibitions in the use of gas primarily for the preparation of food,
- b. Prohibitions in the use of the slurry,
- c. Ethical barriers,
- d. Social cultural forbidden.

In order to deal with these obstacles, in a way that considers local conditions as well as requirement of the project, the assistance and attitude of ruling or generally recognised institutions is of major importance. Women have been kept out of decision-making processes, even though they are the primarily affected group regarding household issues. Their participation can, for instance, be encouraged by integration into authoritative bodies or by forming special female comities. Community participation including local people, educated persons in the community, teachers etc can play an important role to face these problems.
There may be another problem, people who are land less and have no livestock, may not be involved in this project. Especially where cowdung is found free and could be commercialised as a result of new value added to it. In this case the poorer section will be losers of the society, who will continue to suffer from fuel shortage and therefore continue with old habit of the destruction of their own environment. The implementation of a biogas program is also linked to a number of political, administrative and technical problems that need to be resolved at both local and national level. It has occurred that, poor peasants have received loan from rural development projects and spent those money for their own purposes, which are not defined in the project. Regular monitoring in this case is necessary. There are some general administrative problems likely to be encountered with any new rural development program. These include coordination of finance, production, distribution, political activities, local people and project staff together with available staff to carry out the works assigned on them. A well functioning and transparent political structure would make the whole thing even better, and this may be one explanation to why the biogas technology did better in China then India, though the state of India spent more money then China for the program (Singoro, 1998).

Information dissemination, guidance of production, and distribution by co-operation between technicians, the local people and adequate provision of maintenance etc are the important and necessary factors for any successful diffusion of technology. The success of biogas implementation depends on technically sound plant that can be operated under a wide scope of conditions. This is the area where further research is needed to adopt the foreign design to improve their efficiency with efficient handling technique for sludge output to conserve nutrients, and the operation of plants in areas where water supply is limited or not available. Any breakdown in administration, maintenance or technical components at the initial stage of the program can discourage the people who are intended to be served.

Chapter Eight: Implementation of Biogas technology

Biogas projects are quite complex multi-functional including construction; agriculture, economics, and sociology besides planning and management. That’s why proper and active dissemination and implementation of biogas technology is needed and
should be well organised and planned. A successful implementation strategy requires some specific steps within the following fields:

- Implementation campaigns
- Educational and training programs
- Financial promotion
- Administrative, political and organisational aspects
- Social acceptance

8.1 Implementation Campaigns

The basic concept of biogas must be promoted through national, regional and community level. For a successful introduction of this technology, effective motivation and mobilisation of the target groups are needed (AT information, 1997) Thus, implementation campaigns could be an effective way to motivate people. A well co-ordinated and comprehensive plan is necessary which can be centrally controlled and worked out through the participation at grass-rot level. A successful campaign builds an experience in implementation, on direct link with the target groups and having the confidence of developing a sound and appropriate technology.

There are numerous channels of communication that can be used for the dissemination of information regarding biogas. In rural areas, the popularity of printed media is limited due to the low level of literacy. Electric media, folk media (verbal, aural and visual forms) can be used which are highly accepted by the rural people. Local agricultural fairs or market places are vital places, where these communication media can take place.

Again, the target groups can be stratified on different levels: the national level, the regional level and the local level. The language of information should always be close or same to the language of the represented groups. National level includes various concern ministries, NGOs, national and international development agencies and companies and their media of information would be high-level meetings, conferences, articles, TV and radio programs etc.

Regional level includes various government authorities on this level, religious place, NGOs working in development, environment and appropriate technologies etc and appropriate media would be workshops, agriculture fair etc.
Local level includes the end users of biogas technology and the convenient ways for them are demonstration/pilot plants, public meetings, billboards, folk media etc.

The following questions should be cleared to the people at this stage:

- What impact will a national policy of building biogas plants have on the living standard of the rural people?
- What is the potential of biogas for satisfying the overall energy requirements for the target people?
- Will the biogas satisfy a public health by providing a safe, practical and economical method of handling wastes?
- Will the fertiliser produce significantly improved agricultural activity?
- Will community digester create employment opportunity? Will the biogas production help to solve a serious deforestation problem by reducing the need for firewood?

