Design and Implementation of an Energy Neutral Home System for Rural Areas of Bangladesh

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MASTER OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

By

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Dedication

To my Country
The People's Republic of Bangladesh

ACKNOWLEDGEMENT

At first, I am greatly praise to almighty God for successfully completion of my Master Degree thesis work.

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ABSTRACT

Bangladesh is suffering from acute power crisis for a quite long time without any respite. The Government of Bangladesh (GOB) is committed to provide affordable and reliable electricity to all citizens by 2021. However, among the country's 138 million people, only 43% has access to electricity of 176 kWh at present. The power sector includes the generation, transmission, and distribution of electricity among different holdings including residential, commercial, business and service sectors under the guidance of the Power Division of the Ministry of Power, Energy, and Mineral Resources (MPEMR). In the power sector, a number of problems have been reported. These include adverse power crisis, widespread presence of corruption in the procurement and distribution network, poor financial performances, high transmission and distribution losses. Now shortage of conventional fuel is the major problem. Most of the power stations of Bangladesh are based on non-renewable energy resources. Natural resources or non-renewable energy sources such as: fossil fuels, oil, natural gas etc. are completely used or economically depleted. So this is the time to search such a system where the residential areas of Bangladesh become Energy Neutral. This thesis demonstrates such a system in which an Energy Neutral Home (ENH) is designed and implemented for rural areas of Bangladesh. The designed system is able to meet the energy requirement with renewable energy resources without taking any electricity from grid. In this research, biogas is used as primary renewable energy source for the generation of electricity. Besides, this thesis includes the design and cost analysis of an ENH system for an area of 200 houses with only biogas which has lower per unit cost of electricity, a hybrid ENH system with two renewable sources (biogas and solar) and its feasibility study for rural and urban areas, finally a load shedding backup ENH system with only human waste. This research proves the importance of the ENH system all over the Bangladesh by giving an excellent alternative of power generation on the present power crisis of Bangladesh.

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LIST OF ABBREVIATIONS

AH	Ampere Hour
BDT	Bangladeshi Taka
CFT	Cubic Feet
C/N	Carbon/Nitrogen
DOD	Depth of Discharge
ENH	Energy Neutral Home
GS	Grameen Shakti
GTZ	Deutsche Gesellschaftfur Technische Zusammenarbeit
HRT	Hydraulic Retention Time
IPS	Instant Power Supply
IDCOL	Infrastructure Development Company Limited
IFRD	Institute of Fuel Research and Development
LPG	Liquefied Petroleum Gas
LED	Light Emitting Diode
MMCF	Million Cubic Feet
NDBMP	National Domestic Biogas And Manual Program
NMOC	Non Methane Organic Compound
NG	Natural Gas
PPM	Parts Per Million
PV	Photovoltaic
ROC	Renewable Obligation Certificate
SED	Sustainable Energy For Development
SS	Stainless Steel

SNV	Netherlands Development Cooperation
TVS	Total Volatile Solid
TS	Total Solid

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Power crisis is one of the greatest problems of Bangladesh. Bangladesh is suffering from acute power crisis for a quite long time without any respite. Present electricity coverage in Bangladesh is only 43% and per capita electricity consumption is about 176 kWh [1]. Providing access to affordable and reliable electricity to all citizens by 2021 is a national goal of the government of Bangladesh [2]. Currently, against a demand of around 5,200MW, the country is generating around 3,700MW to 4,000 MW power while the demands for power have been rising by 10% every year [3]. About 86% power station in Bangladesh are based on gas, 5% are hydro, 5% are fuel oil and 4% are coal based [4].

Natural resources or energy sources such as: fossil fuels, oil, natural gas etc are completely used or economically depleted. Several small deposits of coal exist on the north eastern region of the country, but these consist of peat, with low caloric value and very deep bituminous coal that will be quite expensive to extract [5]. In 1990, only 2.2% of total households (mostly in urban areas) had piped natural gas connections for cooking and only 3.9% of total households used kerosene for cooking [6]. These are by no means a pleasant scenario as we are rapidly exhausting our non-renewable resources [7]. By including the renewable energy sources, the energy sector green house gas emission reduces and energy security increases. Using renewable energy, both on grid and off grid operation is economically feasible and suitable for distributed generation applications. It has low maintenance and operational cost. Most of them are modular in nature and quick installation is possible. So this is the time to search such a system where the residential areas of Bangladesh become Energy Neutral.

An Energy Neutral Home produces as much energy as it consumes over the course of a year [8]. Energy Neutral is using established methods of energy production such as solar panels, solar water heater and small wind turbines for windy areas and combining them with energy-saving construction practices to provide an affordable house that achieves energy neutrality [9]. The house may draw energy from the grid as needed, such as during evening hours, but send energy back into the grid on sunny days. In all, the house is expected to be a net producer of electricity and carry a net zero energy bill over its life [10].

Moreover, there is a growing awareness of the severe environmental and ecosystem impacts associated with the use of fossil fuels, nuclear power, and large hydro systems. These impacts include land, water, and air pollution, widespread habitat destruction, as well as increasing evidence of links between fossil fuel use and climate change due to global warming. Climate change is recognized as one of the greatest challenges facing Bangladesh, and the world today. The consumption of energy in the residential sector is a significant contributor to Bangladesh's stationary energy greenhouse gas emissions. The study estimated that the residential sector energy consumption is projected to increase to 56% over the period 1990 to 2020. On the other hand, in Bangladesh, commercial energy consumption is around 66% natural gas, with the remainder mostly oil plus limited amount of hydropower and coal [11]. Another study shows 55% increase in global energy-demand between the period 2000 and 2020. For that reason, the developed countries were set their targets to generate, say, 10% of their energy needs from renewables by the year 2010 [12]. So, Energy Neutral Technology is also very much important for Bangladesh.

Energy Neutral Home may offer reduced costs for infrastructure, such as line capacity and peak load generation facilities, as well as reduced network losses and also increase long-term energy supply security. This is particularly important for countries such as Bangladesh, where many networks span large distances, high load growth in some areas is leading to grid constraints, and many lines are reaching the end of their expected working lives. A key advantage of decentralized renewable over traditional centralized supplies is the lower risk they offer in upgrading capacity. The ability to follow load growth more closely by adding incrementally to supply reduces the period of over-capacity that inevitably follows the installation of a large system, and hence also the period of low market prices experienced until load growth catches up. Over the last two to three decades, different strategies have been adopted to support renewals around the world, with a corresponding range of outcomes.

In recent years, Grameen Shakti (GS), Infrastructure development company limited (IDCOL) have emerged as a key player in promoting renewable energy technology in remote, rural and off-grid areas of Bangladesh. GS , IDCOL and others have, therefore, undertaken construction of biogas plants as an alternative to the energy produced from fire wood, the cutting and burning of which is harmful for the environment. The technology uses cow dung, poultry excreta, waste water and other waste to produce biogas, thereby ensuring a smoke-free, odor-free, clean and healthy cooking environment for rural women. Among the 25 organizations involved in transferring the biogas technology, Grameen Shakti (GS) is the lead organization which shares more than 60-70% of biogas plants being constructed in the country [13], [14]. The introduction of biogas has reduced the time that the rural women spend on cooking, in turn allowing them to engage in other productive pursuits. A three cubic meter biogas plant is capable of producing sufficient gas for cooking three meals a day for a family of 6-8 members. Grameen Shakti mainly provides support for installing 6-20 m^3 capacity biogas plants. The owners of these biogas plants, after meeting their own requirements, sell extra gas to nearby families, restaurants, tea-stalls and bakeries. Some owners also use biogas to generate electricity for their own use. For smaller sized biogas plants of 1.2 to 4.8 m^3 capacities, Infra Structure Development Company (IDCOL) implements through different partner organizations including Grameen Shakti in a National Domestic Biogas and Manual Program (NDBMP). This program is financed by Netherlands Development Cooperation (SNV) where there is provision for giving grant of 9,000 BDT per biogas plant irrespective of sizes. The subsidy was provided at 7,000 BDT at the beginning and later on in October 2008 it was increased to 9,000 BDT to compensate for inflation and increase of cost for construction materials. Looking into the households' low income level and increasing trend of construction costs it is proposed to continue with 9,000 BDT till 2012 [14], [15].

1.2 SCOPE OF BIOGAS PLANT IN BANGLADESH

Biogas is a renewable source of energy, can be used as fuel for cooking, lighting, running vehicles and generators, etc. Other natural resources like oil gas etc. are limited and will be exhausted in course of time. That's why the developed and developing countries consider their natural resources very precious and are cautious about extracting those. Fuel demand is increasing with the increase of population. But we have not enough reserve of fuel for our future requirement. Bangladesh with 12.04-15.55 tcf of gas reserves is currently producing about 2,000 mmcfd of gas per day against the demand of more than 2,400 mmcfd which is still growing. Experts apprehend that the stock of natural gas in our country will be exhausted by near 2020 with such increase of demand [16], [17]. As agriculture based country, Bangladesh has huge potentials for utilizing biogas technologies. According to IFRD - there is potential of about four millions of biogas plants in our country, which could meet the household energy need of about 20% of the total families. Moreover, In terms of climate conditions and availability of raw materials Bangladesh is in a favorable condition for propagation of biogas technology. So, it can be a potential renewable energy source by which a home may be completely energy neutral. About 4664 biogas plants have been installed all over the country up to June 2000. It has been observed that about 99% of the plants are in operation and 91% of the owners could meet their household fuel demand from the plants [13]. Again, till November 2009 more than 9000 biogas plants have been constructed in different parts of the country [15]. Considering the situation discussed above, it has already become mandatory to espy the use of biogas technology as a source of appropriate alternative fuel which may be reached to inaccessible areas and nook and corners of the country.

1.3 OBJECTIVES

Objectives of this research are:

(i) To study the feasibility of biogas as a renewable energy source for the Energy Neutral Home (ENH) System.

(ii) To design an Energy Neutral Home (ENH) System that will able to meet the whole energy requirements of a house.

(iii) Calculation of required biogas (waste material such as cow drunk, poultry excreta etc), size of digester etc. for the ENH system.

(iv) Implementation of the ENH system.

(v) Cost Analysis of the designed ENH system for real implementation.

(vi) To design an ENH system for an area also.

(vii) To design a hybrid ENH system

(viii) Feasibility study of ENH system as load shedding backup system.

1.4 METHODOLOGY

The flow chart of functionality is given below:

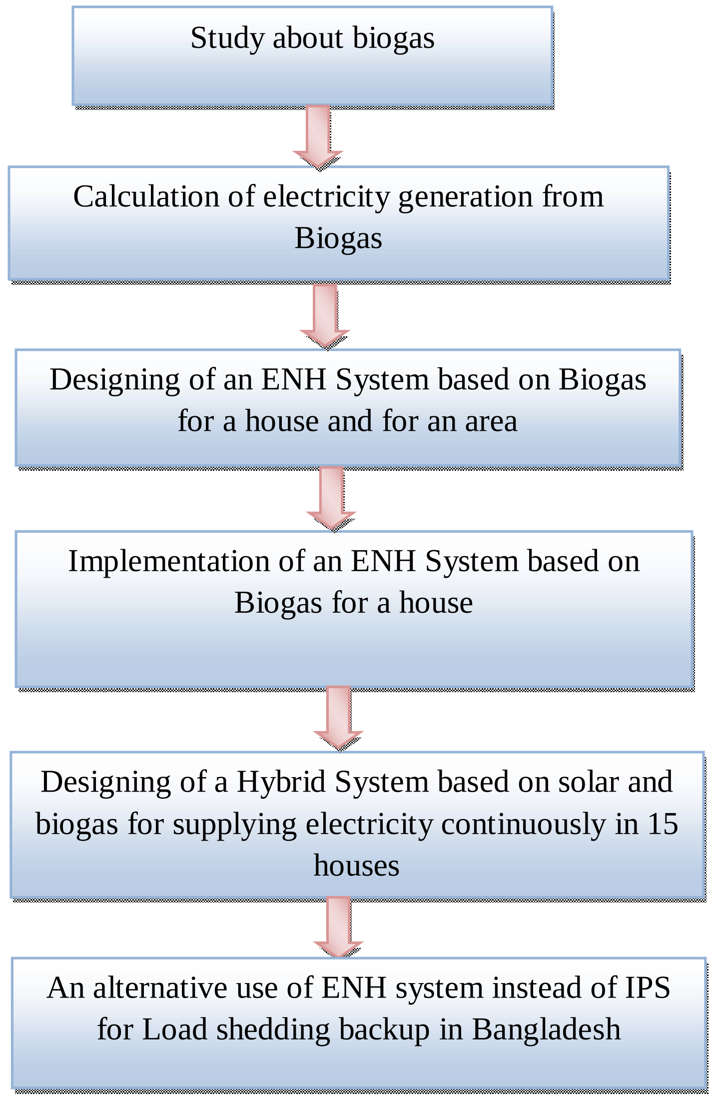


Figure 1.1: Methodology in flow chart.

1.5 THESIS LAYOUT

This thesis consists of fourteen chapters:

Chapter 1 describes the introduction of ENH system which includes introduction, scope of biogas plant in Bangladesh, its objectives and methodology.

Chapter 2 describes the materials and method of the energy neutral home (ENH) system.

Chapter 3 describes about the biogas in details.

Chapter 4 describes about the biogas production factors and biogas application.

Chapter 5 describes the observation of an experimental result to compare the properties of different types of waste.

Chapter 6 describes the calculation of electricity generation of the ENH system.

Chapter 7 describes the design of energy neutral home (ENH) system for a house.

Chapter 8 describes the implementation of the energy neutral home (ENH) system.

Chapter 9 discusses about the result, observation and cost analysis of the implemented ENH system.

Chapter 10 describes a process of design calculation using "C" programming.

Chapter 11 describes the design of an energy neutral home (ENH) system for an area.

Chapter 12 describes the design and cost analysis of a hybrid ENH system.

Chapter 13 describes how an ENH system can be used for load shedding backup instead of IPS.

Chapter 14 contains the conclusion and the suggestions for future work.

And the last portion of the thesis consists of references, keywords and appendix.