8.2 Educational and Training Programs

This is one of the essential elements in the implementation of a biogas program. Proper training is necessary for those persons who are responsible for planning, constructing, operating and repairing the plants. The users also need practical training for everyday plant operation. Following are the personnel required training.

- The owner/operators of biogas system, mainly housewives and farmers,  
- Servicing and maintenance personnel,  
- Mesons, fitters, plumbers etc involved in the construction of biogas system,  
- Planners of biogas units and developers of biogas technology, and  
- Organisers, social workers, the head of a biogas taskforce, foundation or self-help organisation or even a reporter working on a biogas related project.

The success of a training program is largely dependent on its time and duration. The presence of the target group is important because most housewives can only spare time for it during certain hours of the day and it is best for them to close their home. On the other hand, farmers can’t afford the time during harvesting season. So, these things are important and need extra consideration.
Education program means formal know how transfer in schools, colleges or courses for the public and potential users. This program must be integrated and supported professionally on national, regional and local level by the respective ministries and authorities responsible for agriculture, education, health and other relevant fields. Biogas technology can be included in the syllabus of primary and high schools. Agriculture colleges and universities can allow specific biogas courses.

8.3 Financial Promotion and Public Support

The financing of investment and the operational cost should be assessed at the planning stage. Special attention requires answering the question how the running, maintenance and repair costs can be financed. All this expenditures should be calculated against income in the form of regular revenue. A liquidity analysis can show how far the net expenditures have to be financed from outside and how much contribution can be expected from the expected income. State support would be a workable way when the profitability of biogas plant is negative in private scale, but are favourable on a national scale.

Subsidies would be a viable way to make the project popular. Subsidies may consist of grants, low interest/no interest loans, or supplies of materials needs for construction from the government.

8.4 Political and Administrative Frame

The development of biogas technology largely depends on the political will of donor and recipient Government. It is the duty of the administrative authorities to provide the access to the technology. And to organise the material required for this, financial and legal basis.

Government can play a role as promoter and give support in biogas research, information dissemination and regulations for funding, subsidies or tax waving. However, a favourable element is needed for the dissemination of biogas technology that depends on a whole range of decision makers, namely the ministry of finance, the ministry of energy, the ministry of agriculture and livestock, the ministry of education and the ministry of health.
8.5 Social Problems Affecting the Propagation of Biogas Technology

Ethical barriers or socio-cultural taboos are the other obstacles for implementation of a biogas project. Some religions have various strong opinions with regard to cleanliness in connection with human and animal excrement. There is a misunderstanding that illness will result from the handling of human and animal excrement. Since doctors are the most accepted person in these regards, they may be included to eliminate the misunderstanding in the information dissemination stage. Highly respected members of the community, approved educational institutions etc may be able to reduce these obstacles. That’s why local people’s participation is one of the prime needs for a successful implementation of biogas project. Their participation should be assured at the beginning of the planning stage.

Chapter Nine: Household biogas Digester or Community level
Biogas Digester

The high capital cost of biogas pants relative to rural people’s income is a major obstacle for its popularity in the developing countries, and Bangladesh is not an exception in this case. The capital cost of a digester, which can produce 2 Cubic Metre of gas/day, is higher than the average yearly income of a rural household (Roy, 1998). It is clear that the rich section of the community may able to afford the digester and without heavy subsidies, poor people will never be able to afford it. Further more the wealthier families that own enough animals to supply input for the digester may choose it rather than others. However some family may able to afford the capital cost, but the economics of the running biogas system are not always favourable. Much depends on the value assigned to the inputs and outputs. The effective opportunity cost of water and labour varies between locations and weather. It is important to add that water is available everywhere free of cost and the women can do the task of putting inputs in the plants, saving the extra labour charge. Sometime a wealthier family have an extra person to take care of the livestock. He can do the task easily.

There is another solution to reduce capital cost and increase the scope of biogas technology, so that the poor people can get the benefit from biogas plant. The community
level biogas plant may be a viable solution and in India they have started practising in this way. A community plant has a scope of utilising all the animal dung and wastes in the community. But there is a problem in a community as people who has no livestock and what should they do? How do they get share from this plant? The people, who have no cattle, can do some voluntary job for the plant. If they have a pond or any type of water body, they can share their water hyacinth for the same purpose. The voluntary jobs include taking weight of the inputs delivered from the villagers and keep record in the owners pass books and plants ledger books, daily operation and maintenance, keep clean the plants, surroundings etc. They can also return processed sludge to the owner according to the input. The family who has no land can sell their sludge within the community, who needs more, through the volunteers. But the question is how much gas wills each family get and what will be the indicators for these calculations? In India there is a community biogas plant for the Pura Village (WWW.unu.edu/unupress/unupbooks,10-02-00).

The villagers deliver the cowdung and they get electricity for lighting and water supply, they receive payments for cowdung. And pay for electricity services. But in case of cooking if any charge is imposed to the villagers, there is a great possibility to fail the project, because they can get firewood and cowdung free, though it is a time consuming matter. And intensive field survey is needed to find out any solution for this problem.

Again from a community plant no body can enjoy it’s full benefit, like integrated biogas farming (5F), as described earlier. There are some advantages and disadvantages of these two types of plants as listed in table 9.1.

<table>
<thead>
<tr>
<th>Level</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family Level</td>
<td>• Energy contribution of the system,</td>
<td>• High initial capital cost,</td>
</tr>
<tr>
<td></td>
<td>• Fertiliser/Soil conditional value,</td>
<td>• Lack of appropriate information about the system among the</td>
</tr>
<tr>
<td></td>
<td>• Improved sanitation,</td>
<td>potential users,</td>
</tr>
<tr>
<td></td>
<td>• Health and Environmental Quality</td>
<td>• Education level of the people,</td>
</tr>
</tbody>
</table>

Table 9.1: Comparative Advantages and disadvantages of two types of digester
Moreover, for a successful operation of a community plan the primary requirements are an equal system for the collection of digester inputs and fair distribution of the gas and effluent. It is possible if the community has common interest but it is difficult to achieve in highly fragmented societies, where the community cooperation is weak and conflicts of interest is dominant (Roy, 1980). In Bangladesh, this type of picture is found in some places particularly in rural society.

So, decision makers should consider all these things and by conducting a household survey, they may able to find out a workable solution for rural people. They can follow some examples from other developing countries, like India, Nepal, and China etc.

### CHAPTER TEN: ECONOMIC VIABILITY OF A BIOGAS DIGESTER

Cost-benefit analysis is one of the most widely used methods to determine economic viability of any project. There are three aspects of cost-benefit analysis: financial, economic and social evaluations. The financial aspect deals with the profitability of an investment at market price, the economic aspects deal with benefits to

<table>
<thead>
<tr>
<th>Community Level</th>
<th>Availability of resources and raw materials,</th>
<th>Traditions, values, beliefs and attitudes,</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Integrated system level analysis,</td>
<td>Diffusion of technology patterns</td>
</tr>
<tr>
<td></td>
<td>Health and Sanitation</td>
<td>of bureaucracy and social</td>
</tr>
<tr>
<td></td>
<td>Financial and institutional</td>
<td>organisation, cost benefit</td>
</tr>
<tr>
<td></td>
<td>infrastructures.</td>
<td>analysis.</td>
</tr>
</tbody>
</table>

Source: Halwagi, 1986
the nation, while social aspects refer to social benefits of the citizen as well as the country.

Biswas and Lucas (1996) have studied the economic viability of biogas technology in a Bangladesh village. In their study they have shown the cost of the digester based on local government engineering department (LGED) that is tk 16,000 in Bangladeshi currency. Where operation and maintenance cost is 2% of the initial investment, discount rate is 11%, bank interest is 16%, and the loan could be paid back within 5 years whereas the lifetime of the project is 20 years. Table 10.1 shows a base case scenario for a biogas project including benefits from fertiliser, cost of fertilisers are used mainly in crop production. Initial investment of a biogas plant, it’s operation and maintenance (O&M) cost and the interest rate.