CHAPTER 2

MATERIALS AND METHOD OF ENERGY NEUTRAL HOME (ENH) SYSTEM

2.1 EFFECTIVENESS OF RENEWABLE ENERGY BASED ENH SYSTEM IN BANGLADESH

The renewable energy resources in Bangladesh are the solar, biogas, wind, hydro and tidal energy. Tidal energy conversion technology is still not cost effective for Bangladesh. Offshore wind farm is not suitable for Bangladesh because the wind speed is too small in most of places of Bangladesh. Although onshore wind farm is suitable for some of the areas, but wind is not considered too much available resources in Bangladesh. Another renewable energy source of Bangladesh is the small hydro. Small hydro is suitable for some selective spots. The most available and useful renewable resources of Bangladesh are solar and biogas. These two resources are available throughout the country. Electricity generation from biogas is cost effective in Bangladesh. But cost of electricity from photovoltaic cell is still too much high. But the combination of solar and biogas for electricity generation increase the system reliability and also decreases the cost. Where the biogas resource is not too much available solar-biogas hybrid system is cost effective there. But this hybrid system will not be cost effective for the areas that contain available biogas resources.

2.2 SELECTION OF RENEWABLE ENERGY SOURCE

Biogas is a renewable source of energy which is used as fuel for cooking, lighting, running vehicles and generators, etc. On the other hand, solar energy is also an excellent natural resource for the electricity generation. Due to the high cost of solar panel and battery, this design considered an energy neutral home system with biogas as primary source for a home or a residential/commercial area where the energy requirement is met without taking any electricity from grid. The availability of waste is an important factor of the design for biogas generation. If the wastes are available in a specific area, then the proposed system can run only with biogas for the reduction of installation cost. Thus the main objective of this research is to design a system to produce electricity by using biogas. To facilitate the availability of waste for biogas generation, the system should have poultry farms, cow farms or other sources of waste.

2.3 SYSTEM OVERVIEW

The system to be designed is similar to a small power plant. To design a completely energy neutral system, the renewable energy sources will be taken as the input of the plant.

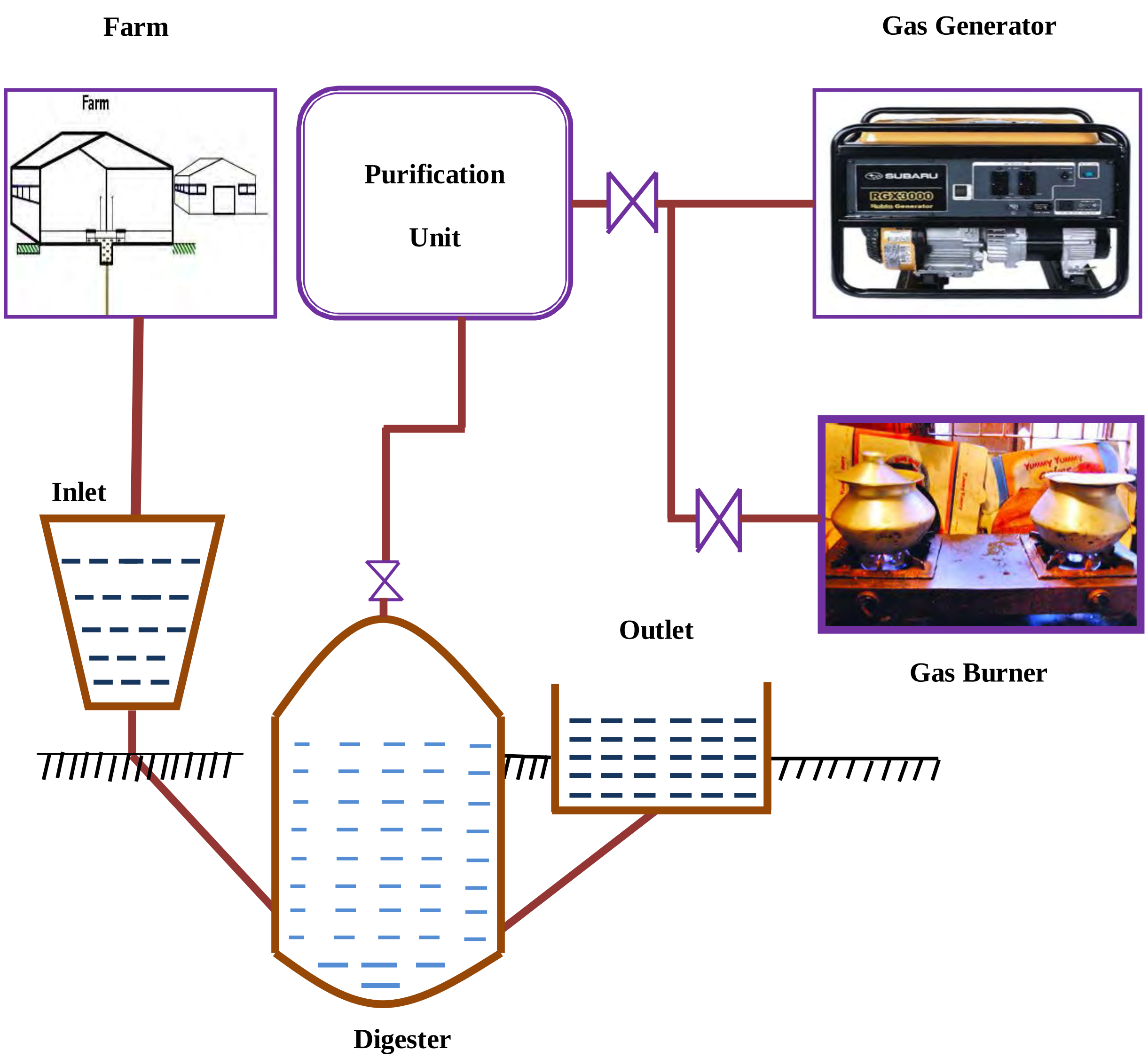


Figure 2.1: Block diagram of the designed ENH system

The system may be designed with single source only or more than one source together as hybrid but the focus is given to cost reduction. Considering the cost, the biogas source is selected as primary source for the proposed system. Poultry farms facilitate the waste for biogas generation in this system. The total load of the system is calculated and based on the calculated load the digester is designed. With this system all the necessary household energy requirements such as electricity generation, cooking etc. can be easily fulfilled. The system block diagram is shown in figure 2.1.

2.4 COMPONENTS AND OPERATION OF DESIGNED ENH SYSTEM

The components can be classified into two types:

1) Components for biogas based electricity generation.
    (a) Receiving tank/ inlet.
    (b) Digester.
    (c) Outlet.
    (d) Gas purification unit.
    (e) Gas generator.
    (f) Biogas burner
2) Control circuit, transmission line and other associate components.

2.5 COMPONENTS FOR BIOGAS

(I) RECEIVING TANK/ INLET: The waste is first taken to the receiver and mixed-up with water to make the favorable total solid (TS) value of the waste. The waste is then sent to the digester.

(II) DIGESTER: Digester is the main part of a biogas plant. The process of gas generation, called fermentation process occurs in the digester. The design of the digester should be such that no air can enter into the digester. The generated gas in the digester gather in the upper part of the digester called gas collected chamber.

(III) OUTLET: Due to the pressure of gas in the gas collection chamber some of waste goes out from the digester every day. They exit through the outlet.

(IV) GAS PURIFICATION UNIT: Biogas produced from poultry waste contains 60-65% methane. It also contains carbon di-oxide, hydrogen sulfide and some other impurities. These impurities affect the generator combustion process. The main purpose of the gas purification unit is to remove mainly the moisture and hydrogen sulfide.

(V) GAS GENERATOR: Gas generators are internal combustion gas engine. They internally burn the biogas and convert the chemical energy of the biogas to mechanical rotation which further converted into electrical energy.

(VI) BIOGAS BURNER: The biogas burners are special type of burners whose design is basically different from normal gas burner. By burning the biogas the biogas burners help in the purpose of cooking.

2.6 CONTROL CIRCUIT, TRANSMISSION LINE AND OTHER ASSOCIATE PARTS

The electricity will be supplied from the generator according to the load curve. The function of the control circuit is to switch the transmission system from biogas plant to the grid. This can be simply done by a manually operated circuit breaker.

In small hybrid system, power will be transmitted within a short distance. So transformer is not required for transmission and distribution purpose. Also protection of the transmission line is not required. Only simple wire is enough for transmission and distribution.

The other associate parts such as pipe line, special SS ball valves, electrical energy (kWh) meter (digital), manometer etc. are also used in the system for supplying the gas to the proper place, recording the electricity uses, monitoring the gas pressure.

CHAPTER 3

BIOGAS

3.1 ORIGIN OF BIOGAS

Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions. The natural generation of biogas is an important part of the biogeochemical carbon cycle. Methanogens (methane producing bacteria) are the last link in a chain of micro-organisms which degrade organic material and return the decomposition products to the environment. In this process biogas is generated, a source of renewable energy [18].

3.2 SUBSTRATE AND MATERIAL BALANCE OF BIOGAS PRODUCTION

In principle, all organic materials can ferment or be digested. However, only homogenous and liquid substrates can be considered for simple biogas plants: faeces and urine from cattle, pigs and possibly from poultry and the wastewater from toilets. When the plant filled, the excrement has to be diluted with about the same quantity of liquid; if possible, the urine should be used. Waste and wastewater from food-processing industries are only suitable for simple plants if they are homogenous and in liquid form. The maximum of gas-production from a given amount of raw material depends on the type of substrate [18].

3.3 COMPOSITION AND PROPERTIES OF BIOGAS

Compositions of biogas produced in anaerobic biogas reactors and at a landfill are shown in table 3.1 and table 3.2.

Table-3.1: Average composition of reactor biogas. [19]

Matter	**%**
Methane, CH_4	55-65
Carbon dioxide, CO_2	35-45
Nitrogen, N_2	0-3
Hydrogen, H_2	0-1
Hydrogen sulfide, H_2S	0-1

Table-3.2: Average composition of biogas recovered at a landfill (landfill biogas) [20], [21].

Matter	**Content**
Methane, CH_4	50 %
Carbon dioxide, CO_2	45 %
Oxygen, O_2	0.8 %
Nitrogen, N_2	5 %
Hydrogen sulfide, H_2S	21 mg/m^3
Halides	132 mg/m^3
NMOC’s (non methane organic compounds)	2700 mg/m^3

Total solid is a very important factor for optimum biogas production. Some solid contents are given in next page.

Table-3.3: The total solid content of common fermentation materials in rural areas (approximately) [22].

Materials	Dry matter content (%)	Water content (%)
Dry rice straw	83	17
Dry wheat straw	82	18
Corn stalks	80	20
Green grass	24	76
Human excrement	20	80
Pig excrement	18	82
Cattle excrement	17	83
Human Urine	0.4	99.6
Pig Urine	0.4	99.6
Cattle Urine	0.6	99.4

For the purpose of practical use CH_4 content is very important which can be analyzed by using digital gas analyzer.

Table-3.4: Biogas production rates of some fermentation materials and their main component. [22]

Materials and their main components	Yield of Biogas m^3/kg TS	Methane content (%)
Animal barnyard manure	0.260 ~ 0.280	50 - 60
Pig manure	0.561	0
Horse droppings	0.200 ~ 0.300	0
Green grass	0.630	70
Flax straw	0.359	0

Materials and their main components	Yield of Biogas m^3/kg TS	Methane content (%)
Wheat straw	0.432	59
Leaves	0.210-0.294	58
Sludge	0.640	50
Brewery liquid waste	0.300 ~ 0.600	58
Carbohydrate	0.750	49
Liquid	1.440	72
Protein	0.980	50

3.4 THE THREE STEPS OF BIOGAS PRODUCTION

Biogas microbes consist of a large group of complex and differently acting microbe species, notable the methane-producing bacteria. The whole biogas-process can be divided into three steps: hydrolysis, acidification, and methane formation. Three types of bacteria are involved [23], [24].

A. HYDROLYSIS:

In the first step (hydrolysis), the organic matter is enzymolyzed externally by extracellular enzymes (cellulose, amylase, protease and lipase) of microorganisms. Bacteria decompose the long chains of the complex carbohydrates, proteins and lipids into shorter parts. For example, polysaccharides are converted into monosaccharide. Proteins are split into peptides and amino acids.

B. ACIDIFICATION:

Acid-producing bacteria, involved in the second step, convert the intermediates of fermenting bacteria into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2). These bacteria are facultative anaerobic and can grow under acid conditions. To produce acetic acid, they need oxygen and carbon. For this, they use the oxygen solved in the solution or bounded-oxygen. Hereby, the acid-producing bacteria create an anaerobic condition which is essential for the methane producing microorganisms. Moreover, they reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. From a chemical standpoint, this process is partially endergonic (i.e. only possible with energy input), since bacteria alone are not capable of sustaining that type of reaction.

C. METHANE FORMATION:

Methane-producing bacteria, involved in the third step, decompose compounds with a low molecular weight. For example, they utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural conditions, methane producing microorganisms occur to the extent that anaerobic conditions are provided, e.g. under water (for example in marine sediments), in ruminant stomachs and in marshes. They are obligatory anaerobic and very sensitive to environmental changes. In contrast to the acidogenic and acetogenic bacteria, the methanogenic bacteria belong to the archaebacter genus, i.e. to a group of bacteria with a very heterogeneous morphology and a number of common biochemical and molecular-biological properties that distinguish them from all other bacterial general. The main difference lies in the makeup of the bacteria’s cell wells.