Table 10.1: Base case scenario for biogas project

<table>
<thead>
<tr>
<th>Cost of Fertiliser Tk per Kg</th>
<th>Benefit from fertiliser Tk per year</th>
<th>Initial Investment Tk</th>
<th>O &amp; M Cost (Tk)</th>
<th>Interest rate (%)</th>
<th>Payback period (yr)</th>
<th>Net Present Value (NPV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euria</td>
<td>Potash</td>
<td>TSP</td>
<td>Initial</td>
<td>O &amp; M</td>
<td>Interest</td>
<td>Payback</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>10</td>
<td>1040</td>
<td>16000</td>
<td>320</td>
<td>16</td>
</tr>
</tbody>
</table>

Source: Biswas, and Lucas, 1996

They have shown that the project does not appear to be viable by doing a sensitivity analysis. They suggest that a cluster containing 1-7 households belonging to the same family could sell their excess gas to nearby clusters. Women can be offered loan of tk 6,500 to buy livestock with the condition that they will buy biogas from nearby cluster. They will continue to buy once they become solvent Two base case for producers and buyers of biogas are shown in table 10.2 and 10.3.

Table 10.2: Base case of the biogas project using viability tools (for producers)

<table>
<thead>
<tr>
<th>Cost (tk)</th>
<th>Annual Benefits (tk)</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Investment</td>
<td>Annual O&amp;M cost</td>
<td>Fertiliser</td>
</tr>
<tr>
<td>39000</td>
<td>780</td>
<td>2389</td>
</tr>
</tbody>
</table>

Source: Biswas and Lucas, 1996

Table 10.3: Base case of the household earning projects (for buyer)

<table>
<thead>
<tr>
<th>Cost (tk)</th>
<th>Annual Benefits (tk)</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working capital</td>
<td>Annual payment for biogas</td>
<td>Annual maintenance cost</td>
</tr>
<tr>
<td>6500</td>
<td>11345</td>
<td>7500</td>
</tr>
</tbody>
</table>
According to table 10.2, the net present value (NPV) is sensitive to capital cost and government subsidy could encourage villagers to build biogas plant. And in table 10.3, they have examined that NPV is sensitive to the price of livestock and any change in the price of livestock will affect NPV negatively or positively.

Biswas and Lucas (1996) have concluded that biogas technology has not been economically viable and any benefits from the sludge would not be sufficient to cover the initial investment. NPV is highly sensitive to the capital cost and if it is decreased by 65%, the project would be viable. They have claimed that income-generating activities would help them to get sufficient income and then they will able to purchase biogas at quite high price and repay the lending money. This is the way they have suggested for a plant to become viable economically.

In case of a biogas project, it is difficult to calculate actual cost-benefit analysis because there are some uncertainties or inadequate stream of calculations of inputs (costs) and output (benefits) based on physical project quantities and prices (Moulik, 1981). There is a lack of standardised data about the quality and quantity of inputs and outputs due to decentralised operating conditions. In such uncontrolled situation, it is impossible to get actual data about these. For the same reason, the lifetime of a biogas digester cannot be standardised of various designs. Again, there are also some problems with pricing of inputs and outputs, because they are largely dependent on domestic market price, inflation, the world energy price, contribution to foreign exchange saving and earning or import and export. Also problems occur regarding traded and non-traded inputs and outputs. In many areas in developing world, inputs like animal dung, biomass etc with labour and outputs like biogas, sludge are often non-traded goods because of the unstable labour market. Thus the opportunity cost of may be zero, while it could be substantial from the nation’s point of view. Large numbers of indirect benefits are involved in a biogas program, which has a great impact on society and economy but that cannot be easily assessed in monetary value.

Considering all these limitations, the question is what should be done to get accurate result for a decision-making process. It is possible to re-examine the results of the cost benefit analysis for the high capital cost and the monetary benefits will not be sufficient
for its popularity and expansion of private household owners. Also it is hard to believe that government subsidy, credit facilities etc can influence private households to adopt biogas project. But if all the indirect benefits could be quantified, benefits would outweigh costs. In this relation, some observations from the field can be discussed (Moulik, 1981). In China, the experienced Chinese farmers found some advantages using biogas. They found a considerable agronomic advantage like an increase in crop yields of 10 to 15% by using bio-fertiliser. They also discovered some additional advantages of integrating all the agronomic factors, including humus and health improvements. There is another explanation from India. By using biogas, a family saved $ 42 U.S. per year on medical expenses, 50% of the cost for chemical fertilisers by replacing it with biomanure and a saving of 3 hours in cooking times the could be utilised either in leisure or economic activities. Some of these factors can be quantified in monetary value, but other benefits cannot be quantified as convenience and comfort in cooking. By practising a biogas system, the private owners can maximise the benefits not only in monetary terms but also in non-quantifiable terms and make biogas viable for investment.

There is another conclusion indicates that the economic viability will increase with an increase in size of the biogas plant. So, it can be said that a community-level biogas plant is more viable than family size plant. Also there are three important outcomes that can be found from a community plant. Firstly, this plant will offer more diversifying use of gas beyond cooking and lighting. Secondly, it will maximise the recycling of available organic wastes and thirdly, it will able to be less sensitive to temperature problems in winter.

Again, a biogas program would be viable if all the micro level long-term social benefits could be included. A biogas program in a country can give benefits to the nation in terms of prevention of deforestation, cost reduction for sanitation and health facilities, increase in crop productivity and soil fertility, internal employment generation with relatively less administrative cost, improvement of the quality of life and hygiene. It can be strongly argued that after considering all these indirect benefits, it would be well worth to make a biogas program a highly desirable and viable investment decision for the nation.
Chapter Eleven: Recommendation and conclusion

In Bangladesh, unequal distribution of the grid line electricity or other forms of energy are the main reason for not having sufficient supply of household energy for rural people. Also there is a question about the ability of the authority to provide sufficient conventional energy within a short period. The high current charge of grid line electricity prevents rural communities from having this electricity connection for household. So, people will use more agricultural residues, dung, as a result of increasing scarcity of fuelwood. In this way, the nutrient value of dung, which is a good soil conditioner, has been lost partially.

In order to avoid these problems and upcoming problems an alternative energy source is a prime need for the rural households. There are a number of alternative energy sources like solar energy, wind energy, hydropower, biogas etc. Different options need different types of investments, and investigations to examine their viability. Different alternatives could be suitable in different parts of Bangladesh.

A biogas digester is not as easy to handle the simplicity of its equipment might suggest. The temperature, the chemical balance and the methanogenic bacteria require careful management. The digester must be fed according to a schedule with accurate liquidity, pH and carbon/nitrogen ratio. Any change may cause decreases in the gas production. Indigenous research, field experiments, design improvements etc are needed with coordination of relevant governmental authority and NGO

In this regard, the full support of the government is important. Work should be carried out with different substrate materials to assure a high degree of gas production from these materials. Field investigations are needed to measure the crop yield grown with sludge as compared to those grown otherwise. There is a need to receive guarantee from the state government for technical support of biogas extension services. The training for operation and maintenance needs available technical assistance, when problems will arise. One important thing is that the government cannot support this technology forever. The villagers must contribute and government can provide some financial and technical support to them
consideration and attempts should be made to examine the possibility of technology transfer. Biogas technology must be developed considering the local climate of the host country. Since the conditions vary significantly between developed and developing countries, technology transfer is very limited. Biogas plants in developed countries can contribute to various basics and development needs. In certain instances the biogas system can be a “money maker” to the rural people. Using biogas for cooking, the time would be saved that could be utilised properly otherwise no benefit will come. That is why a loan should be given for increasing the household revenue at the same time. There is a gap between urban and rural areas of Bangladesh. This gap will be narrowed and biogas technology can help in this regard that must be counted as ‘social benefit’. The provision of regular monitoring of biogas digester should be made for its sound operation and maintenance.
Reference