A simplified generic chemical equation for the overall processes outlined above is as follows:

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$$

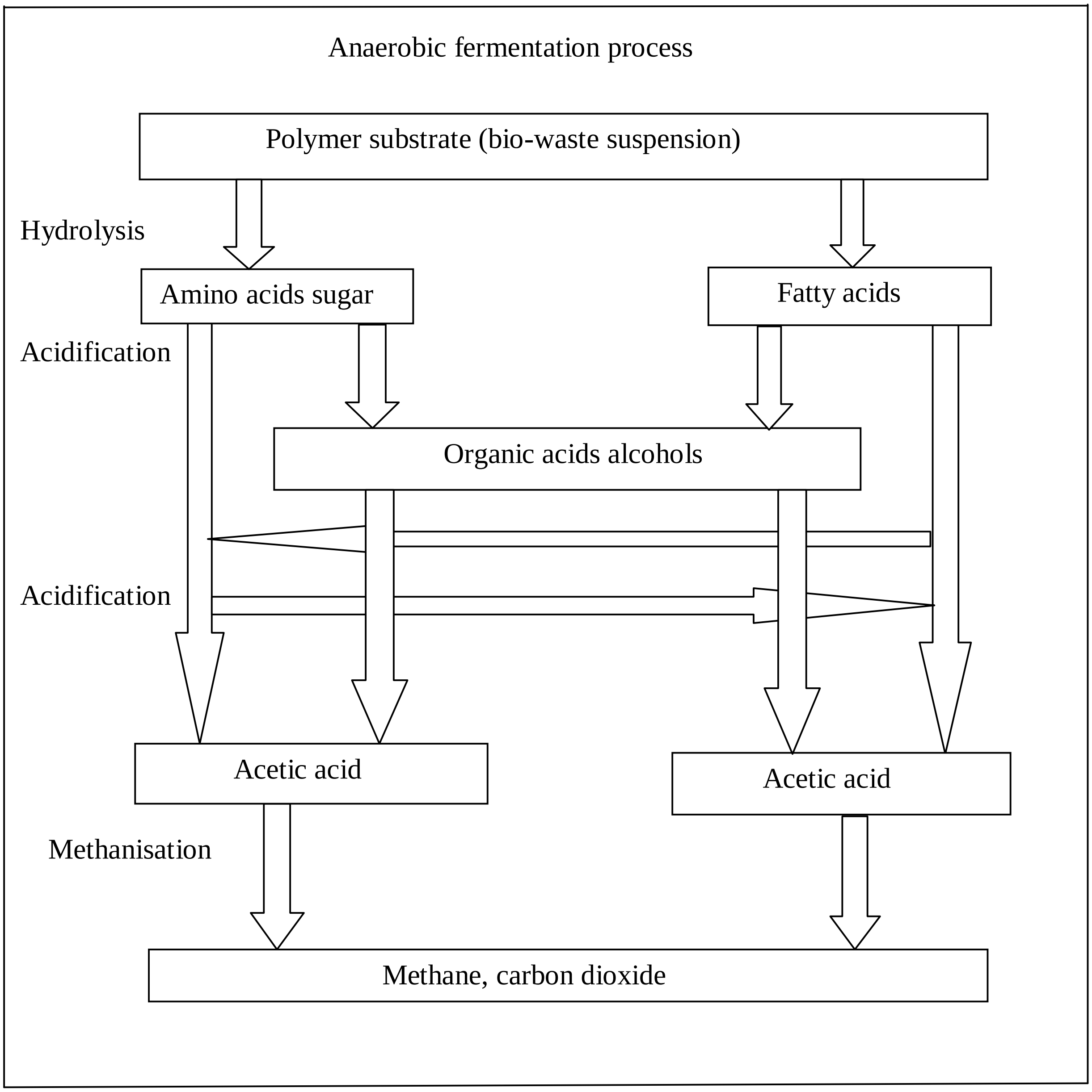


Figure-3.1: Block diagram of anaerobic fermentation process

Another way it can be shown as

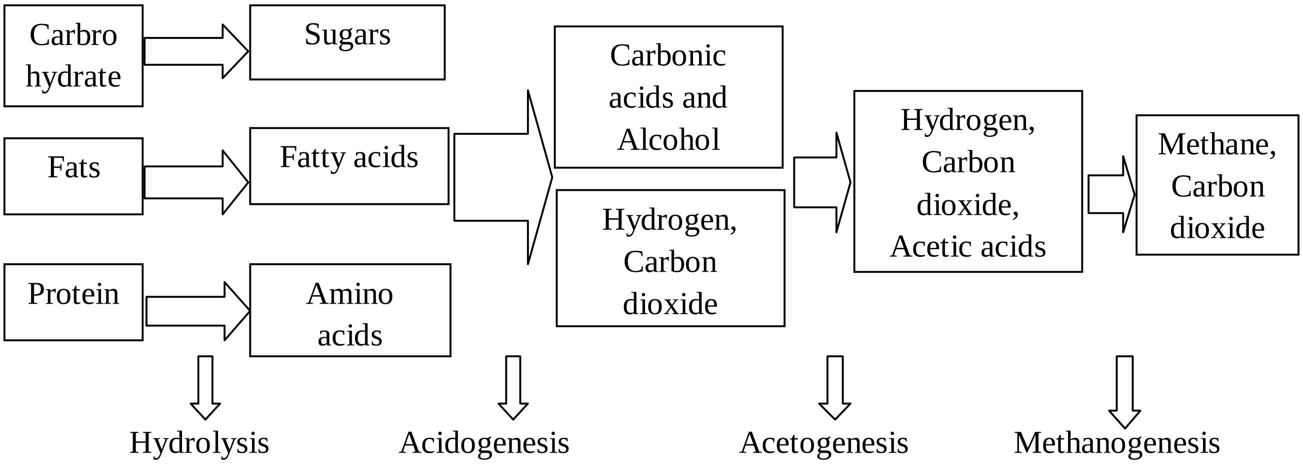


Figure-3.2: Block diagram of anaerobic fermentation process [23]

CHAPTER 4

BIOGAS PRODUCTION FACTORS AND BIOGAS APPLICATION

4.1 ANAEROBIC DIGESTION

Anaerobic digestion is a series of processes in which microorganisms break down bio-degradable material in the absence of oxygen. It is widely used to treat wastewater sludge's and organic wastes because it provides volume and mass reduction of the input material. As part of an integrated waste management system, anaerobic digestion reduces the emission of landfill gas into the atmosphere. Anaerobic digestion is a renewable energy source because the process produces methane and carbon dioxide rich biogas suitable for energy production helping replace fossil fuels. Also, the nutrient-rich solids left after digestion can be used as fertilizer.

The digestion process begins with bacterial hydrolysis of the input materials in order to break down insoluble organic polymers such as carbohydrates and make them available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. Acetogenic bacteria then convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Methanogens, finally are able to convert these products to methane and carbon dioxide.

Previously, the technical expertise required to maintain anaerobic digesters coupled with high capital costs and low process efficiencies had limited the level of its industrial application as a waste treatment technology. Anaerobic digestion facilities have, however, been recognized by the United Nations Development Programmers as one of the most useful decentralized sources of energy supply, as they are less capital intensive than large power plants [22], [23], [25], [26].

4.2 TYPES OF ANAEROBIC DIGESTION [18], [24]

There are two types of anaerobic digestion:-

(I) MESOPHILIC DIGESTION:

Different species of bacteria are able to survive at different temperature ranges. Ones living optimally at temperatures between 35-40°C are called mesophiles or mesophilic bacteria. And the feedstock remains in the digester typically for 15-30 days. Mesophilic digestion tends to be more robust and tolerant than the thermophilic process but gas production is less.

(II) THERMOPHILIC DIGESTION:

Some of the bacteria can survive at the hotter and more hostile conditions of 55-60°C, these are called thermophiles or thermophilic bacteria. And the residence time is typically 12-14 days. Thermophilic digestion systems offer higher methane production, faster throughput and better pathogen, but require more expensive technology, greater energy input and a higher degree of operation and monitoring. During this process 30-60% of the digestible solids are converted into biogas.

(III) PSYCHROPHILIC DIGESTION:

Another type of digestion is psychrophilic digestion which is occurred at the temperature range below 20°C. The bacteria at that temperature range are called psychrophiles or psychrophilic bacteria.

Mesophilic digestion is the most common approach since it is more reliable and plant management is easier.

4.3 ADVANTAGES OF ANAEROBIC DIGESTION AND PRODUCTION OF BIOGAS [27]

Processing organic waste anaerobic ally to create Biogas is a sustainable renewable waste to energy solution. The process offers numerous advantages over conventional technologies and if waste materials are used in the process in following ways:-

(i) Preventing the uncontrolled emissions of CH_4 (22 times more powerful than CO_2 as a greenhouse gas) from landfill.

(ii) The Bio fertilizer produced can displace mineral fertilizers. Nutrients a conserved with more than 90% of nutrients entering anaerobic digest conserved through the digestion process. By conserving nitrogen during digestion the C:N ratio of the treated manure is more favorable for plant growth.

(iii) Reducing the transport of waste.

(iv) Renewable electricity and heat can be produced, reducing greenhouse gas (GHG) emissions. Since anaerobic digestion operates in a closed system, substantial reductions in greenhouse gas emissions are achieved. Ammonia losses, while not of direct GHG concern, are also reduced.

(v) Odor levels are greatly reduced during manure processing, creating alternatively odor-free end product (closed vessel processing confines odorous compounds which are converted to other chemicals). The product of digestion has no more odour than compost.

(vi) Improvement in slurry characteristics such as: fluidity, crop compatibility, homogeneity, reduction of weed germs.

(vii) Anaerobic digestion greatly reduces pathogen levels. Pre- or post-digester technologies can ensure pathogen-free end products.

(viii) Production of electricity and heat provides valuable income.

(ix) Reducing the demand for additional mineral nitrogen helps decrease the use of natural gas for production of new mineral nitrogen, as well as reduce greenhouse gas emissions associated with nitrogen fertilizer production.

(x) Reduced land fill tax and climate change levy charges.

(xi) Income from Renewable Obligation Certificates (ROCs).

(x) Positive use of organic waste materials reduces land and water pollution.

4.4 DISADVANTAGES OF ANAEROBIC DIGESTION [27]

The disadvantages of anaerobic digestion are given below:

(i) Longer start-up time to develop necessary biogas inventory

(ii) May require alkalinity and/or specific ion addition

(iii) May require further treatment with an aerobic treatment process to meet discharge requirements.

(iv) Biological nitrogen and phosphorus removal is not possible

(v) Much more sensitive to the adverse effect of lower temperatures on reaction rates

(vi) May need heating (often by utilization of process gas) to achieve adequate reaction rates

(vii) May be more less stable after ‘toxic shock’ (e.g. after upsets due to toxic substances in the feed)

(viii) Increased potential for production of odors’ and corrosive gases.

(xi) Hazards arise from explosion.

(x) Anaerobic treatment is not effective for treatment of methanogenic landfill leach ate, it may (rarely) be efficacious for the early stage leach ate production period while the waste is still acetogenic.

4.5 VIABILITY OF ANAEROBIC DIGESTION [27]

The viability of an anaerobic digestion plant will depend on:-

(i) The availability of waste to give a feedstock of zero cost, and if a gate fee is charged for the waste received.

(ii) Whether the electricity generated is displacing existing demand and the type of contract.

(iii) The value at which the renewable obligation certificates (ROCs) are traded.

(iv) Whether value is derived from surplus heat and the bio fertilizer produced.

(v) Scale and location of the anaerobic digestion plant.

4.6 CONSIDERATION IN BIOGAS PRODUCTION [23], [24]

4.6.1 TECHNICAL CONSIDERATIONS

The biogas plant consists of two components: a digester and a gas holder. The digester is a cube-shaped or cylindrical waterproof container with an inlet into which the fermentable mixture is introduced in the form of liquid slurry. The gas holder is normally an air proof steel container that, by floating like a ball on the fermentation mix, cuts off air to the digester and collects the gas generated. In one of the most widely used designs the gasholder is equipped with a gas outlet, while the digester is provided with an overflow pipe to lead the sludge out into a drainage pit. The construction, design, and economics of biogas plants have been dealt with in the literature for biogas plant construction, important criteria are: a) the amount of gas required for a specific use or uses, and b) the amount of waste material available for processing.

4.6.2 ENVIRONMENTAL AND OPERATIONAL CONSIDERATIONS

(I) RAW MATERIALS [28]:

Raw materials may be obtained from a variety of sources - livestock and poultry wastes, night soil, crop residues, food-processing and paper wastes, and materials such as aquatic weeds, water hyacinth, filamentous algae, and seaweed. Different problems are encountered with each of these wastes with regard to collection, transportation, processing, storage, residue utilization, and ultimate use. Residues from the agricultural sector such as spent straw, hay, cane trash, corn and plant stubble, and biogases need to be shredded in order to facilitate their flow into the digester reactor as well as to increase the efficiency of bacterial action. Succulent plant material yields more gas than dried matter does, and hence materials like brush and weeds need semi-drying. The storage of raw materials in a damp, confined space for over ten days initiates anaerobic bacteria action that, though causing some gas loss, reduces the time for the digester to become operational.

(II) INFLUENT SOLIDS CONTENT [28], [29], [30]:

Production of biogas is inefficient if fermentation materials are too dilute or too concentrated, resulting in, low biogas production and insufficient fermentation activity, respectively. Experience has shown that the raw-material (domestic and poultry wastes and manure) ratio to water should be 1:1, i.e., 100 kg of excrete to 100 kg of water. In the slurry, this corresponds to a total solids concentration of 8 - 11 per cent by weight.

(III) LOADING [28], [31]:

The size of the digester depends upon the loading, which is determined by the influent solids content, retention time, and the digester temperature. Optimum loading rates vary with different digesters and their sites of location. Higher loading rates have been used when the ambient temperature is high. In general, the literature is filled with a variety of conflicting loading rates.

In practice, the loading rate should be an expression of either (a) the weight of total volatile solids (TVS) added per day per unit volume of the digester, or (b) the weight of TVS added per day per unit weight of TVS in the digester. The latter principle is normally used for smooth operation of the digester.

(IV) SEEDING [28], [31]:

Common practice involves seeding with an adequate population of both the acid-forming and methanogenic bacteria. Actively digesting sludge from a sewage plant constitutes ideal "seed" material. As a general guideline, the seed material should be twice the volume of the fresh manure slurry during the start-up phase, with a gradual decrease in amount added over a three-week period. If the digester accumulates volatile acids as a result of overloading, the situation can be remedied by reseeding, or by the addition of lime or other alkali.

(V) pH [28], [31]:

Low pH inhibits the growth of the methanogenic bacteria and gas generation and is often the result of overloading. A successful pH range for anaerobic digestion is 6.0 - 8.0; efficient digestion occurs at a pH near neutrality. A slightly alkaline state is an indication that pH fluctuations are not too drastic. Low pH may be remedied by dilution or by the addition of lime.

(VI) TEMPERATURE [28], [30], [31], [32]:

With a mesophilic flora, digestion proceeds best at 30 - 40°C; with thermophiles, the optimum range is 50 - 60°C. The choice of the temperature to be used is influenced by climatic considerations in general, there is no rule of thumb, but for optimum process stability, the temperature should be carefully regulated within a narrow range of the operating temperature. In warm climates, with no freezing temperatures, digesters may be operated without added heat. As a safety measure, it is common practice either to bury the digesters in the ground on account of the advantageous insulating properties of the soil, or to use a greenhouse covering. Heating requirements and, consequently, costs, can be minimized through the use of natural materials such as leaves, sawdust, straw, etc., which are composted in batches in a separate compartment around the digester,

(VII) NUTRIENTS [28], [30], [32], [33]:

The maintenance of optimum microbiological activity in the digester is crucial to gas generation and consequently is related to nutrient availability. Two of the most important nutrients are carbon and nitrogen and a critical factor for raw material choice is the overall C/N ratio. Domestic sewage and animal and poultry wastes are examples of N-rich materials that provide nutrients for the growth and multiplication of the anaerobic organisms. On the other hand, N-poor materials like green grass, corn stubble, etc., are rich in carbohydrate substances that are essential for gas production. Excess availability of nitrogen leads to the formation of NH_3, the concentration of which inhibits further growth. Ammonia toxicity can be remedied by low loading or by dilution. In practice, it is important to maintain, by weight, a C/N ratio close to 30:1 for achieving an optimum rate of digestion. The C/N ratio can be judiciously manipulated by combining materials low in carbon with those that are high in nitrogen, and vice versa.

(VIII) TOXIC MATERIALS [28], [31], [32]:

Wastes and biodegradable residue are often accompanied by a variety of pollutants that could inhibit anaerobic digestion. Potential toxicity due to ammonia can be corrected by remedying the C/N ratio of manure through the addition of shredded biogas of straw, or by dilution. Common toxic substances are the soluble salts of copper, zinc, nickel, mercury, and chromium. On the other hand, salts of sodium, potassium, calcium, and magnesium may be stimulatory or toxic in action, both manifestations being associated with the action rather than the anionic portion of the salt. Pesticides and synthetic detergents may also be troublesome to the process.

(IX) STIRRING [28], [31], [32], [33], [34]:

When solid materials not well shredded are present in the digester, gas generation may be impeded by the formation of a scum that is comprised of these low-density solids that are enmeshed in a filamentous matrix. In time the scum hardens, disrupting the digestion process and causing stratification. Agitation can be done either mechanically with a plunger or by means of rotational spraying of fresh influent. Agitation, normally required for bath digesters, ensures exposure of new surfaces to bacterial action, prevents viscid stratification and slow-down of bacterial activity, and promotes uniform dispersion of the influent materials throughout the fermentation liquor, thereby accelerating digestion.

(X) RETENTION TIME [28], [30]:

Other factors such as temperature, dilution, loading rate, etc., influence retention time. At high temperature bio-digestion occurs faster, reducing the time requirement. A normal period for the digestion of dung would be two to four weeks.

(XI) HEALTH HAZARDS [35]:

Health hazards are associated with the handling of night soil and with the use of sludge from untreated human excrete as fertilizer. In general, published data indicate that a digestion time of 14 days at 35℃ is effective in killing (99.9 per cent die-off rate) the enteric bacterial pathogens and the enteric group of viruses. However, the die-off rate for roundworm (Ascaris lumbricoides) and hookworm (Ancylostoma) is only 90 per cent, which is still high. In this context, biogas production would provide a public health benefit beyond that of any other treatment in managing the rural health environment of developing countries.

4.7 UTILIZATION OF BIOGAS AND SLURRY [23]

4.7.1 USES OF BIOGAS

As explained earlier, biogas is a mixture of different gases such as methane (50-60%), carbon dioxide (30-40%), hydrogen sulfide (less than 1%) and other gases such as nitrogen, hydrogen and carbon monoxide in traces. Biogas is a wet gas because it picks up water vapor from the slurry. Biogas is a flammable gas produced by microbes when organic materials are fermented in a certain range of temperature, moisture contents under anaerobic conditions. The main component of biogas is methane, which is colorless, odorless and tasteless, but due to the presence of other gases it gives slight smell of garlic or rotten eggs. Methane is formed from the fermentation of animal waste or any other cellulose organic materials such as decaying vegetables, straw and so on. However, for this to work certain conditions such as air tightness, suitable temperature, necessary nutrients, water contents, and maintaining suitable pH balance must be maintained. Since biogas is a high quality fuel, it can be used for many purposes besides cooking and lighting, such as fuel for running dual fuel engine, for agro processing, pumping water and for generating electricity. A brief description of each use is given below:

4.7.1.1 COOKING

The main use of biogas, at present, is for domestic purposes, such as cooking and lighting. Biogas can be used with suitably designed burners to give a clean, smokeless, blue flame, which is ideal for cooking. More than 87 percent of the people in Nepal use firewood for cooking. If the trend continues all forest will disappear in less than 25 years. It is believed that biogas will help in reducing deforestation as majority of the biogas owners use the gas for cooking.

4.7.1.2 LIGHTING

Most of the Nepalese people in rural settlements use kerosene for lighting lamps. Nepal has no indigenous sources of kerosene. As such the country has to spend scarce foreign exchange and supplies are often unpredictable. Biogas owners especially in the hills where there is no electricity prefer the use of biogas facilities for lighting.

4.7.2 USES OF BIO-SLURRY [36]

The various uses of slurry can be summarized as follows:

4.7.2.1 FERTILIZER

Fertilizer is an essential input for any crop. The slurry is rich in various plant nutrients such as nitrogen, phosphorous and potash. Well-fermented biogas slurry improves the physical, chemical and biological properties of the soil resulting qualitative as well as quantitative yield of food crops. Nitrogen remains in the effluent of bio fertilizer from the slurry, whiles one escapes as ammonia gas. When the effluent is dried, most of the nitrogen is lost. Slurry from the biogas plant is more than a soil conditioner, which builds good soil texture, provides and releases plant nutrients. It was found that the slurry from an aerobic fermentation of a biogas digester improves the physical and chemical properties of the soil. Since there are no more parasites and path organism the slurry, it is highly recommended for use in farming. The economic value of the slurry shows that investment can be gained back in three to four year's time if slurry is properly used.

4.7.2.2 FEEDING FISH AND ANIMALS

Other uses of the slurry include putting it into ponds as feed for a algae, water hyacinth, fish or ducks; using it in hydroponics, where plants are grown in a nutrient rich solution on a graveled or even using it as feed supplement for pigs and chickens. The author conducted an experiment in feeding slurry (about 15%) to the fishpond and about 200 fishes were harvested at the end of the experiment.

4.7.2.3 MUSHROOM CULTIVATION

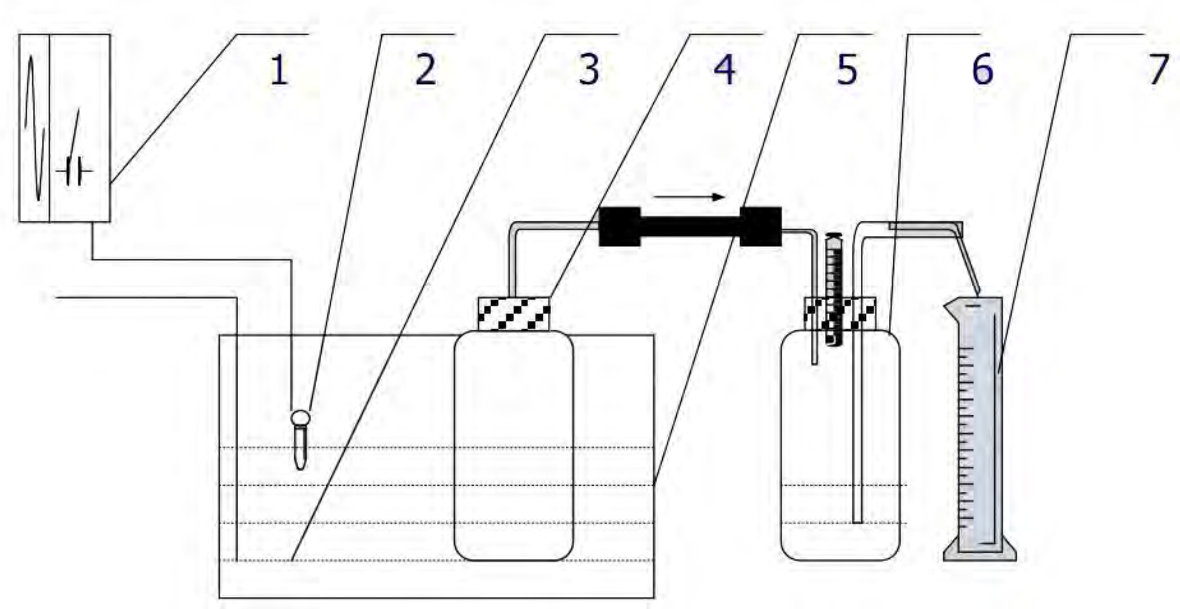
The slurry coming from the plants can also be used for mushroom cultivation. The slurry mixed with powder of rice straw or wheat straw, water, lime, urea, calcium super phosphate, powder of maize when put in a plastic bag with some seeds of mushroom and keeping in a room temperature of about 22-25 degree Celsius will be ready for cultivation within about six weeks.

CHAPTER 5

OBSERVATION OF AN EXPERIMENTAL SETUP

5.1 OBSERVATION FROM AN EXPERIMENTAL SETUP

To observe the gas production capacity and other characteristics of the different types of waste, a standard result of a research is taken into account [37]. In this research, the author's main objective was to investigate the anaerobic treatability and biogas production characteristics of different materials at different temperature. The reason behind that research was to help to reduce the environmental pollution because every year in the world several million tons of agricultural wastes are disposed through different ways, which has polluted living environment. The experimental setup used is shown in figure 5.1.



Description of all parts of the experimental setup
1. Temperature controlled box, **2.** Temperature sensor, **3.** Heated wire, **4.** Fermentation reactor, **5.** Water bath, **6.** Biogas gathered device, **7.** Measuring cylinder

Figure 5.1: The process setup. [37]

The setup shown in figure 5.1 was adopted with controllable constant-temperature fermented process where pig dung, cow dung, chicken dung, night soil of human, wheat straw, rice straw and corn stalk were selected as fermented materials. The chosen anaerobic fermentation temperatures were 25^0C, 30^0C, 35^0C and 40^0C. Every fermentation reactor was seeded with 500 g of the culture, after the addition of materials, water was added. The final weight and total solid (TS) of fermentation slurry was 3.5 Kg and 8% respectively.

5.2 THE EXPERIMENTAL RESULT

The experimental results of the research are depicted in figures 5.2 to 5.5.

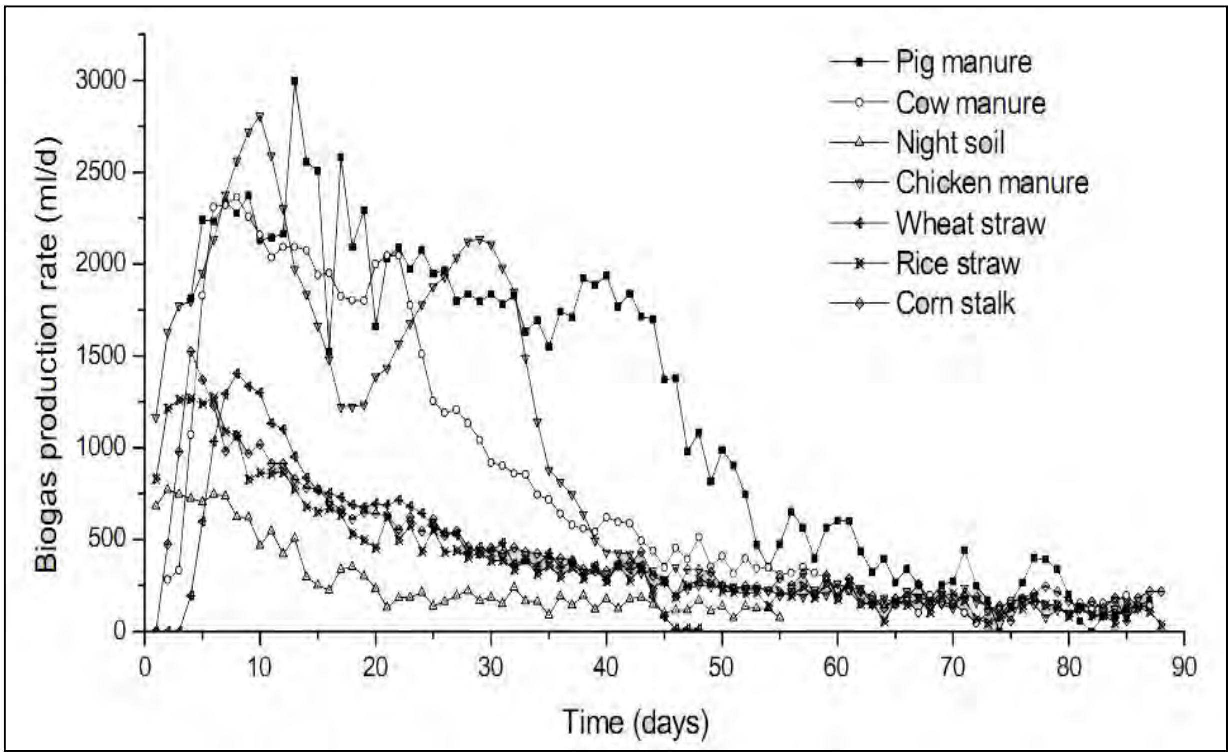


Figure 5.2: Biogas production rates of seven materials at 25 °C [37]

From figure 5.2 it is clear that pig manure, cow manure, chicken manure, night soil, wheat straw, rice straw and corn stalk can all produce biogas. The gas production peak of these was generally within 30 days. Again, the pig manure, cow manure and chicken manure had several gas production peaks.

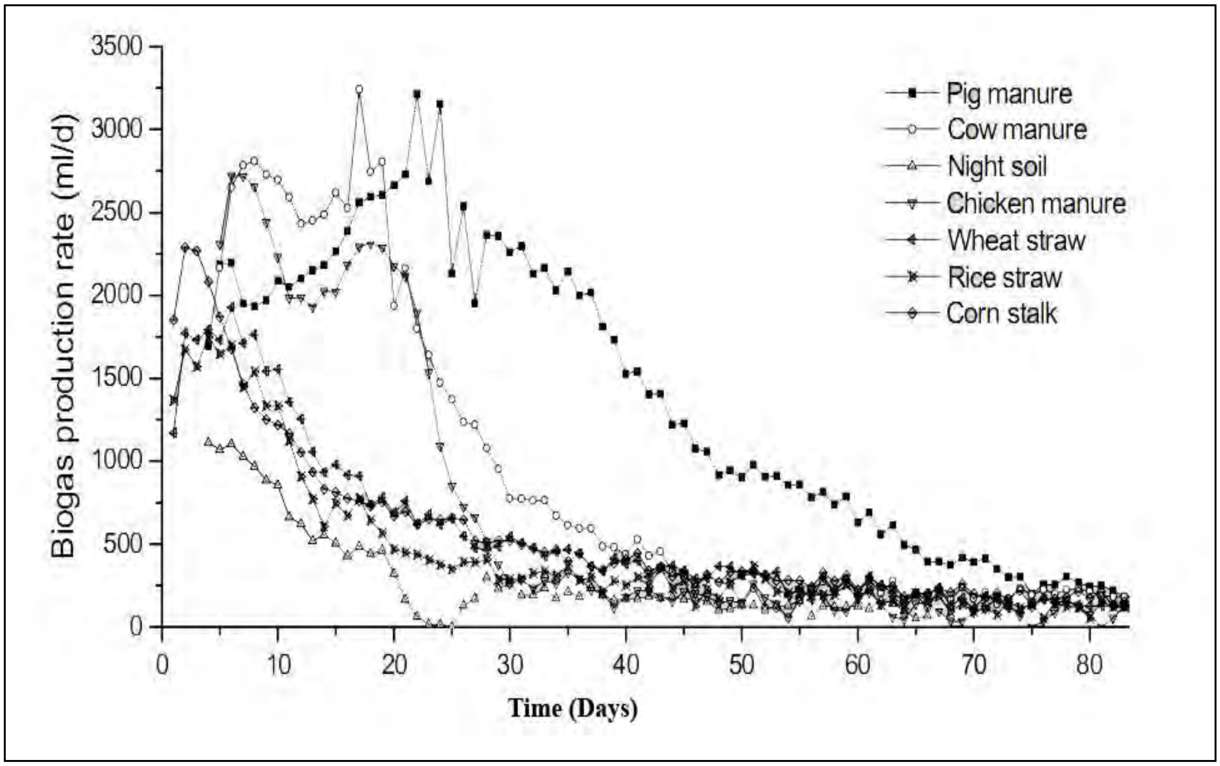


Figure 5.3: Biogas production rates of seven materials at 30 °C [37]

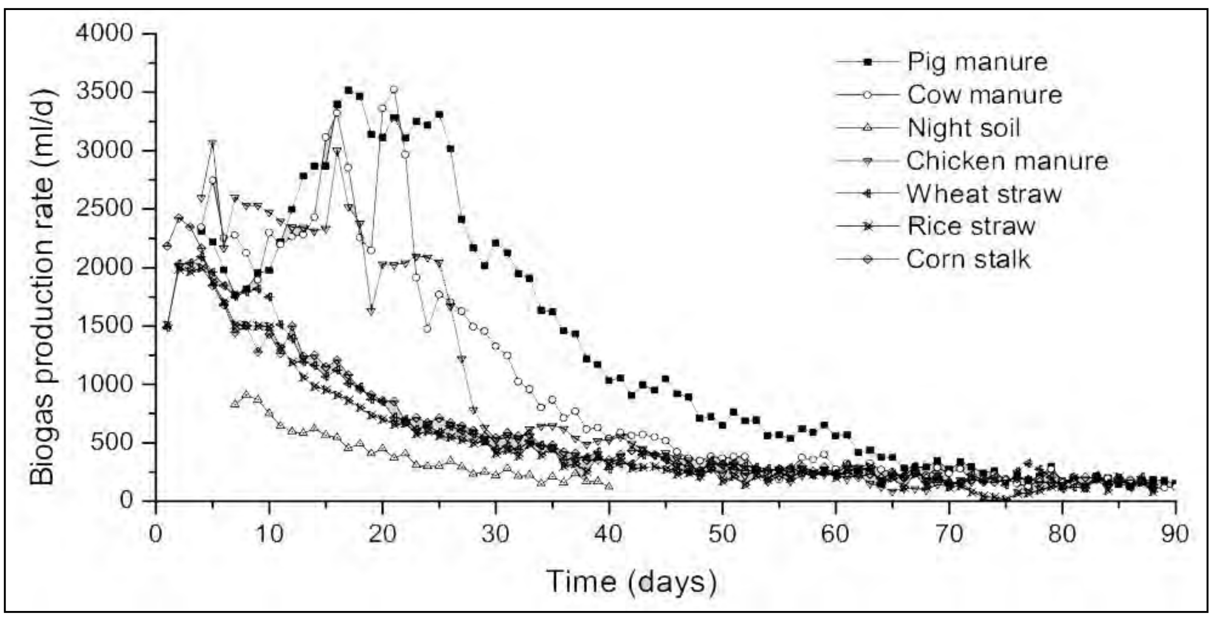


Figure 5.4: Biogas production rates of seven materials at 35 °C [37]

The figure 5.3 and figure 5.4 declare that the biogas production characteristics of pig dung was best, under the constant temperature of 30^0C, the cumulative biogas production was 113767 ml, the biogas production rate of dry matter was 474.0 ml/g TS, and the reaction time was 89 days. The worst was night soil, under the constant temperature of 35^0C the cumulative biogas production was 14543 ml, the biogas production rate of dry matter was 60.6 ml/g TS, and the reaction time was 36 days.

On the other hand, except night soil, the biogas production characteristics of the dung were better than straws, the biogas production characteristics of corn stalk was better than wheat straw and rice straw. Under the constant temperature of 35^0C, the cumulative biogas production of dry matter was 54547 ml, the biogas production rate of dry matter was 227.3 ml/g TS, and the reaction time was 90 days. If crop straw were used as fermentation material had best mixed with dung of livestock.

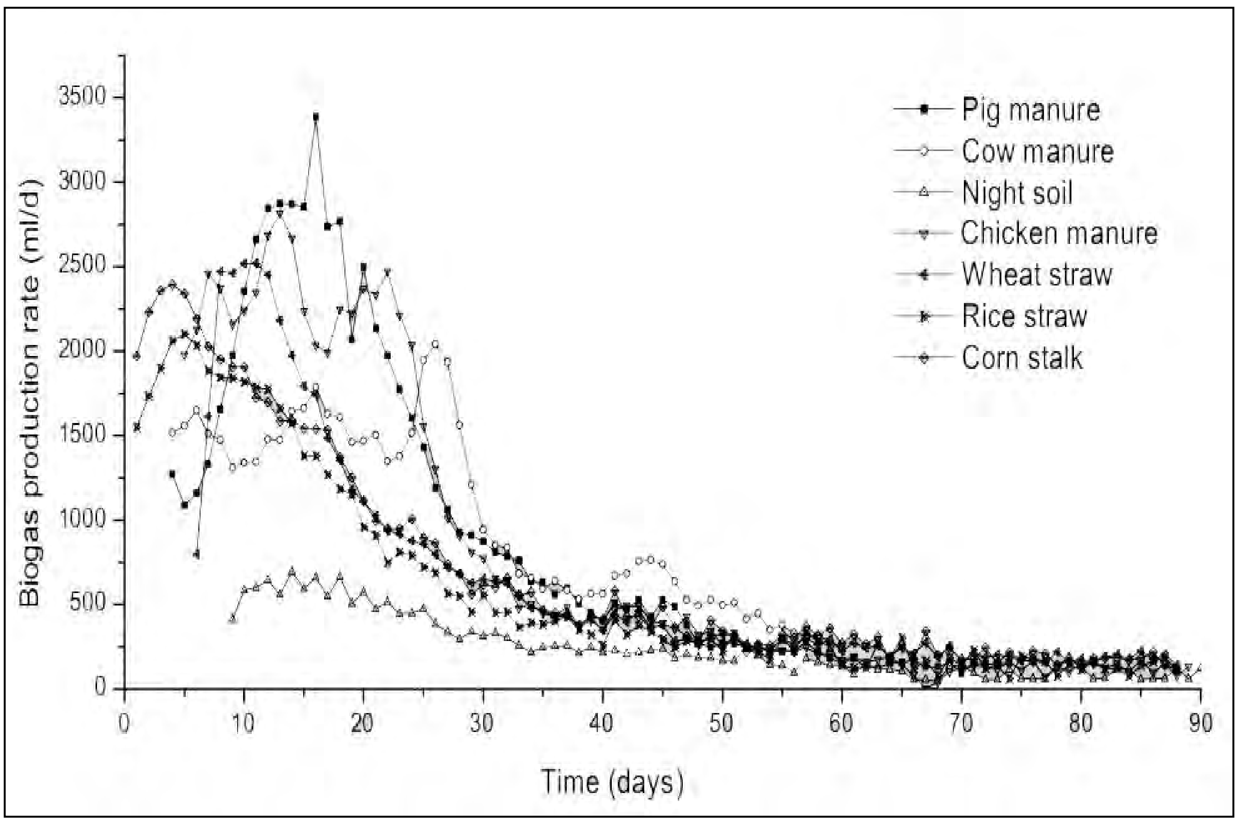


Figure 5.5: Biogas production rates of seven materials at 40 °C [37]

5.3 DISCUSSION ON RESULT OF THE EXPERIMENT

So, finally it can be concluded here from the result of this research that-

a) Seven kinds of raw materials can all be used in anaerobic fermentation.
b) The biogas production characteristics of pig dung was best, the worst was night soil.
c) Except night soil, biogas yields of the dung were better than straws, biogas production characteristics of corn stalk was better than wheat straw and rice straw.

CHAPTER 6

CALCULATION OF ELECTRICITY GENERATION

6.1 DATA COLLECTION

GTZ (Deutsche Gesellschaft fur Technische Zusammenarbeit) office of Gulshan-2, Dhaka 1212, Bangladesh, is visited for collecting information about biogas plant on January, 2011. Some practical data of biogas generation from poultry waste and cow dung is provided by Dr. Engineer Khursheed-Ul-Islam, senior advisor of the project Sustainable Energy for Development (SED) under GTZ. One of their running projects in Dhaka is also visited. The next visited company is Rahman Renewable Energy Co. Ltd, Local Office of IDCOL (Infrastructure Development Company Limited), Joydebpur, Gajipur, Bangladesh. IDCOL installs biogas plant for cooking purpose in different places of Bangladesh. Some information about the cost of biogas plant installation is supplied by the officers of IDCOL. Mr. Md. Rafiqul Islam, executive director of SEED Bangla Foundation also helped at the time of implementation of the ENH system.

6.2 CALCULATION OF ELECTRICITY GENERATION FROM POULTRY WASTE

Let the number of broiler = n

From practical data each broiler gives 100 gm of waste per day [38].

So, from n number of broilers the total available waste,

$$= \frac{n \times 100}{1000} = 0.1n\ kg$$

Again, practically $0.07\ m^3$ of biogas is got from 1 kg of waste [39].

So, total biogas obtained from n number of broilers

$$= 0.1n \times 0.07\ m^3 = 0.007n\ \ m^3$$

From each cubic meter biogas the produced electricity is 1.4 kWh [39].

So, from n number of broilers the electricity obtained

$$= 0.007n \times 1.4 = .0098n \approx 0.01n\ kWh$$

If the electricity is used for 10 hours/day then capacity of the poultry farm for electricity generation can be obtained by the following equation

$$Capacity = \frac{0.01n}{10}\ kW, where\ n\ is\ the\ number\ of\ boiler$$

As example, if a farm has 10,000 number of broiler then it's capacity

$$C = \frac{0.01 \times 10{,}000}{10} = 10\ kW$$

For only one broiler the produced electricity per day,

$$= \frac{0.01}{10} = 0.001\ kW = 1\ W$$

So, finally it can be said that 1w electricity is produced from one broiler and 1 kW electricity is produced from 1 thousand broilers for 10 hours/day electricity consumption.

Table 6.1: Amount of Biogas and Electricity production from poultry waste.

No of broiler	Estimated gas production capacity (m^3)	Waste required/day (kg)	Water required per day (liter)	Required manure for primary charging (kg)	Estimated using time (hour)	Capacity of electricity generation (kW)
1000	7	90	180	4500	5	2
10,000	70	920	1840	40,000	10	10
30,000	210	2900	5800	120,000	10	30
50,000	350	4400	8800	220,000	10	50
1,00,000	700	8800	17600	440,000	10	100

6.3 CALCULATION OF ELECTRICITY GENERATION FROM COW DUNG

On an average each cow gives 10 kg cow dung per day [38].

For n number of cows, total cow dung $= 10n\ kg$

Again, practically $0.037\ m^3$ biogas is produced from 1 kg of waste [39], [40].

So, total biogas obtained from n number of cows

$$= 10n \times 0.037\ m^3 = 0.37n\ \ m^3$$

From each cubic meter biogas the produced electricity is 1.4 kWh [39].

So, from n number of cows electricity obtained

$$= 0.37n \times 1.4 = 0.518n\ kWh$$

For 10 hours/day, the capacity of the farm for electricity generation can be obtained by the following equation

$$Capacity = \frac{0.518n}{10}\ kW, where\ n\ is\ the\ number\ of\ broiler$$

As for example, if a farm has 20 number of cows then its capacity

$$C = \frac{20 * 0.518}{10} = 1\ kW$$

For only one cow we get electricity per day,

$$= \frac{0.518}{10} = 0.0518\ kW = 50\ W$$

So, finally it can be said that 50w electricity is produced from one cow and 50kW electricity is produced from 1 thousand cows for electricity consumption of 10 hours/day.

Table 6.2: Amount of Biogas and Electricity production from cow dung.

No of cow	Estimated gas production capacity (m^3)	Waste required/day (kg)	Water required per day (liter)	Required manure for primary charging for HRT of 40 days (kg)	Estimated using time (hour)	Capacity of electricity generation (kW)
20	**7.4**	**200**	**200**	**8000**	**5**	**2.0**
50	**18.5**	**500**	**500**	**20,000**	**10**	**2.5**
100	**37**	**1000**	**1000**	**40,000**	**10**	**5**
250	**92.5**	**2500**	**2500**	**1,00000**	**10**	**12.5**
500	**185**	**5000**	**5000**	**2,00000**	**10**	**25**

6.4 CALCULATION OF ELECTRICITY GENERATION FROM HUMAN WASTE

On an average each person gives 0.5 kg of waste per day [38].

For n numbers of persons the total waste $= 0.5n\ kg$

At ordinary temperature (30^0 C) biogas obtained from human waste 0.365 m^3/ kg TS [41].

Again TS value of human waste = 20%

So, total biogas obtained from n number of persons

$$= 0.5n \times 0.2 \times 0.365\ m^3 = 0.0365n\ \ m^3$$

From each cubic meter biogas the produced electricity is 1.4 kWh [39].

So, from n number of persons electricity obtained

$$= 0.0365n \times 1.4 = 0.0511n\ kWh$$

If the electricity is used for 2 hours/day then capacity of the farm for electricity generation can be obtained by the following equation

$$Capacity = \frac{0.0511n}{2}\ kW, where\ n\ is\ the\ number\ of\ persons$$

As example, if a 5 storied building has 45 number of persons then its capacity

$$C = \frac{0.0511 \times 45}{2} = 1.15\ kW$$

CHAPTER 7

DESIGN OF ENERGY NEUTRAL HOME (ENH) SYSTEM FOR A HOUSE

7.1 SELECTION OF SITE

The site that is nearest to the place of raw materials as well as appliances to be used for the following reasons.

a) Extra labour requires to feed the digester if it is too far from the source of raw materials.
b) Longer length of gas distribution pipe line will reduce the design pressure in a considerable amount.
c) Construction cost will be higher.
d) Condensate could be trapped if any sag in long gas pipe line which may block the gas pipe line.

Considering the reasons stated above, the site is selected in Pomora, Burirdokan (Talukder Para), Rangunia, Chittagong where all of the facilities exist. The design factors of the system are selection of site, the availability of waste, the nature of waste, the size of the digester, the amount of load and the capacity of the generator. By considering these design factors the location of the system is selected. The address of the selected location is Village: Pomora, Talukder Para, P.S.: Rangunia, District: Chittagong, Bangladesh. The Owner of the selected home is Mr. Anil Kanti Das. There are five poultry farms in selected location and thus poultry wastes are available here which facilitates the biogas generation.

7.2 DESIGN PARAMETERS [40], [41]

7.2.1 HYDRAULIC RETENTION TIME (HRT)

Hydraulic retention time of manure is the number of days during which we get a considerable amount of gas. In the climate of Bangladesh a certain amount of manure can produce gas about 40-45 days [40].

So, for Bangladesh HRT=40 days. The HRT for poultry manure is shown in figure 7.1.

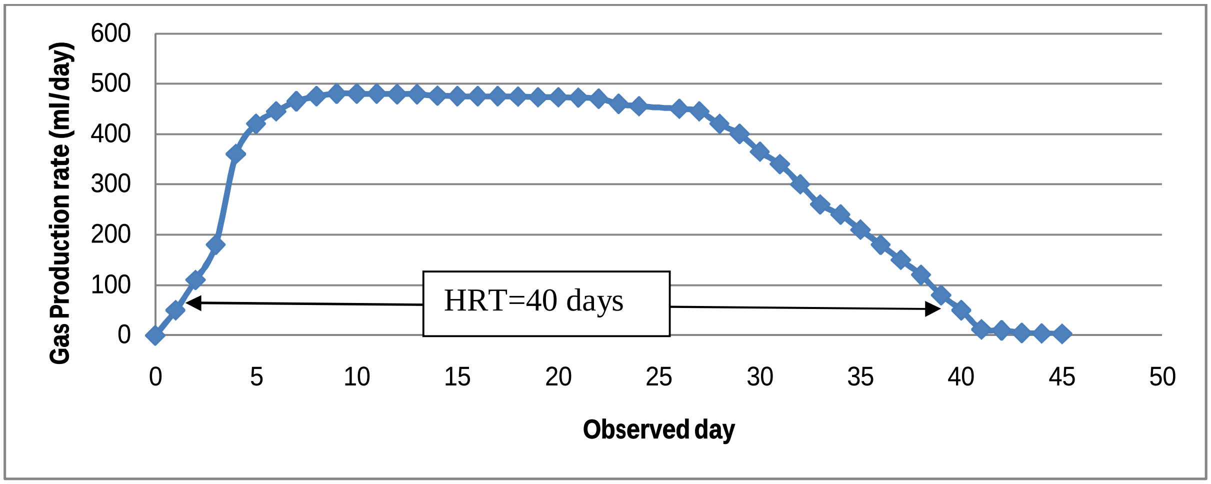


Figure 7.1: Hydraulic retention time (HRT) for poultry manure.

7.2.2 TOTAL SOLID (TS)

Total solid indicate the amount of material without considering the liquid part. Total solid contained in a certain amount of materials is usually used as the material unit to indicate the biogas producing rate of materials.

Most favorable TS value desired is 8% for smooth fermentation process.

7.2.3 FRESH DISCHARGE

Fresh discharge is the total amount of manure including moisture content directly obtained from the cow, chicken, human etc.

7.2.4 LIQUID PART

It is the amount of water to be added with fresh discharge to make the TS value 8%. The table 7.1 shows the amount of solid and liquid contents in different types of waste.

Table 7.1: The solid and liquid content of common fermentation materials. [41]

Materials	Dry matter content (%)	Water content (%)
Human	20	80
Cow	16	84
Chicken	20	80
Pig	20	80

7.2.5 RELATIONSHIP BETWEEN TEMPERATURE AND HRT (FOR CONSTANT TS VALUE OF 8%)

When the temperature increases, then the HRT value decreases. This is depicted in figure 7.2. On the other hand, table 7.2 shows the amount of TS value and water to be added for different types of waste.

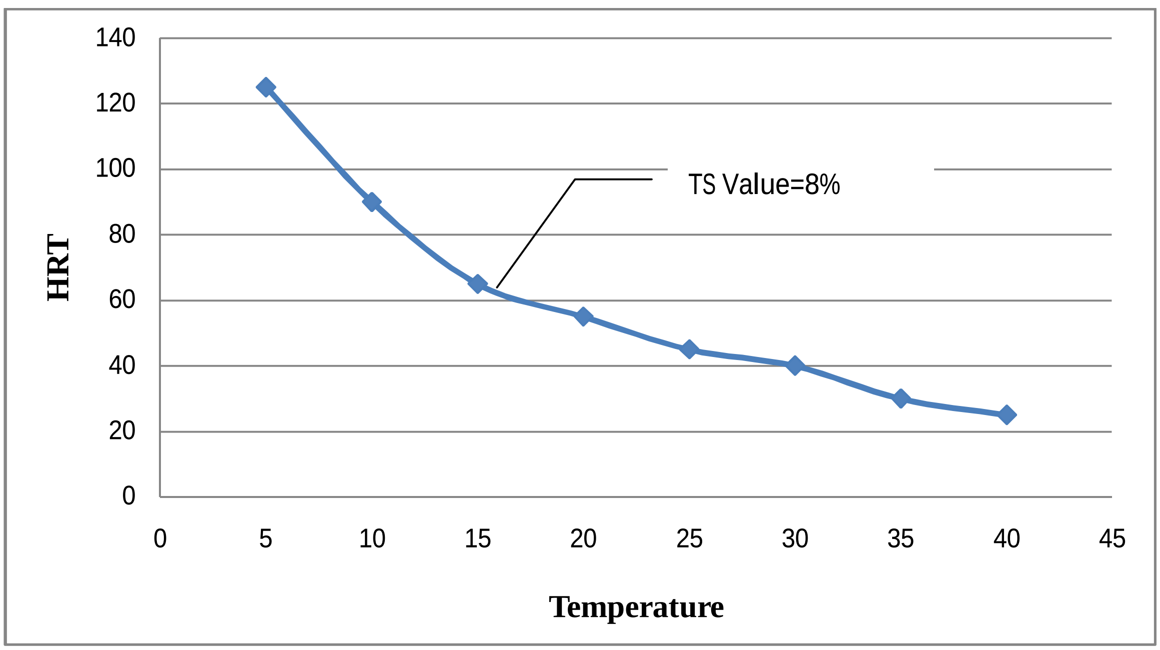


Figure 7.2: Temperature Vs. HRT curve at constant TS value. [41]

Table 7.2: Table showing discharge per day, TS value of fresh discharge and water to be added to make favorable TS condition. [41]

Kinds	**Body weight (kg)**	**Discharge per day (kg)**	**TS value of fresh discharge (% by wt.)**	**Water to be added with fresh discharge to make the TS value 8% (kg)**
Human	50	0.5	20	0.75
Cow	200	10	16	10
Chicken	1.5	0.1	20	0.15
Pig	50	5	20	7.5

7.2.6 C/N RATIO

It is the carbon to nitrogen ratio. This ratio indicates the biogas production capacity of different types of waste. Favorable range of the C/N ratio is from 20:1 to 30:1 to have proper biogas production capacity [38], [40]. The C/N ratio for various types of waste is given in table 7.3.

Table 7.3: Carbon-Nitrogen ratios of some common fermentation materials (approximately). [38]

Material	**Carbon content of material (%)**	**Nitrogen content of materials (%)**	**Carbon-nitrogen ration (C/N)**
Fresh Cattle Dung	46	0.53	87:1
Fresh pig manure	7.8	0.6	13:1
Fresh Human Waste	2.5	0.85	29:1
Fresh sheep dropping	16	0.55	29:1
Dry rice straw	42	0.53	67:1
Fallen leaves	41	1	41:1

7.3 BIOGAS PLANT DESIGN OF THE SYSTEM

7. 3.1 THE ENERGY DEMAND OF A STANDARD HOME

The gas containing capacity of the digester in the designed system is 6 m^3 which is a standard value to neutralize a home. To meet the energy requirement the proportion of the produced gas is depicted in figure 7.3. The energy demand of the designed system is shown in table 7.4. The used loads in the system are seven energy saving bulbs (two bulbs of 12W, three bulbs of 15W and two bulbs of 25W), four ceiling fans (75W), one color TV (100W) and one refrigerator (150W). According to the energy demand the amount of load is calculated as shown in table 7.5. From that table it is clear that the maximum demand is 400W at the interval 6 to 10 PM throughout a day. The load curve is shown in figure 7.4 where the total unit of used electricity is 5.1 kWh per day. The proportion of gas for house hold uses is calculated as below:

Taking the HRT value of 40 days,

0.037 m^3 gas is produced from 1 kg cow dung where the waste to water mixing ratio is 1:1.

0.07 m^3 gas is produced from 1 kg poultry waste where the waste to water mixing ratio is 1:2.

To run a biogas burner for 1 hour, the required amount of gas is 0.4 m^3. [40]

So, to run two biogas burners for 2.5 hour, the required amount of gas is = 2 x 2.5 x 0.4 = 2 m^3.

The rest of the gas (4 m^3) is used for electricity generation.

Thus according to the calculated proportion, the percentage is shown in figure 7.3.

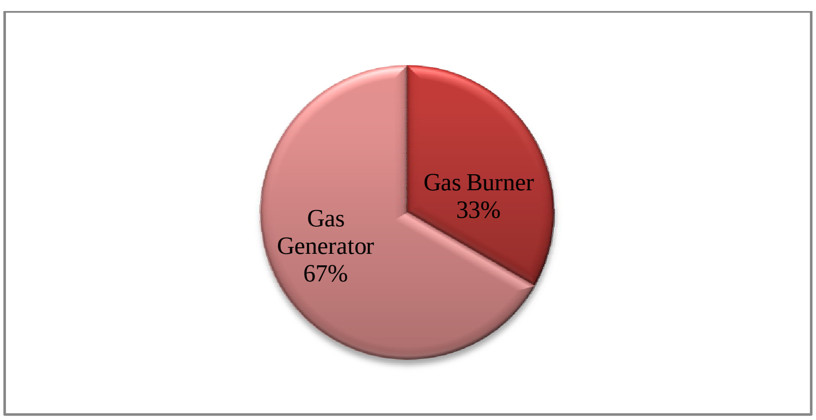


Figure 7.3: The proportion of gas for electricity and cooking.

Table 7.4: The energy demand of the proposed system.

Load	Rating (Watts)	Number	Total Power (Watts)
Energy Saving Bulb	15	3	45
Energy Saving Bulb	25	2	50
Energy Saving Bulb	12	2	24
Ceiling Fan	75	4	300
Color TV	100	1	100
Refrigerator	150	1	150
		Total	669

Table 7.5: Load Calculation according to the demand

Time	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
Load (W)	0	0	0	250	300	0	400	400	300	300	300	300

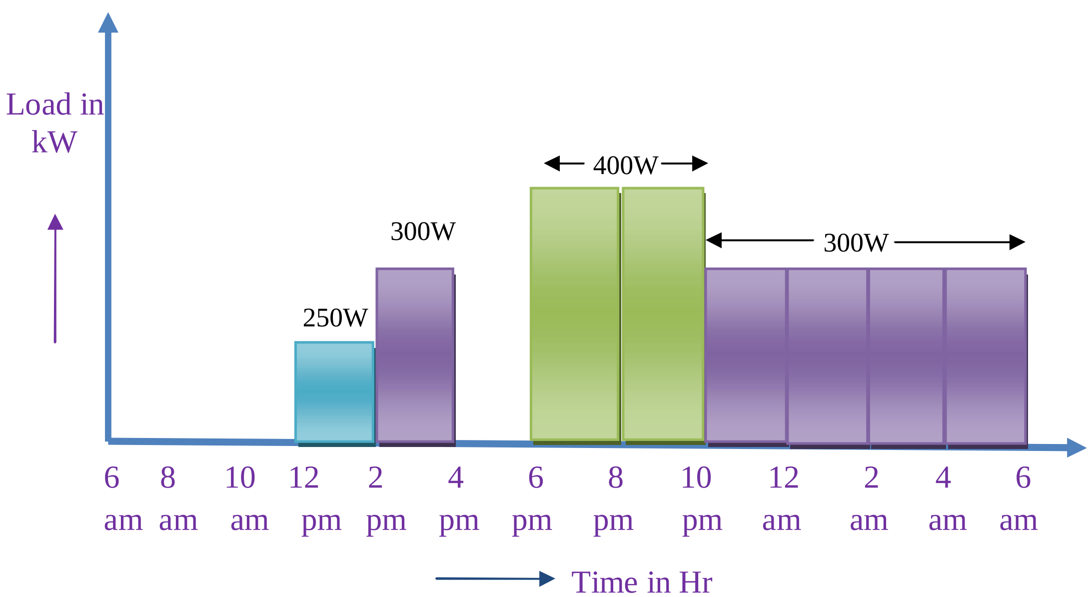


Figure 7.4: Load curve for electricity supply

7.3.2 DESIGN OF BIOGAS PLANT

For the designed ENH system the biogas plant (gas containing capacity of $6m^3$) is essential which needs a poultry farm of about 800 broilers (or layers) or a cow farm of 16 cows. The biogas plant for the system is designed for two options separately. The biogas plant design mainly consists of digester design and design of hydraulic chamber. The digester cross section and the geometrical assumptions are shown in figure 7.5 and table 7.6 respectively.

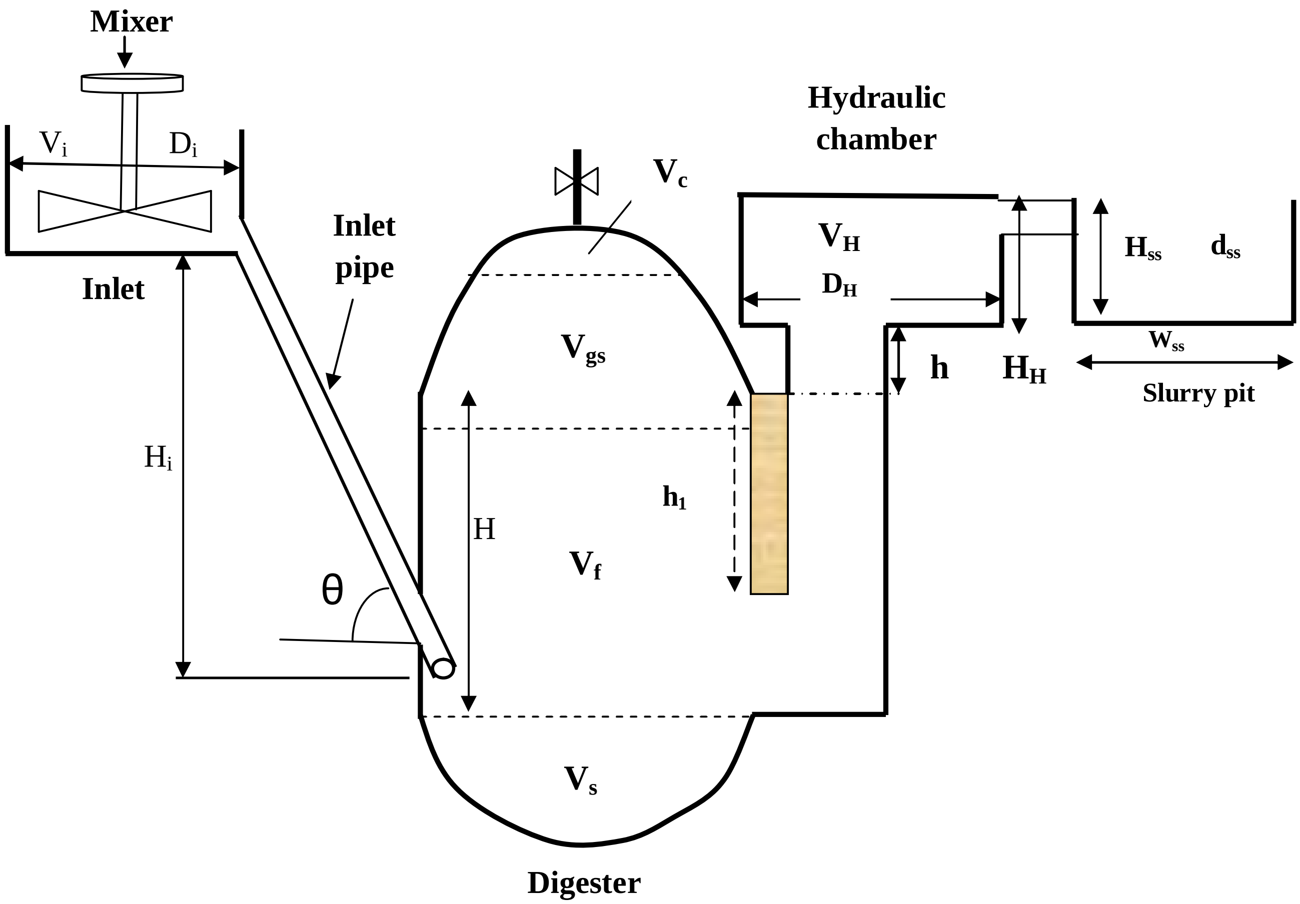


Figure 7.5: Schematic diagram of the biogas plant

Here, Volume of inlet = V_i, Volume of gas collecting chamber = V_c

Volume of gas storage chamber = V_{gs}, Volume of fermentation chamber = V_f

Volume of sludge layer = V_s, Volume of hydraulic chamber = V_H

Total volume of digester **V** $= V_c + V_{gs} + V_f + V_s$

Diameter of inlet = D_i, Diameter of digester = D

Diameter of hydraulic chamber = D_H, Depth of slurry pit = d_{ss}

Height of inlet pipe from inlet chamber to down level = H_i

Height between lower level of gas storage chamber and sludge layer = H

Height of the hydraulic chamber from digester manure level = h_1

Height of the hydraulic chamber to lower level of gas storage chamber = h

Height of the hydraulic chamber = H_H, Height of the slurry pit = H_{ss}

Width of the slurry pit = W_{ss}, The inclined angle of inlet pipe = θ

Table 7.6: Geometrical assumption for digester design [38]

For Volume	For geometrical dimensions
$V_c \leq 5\%V$ $V_s \leq 15\%V$ $V_{gs} + V_f = 80\%V$ $V_{gs} = V_H$ $V_{gs} = 0.5(V_{gs} + V_f + V_s)K$, where K=gas production rate per cubic meter volume per day. For Bangladesh K=0.4 m^3/day	$D = 1.3078 \times V^{1/3}$ $V_1 = 0.0827D^3$ $V_2 = 0.05011D^3$ $V_3 = 0.3142D^3$ $R_1 = 0.725D$ $R_2 = 1.0625D$ $f_1 = D/5$ $f_2 = D/8$

7.3.2.1 DESIGN OF BIOGAS PLANT BASED ON POULTRY WASTE

7.3.2.1.1 VOLUME CALCULATION OF DIGESTER CHAMBER

Let HRT =40 days (for temperature 30°C)

Every broiler or layer hen gives 100gm manure per day.

Total discharge=800$\times$ 0.1 kg = 80 kg

TS of fresh discharge=$0.2 \times 80\ kg = 16\ kg$

To make the TS value of 8% for favorable condition some additional water has to mix with fresh discharge. The required water to be added can be calculated by the following way:

8 kg solid equivalent to 100 kg of influent

$$\therefore \text{ 16 kg solid equivalent} = \frac{100 \times 16}{8} = 200\ kg$$

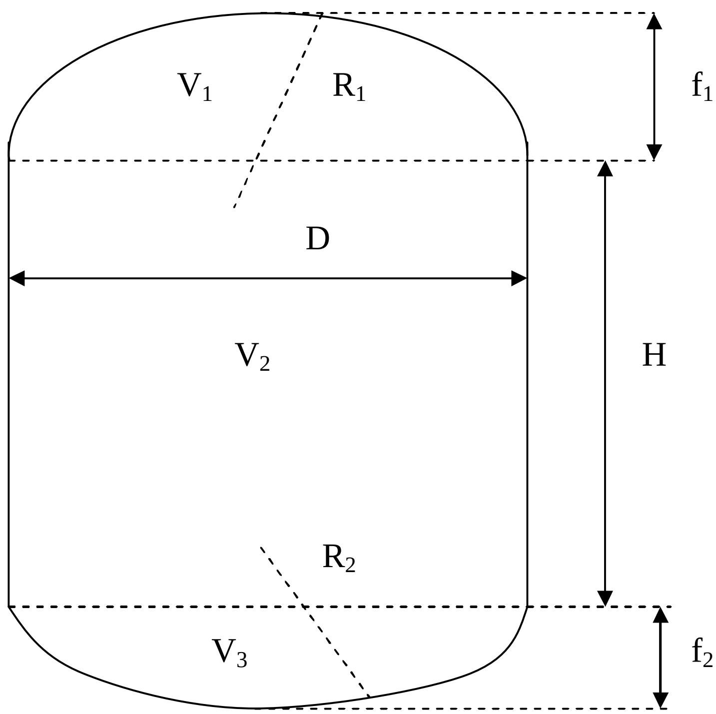


Figure 7.6: Different measurement parameters of digester.

So, total influent required, Q= 200 kg per day.

Required water to be added to make TS value 8% $=200 - 80\ kg = 120\ kg$

Working volume of digester$= V_{gs} + V_f$

$$V_{gs} + V_f = Q \times HRT = 200\frac{kg}{day} \times 40\ days = 8000\ kg = 8\ m^3$$

From geometrical assumption:

$V_{gs} + V_f = 80\%V$ Or, 8=0.8V (Putting the value of $(V_{gs} + V_f)$)

Or, $V = 10\ m^3$

And $D = 1.3078V^{1/3} = 2.817\ m \approx 2.82\ m$

Again,

$V_3 = \frac{3.14 \times D^2 \times H}{4}$ $or, 0.3142D^3 = \frac{3.14 \times D^2 \times H}{4}$

$\therefore H = \frac{4 \times 0.3142 \times D}{3.14} = 1.13\ m$

Now we find from assumption as we know the value of 'D' and 'H'

f_1= D/5=2.82/5=0.564 m

f_2=D/8=2.82/8=0.3525 m

R_1=0.725D=0.725×2.82= 2.04 m

R_2=1.0625D=1.0625×2.82= 3 m

$V_1=0.0827D^3=0.0827\times(2.82)^3=1.85\ m^3$

$V_c=0.05V=0.05\times10\ m^3=0.5\ m^3$

The value of inclined angle of inlet pipe, $\theta = 60^0$ [40]

7.3.2.1.2 VOLUME CALCULATION OF HYDRAULIC CHAMBER

From assumptions,

$V_c = 0.05V = 0.5\ m^3$

$V_s = V - (V_{gs} + V_f + V_c) = 10 - (8 + 0.5) = 1.5\ m^3$.

Now the volume of gas storage chamber should be 50% of the gas produced in a day.

So, $V_{gs} = Amount\ of\ the\ daily\ gas\ yield$ $= TS \times gas\ production\ rate\ per\ kg\ TS$

$= 16 \times 0.35\ m^3\ per\ kg\ TS = 5.6\ m^3$

$V_c + V_1 = 0.5 + 1.85 = 2.35\ m^3$

Now, the discharge of outlet should be the same of inlet recharge.

So, out let discharge, $V_{dis} = \frac{200\,kg}{1000} = 0.2\,m^3$ (as 200 $kg \approx 200\,liter$)

Total volume of the gas staying chamber $= V_c + V_1 + V_{dis} = 2.35 + 0.2 = 2.55\,m^3$

Now, the pressure of digester can be calculated.

Let the normal pressure of the digester is $P_i = 4\,kPa\ or\ 40\,mbar$.

Final pressure after gas being stored = P_f

The produced gas should have to stay within 2.55 cubic meters volume. So, according to Boyle's law,

$$P_i \times (total\ gas\ produced + 2.55) = P_f \times 2.55$$

$$Or, 4 \times (5.6 + 2.55) = P_f \times 2.55 \quad \text{Or, } P_f = 12.78\,kPa$$

Let, height of the hydraulic chamber is h. The pressure of the hydraulic chamber should be 12.78 kPa so that only the inlet recharge will be discharge.

$$P_f + H\rho g = H\rho g + h_1\rho g + h\rho g$$

$$Or, h + h_1 = \frac{P_f}{\rho g} = \frac{12.78 \times 1000}{1000 \times 9.81} = 1.3\,m$$

Let, height of the hydraulic chamber from digester manure level, $h_1 = 0.3\,m$

So, height of the hydraulic chamber to digester manure level, $h = 1.3 - 0.3 = 1\,m$

Now, the volume of the hydraulic chamber is equals to the discharge per day.

If D_H is the diameter of the hydraulic chamber then,

Let $H_H = 1$ m

$$\pi \left(\frac{D_H}{2}\right)^2 H_H = 0.2\ [as\ 200\,kg \approx 200\,liter = 0.2\,m^3]$$

$$Or, D_H = \sqrt{\frac{4 \times 0.2}{\pi \times H_H}} = \sqrt{\frac{0.8}{3.1416}} = 0.167\,m$$

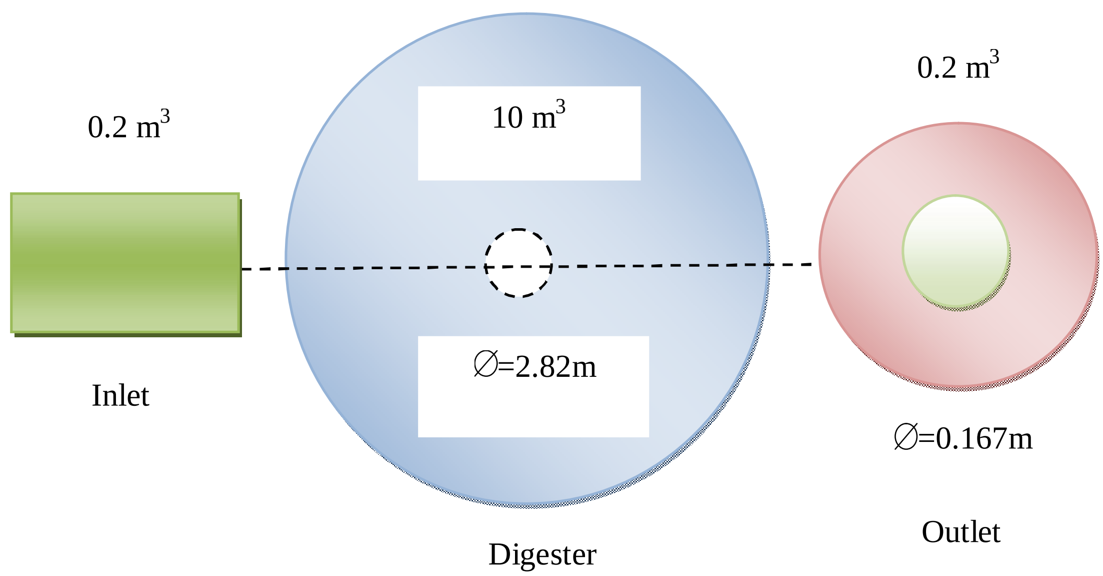


Figure 7.7: Design layout of digester, inlet and outlet based on poultry waste.

The design parameters (H_{ss} ,W_{ss} and d_{ss}) of slurry pit should be calculated according to the following rules [40]:-

a) The height should be double of width.
b) The depth should not more than 1m because of easy collection of slurry from the pit.
c) Depending on the plant location the design parameters can be altered.

As the calculation of design parameters vary with location so the calculation of design parameters of slurry pit is not shown here.

7.3.2.2 DESIGN OF BIOGAS PLANT BASED ON COW DUNG

On an average, each cow gives 10 kg cow dung per day [38].

If the number of cow is n then total cow dung $= 10n\ kg$

Again practically $0.037\ m^3$ of biogas is got from 1 kg of waste [39].

So, total biogas obtained from n number of cows

$$= 10n \times 0.037\ m^3 = 0.37n\ \ m^3$$

From each cubic meter biogas 1.4 kWh electricity is obtained.

So, from n number of cows electricity obtained $= 0.37n \times 1.4 = 0.518n\ kWh$

To generate 5.1 kWh electricity the essential number of cows,

$$0.518n = 5.1 \quad Or, n = \frac{5.1}{0.518} = 9.84 \approx 10$$

To produce 2 m^3 gases the essential number of cows,

$$0.37n = 2 \quad Or, n = \frac{2}{0.37} = 5.4 \approx 6$$

So, total number of cow = (10+6) = 16

7.3.2.2.1 VOLUME CALCULATION OF DIGESTER CHAMBER

Let HRT =40 days (for temperature 30°C)

As from every cow 10 kg manure is obtained per day.

So, total discharge =16$\times$ $10\ kg = 160kg$

Different measurement parameters of digester are depicted in figure 7.6.

TS of fresh discharge =$0.16 \times 160\ kg = 25.6\ kg$

To make the TS value of 8% for favorable condition some additional water has to mix with fresh discharge. The required water to be added can be calculated by the following way:

8 kg solid equivalent 100 kg of influent

$$\therefore 25.5 \text{ kg solid equivalent } = \frac{100 \times 25.6}{8} = 320\ kg$$

So, total influent required, Q= 320 kg.

Required water to be added to make TS value 8% = $320 - 160\ kg = 160\ kg$

Working volume of digester = $V_{gs} + V_f$

$$V_{gs} + V_f = Q \times HRT = 320 \frac{kg}{day} \times 40\ days = 12800\ kg = 12.80\ m^3$$

From geometrical assumption:

$V_{gs} + V_f = 80\%V$

Or, 12.8 = 0.8V (Putting the value of (V_{gs} + V_f))

Or, $V = 16\, m^3$

And $D = 1.3078V^{1/3} = 3.29m \approx 3.3\, m$

Again,

$$V_3 = \frac{3.14 \times D^2 \times H}{4} \; or, 0.3142D^3 = \frac{3.14 \times D^2 \times H}{4}$$

$$\therefore H = \frac{4 \times 0.3142 \times D}{3.14} = 1.31\, m$$

Now we find from assumption as we know the value of 'D' and 'H'

f_1 = D/5 = 3.3/5 = 0.66 m

f_2 = D/8 = 3.3/8 = 0.4125m

R_1 = 0.725D = 0.725×3.3 = 2.3925m

R_2 =1.0625D =1.0625×3.3 = 3.50625m

$V_1 = 0.0827D^3 = 0.0827\times(3.3)^3 = 2.97\ m^3$

$V_c = 0.05V = 0.05\times16\ m^3 = 0.8\ m^3$

7.3.2.2.2 VOLUME CALCULATION OF HYDRAULIC CHAMBER

From assumptions,

$V_c = 0.05V = 0.8\, m^3$

$V_s = V - (V_{gs} + V_f + V_c) = 16 - (12.8 + 0.8) = 2.4\, m^3$.

Now the volume of gas storage chamber should be 50% of the gas produced in a day.

So, $V_{gs} = Amount\ of\ the\ daily\ gas\ yield$

$= TS \times gas\ production\ rate\ per\ kg\ TS$

$= 25.6 \times 0.35\, m^3 per\ kg\ TS = 8.96\, m^3$

$V_c + V_1 = 0.8 + 2.97 = 3.77\, m^3$

Now, the discharge of outlet should be the same of inlet recharge.

So, out let discharge

$$V_{dis} = \frac{320}{1000} = 0.32\, m^3\ [as\ 320\ kg \approx 320\ liter]$$

Total volume of the gas staying chamber $= V_c + V_1 + V_{dis} = 3.77 + 0.32 = 4.09\, m^3$

Now, the pressure of digester can be calculated. The minimum pressure required to run a generator is at least 4 kPa.

Let the normal pressure of the digester is $P_i = 4\ kPa\ or\ 40\ mbar$.

and final pressure after gas being stored = P_f

The produced gas should have to stay within 1.64 cubic meters volume. So, according to Boyle's law,

$$P_i \times (total\ gas\ produced + 4.09) = P_f \times 4.09$$

$$Or, 4 \times (8.96 + 4.09) = P_f \times 4.09$$

$$Or, P_f = 12.76\ kPa$$

Let, height of the hydraulic chamber is h. The pressure of the hydraulic chamber should be 12.76 kPa so that only the inlet recharge will be discharge.

$$P_f + H\rho g = H\rho g + h_1\rho g + h\rho g$$

$$Or, h + h_1 = \frac{P_f}{\rho g} = \frac{12.76 \times 1000}{1000 \times 9.81} = 1.30\, m$$

Let, height of the hydraulic chamber from digester manure level, $h_1 = 0.3\, m$

So, height of the hydraulic chamber, $h = 1.8 - 0.3 = 1m$

Now, the volume of the hydraulic chamber is equals to the discharge per day.

If D_H is the diameter of the hydraulic chamber then,

$$\text{Let } H_H = 1\text{m, So, } \pi\left(\frac{D_H}{2}\right)^2 H_H = 0.32 \text{ [as 320 kg} \approx \text{320 liter} = 0.32\ m^3]$$

$$Or, D_H = \sqrt{\frac{4 \times 0.32}{\pi \times H_H}} = \sqrt{\frac{1.28}{3.1416}} = 0.407\ m$$

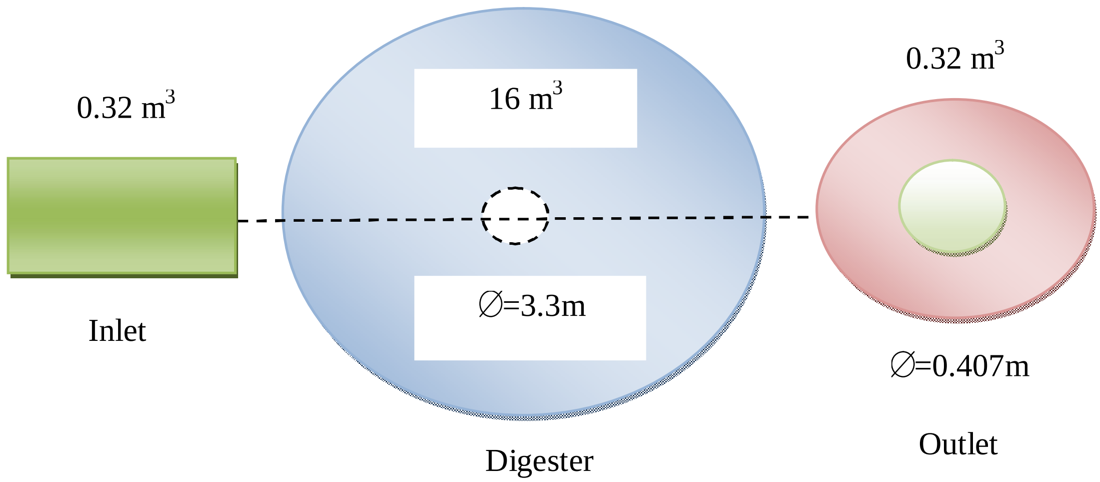


Figure 7.8: Design layout of digester, inlet and outlet for cow waste.

CHAPTER 8

IMPLEMENTATION OF THE ENERGY NEUTRAL HOME (ENH) SYSTEM

8.1 THE STEPS OF IMPLEMENTATION

For the implementation of the system the following steps are followed:

a) Soil digging of the selected location.
b) Construction of main parts of biogas plant such as digester, inlet and outlet according to the design.
c) Waste collection.
d) Filling up the digester with cow dung initially, after then by poultry waste.
e) Pipelining of the plant.
f) Setting up of the other accessories such as biogas burner, purifier, generator and electrical wiring.
g) Observation of the experimental result by burning up the biogas burner and running the generator with full load.

8.2 IMPLEMENTATION OF THE SYSTEM

8.2.1 DIGGING OF THE SOIL IN THE SELECTED LOCATION

The first step of the implementation of the designed ENH system is soil digging. Some photographs of this step are shown in picture 8.1.

(a)

(b)

(c)

(d)

Picture 8.1: The digging of soil for the construction of digester (continued).

8.2.2 CONSTRUCTIONS OF DIGESTER, INLET AND OUTLET

The construction process of the digester, inlet and outlet of the biogas plant are revealed in picture 8.2. Since the designed system was implemented during rainy season, some difficulties such as filling up of digester hole by water, problem of preparing base of digester etc. were faced during the digester construction as shown in picture 8.3. To solve those problems irrigation was necessary which was done by a pump.

(a)

(b)

Picture 8.2: The base construction of digester.

(a)

(b)

Picture 8.3: The irrigation of the water from digester hole.

An inlet pipe of 6 inch diameter is connected to the down position of the digester as shown in picture 8.4.

(a) (b)

Picture 8.4: The connected inlet pipe to the digester.

After the construction of the digester, the construction of hydraulic chamber is started that are shown in pictures 8.5 and 8.6. In the design the hydraulic chamber is of circular shape. But due to the shortage of space this is made as square shape which does not affect the gas production because it mainly depends upon the digester.

(a) (b)

(c) (d)

Picture 8.5: The formation of digester and hydraulic chamber.

(a) (b)

Picture 8.6: The formation of digester's dome.

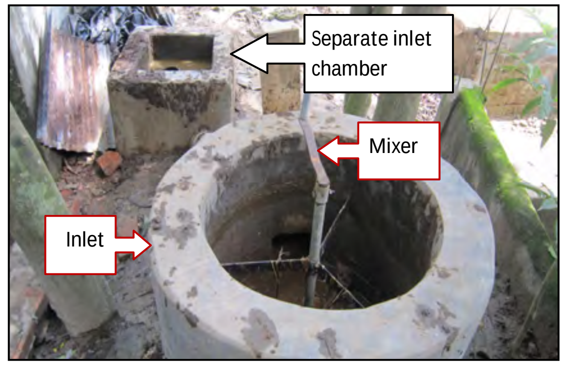
The dome shape of the digester is given by following a special process. It is done slowly by tighting some bricks with steel wires as shown in pictures 8.5 and 8.6.

(a) (b)

Picture 8.7: The final structure of digester and hydraulic chamber.

The final structure is made as shown in picture 8.7. The dome shape part (upper part) of the digester contains the necessary gas for household use. Two pipes of 1.5 inch and 1 inch diameter are set at the top of the digester. The pipe of 1.5 inch diameter is used for gas distribution and the pipe of 1 inch diameter is used to measure gas pressure. A pressure meter is set to monitor the available gas pressure in the digester.

(a)



(b)

Picture 8.8: The construction of inlet.

After the construction of the digester and hydraulic chamber, the construction of inlet is started as shown in picture 8.8(a). A mixer is also set to the inlet as shown in picture 8.8(b). A separate chamber is made covering the main inlet pipe to remove the stones, straw or other hard materials. Because the poultry waste contains many small stones and cow dung has long straw or other hard materials. This is one type of precaution which should be maintained because if the stones, bones or other hard materials enter into the digester, then the bottom part of the digester will be filled up within a short time. Then the effective digester size will be reduced. The reduction of the digester size will affect the waste material containing capacity and thus gas production.

8.2.3 CONSTRUCTION OF SLURRY PIT

After the construction of the main parts of the system, the slurry pit is constructed. The slurry pit of the system is depicted in picture 8.9. The size of the slurry pit may vary. If it is large, then its capacity will be more. It will have the bio-slurry which is most suitable for the plant, fishing etc.

(a)

(b)

Picture 8.9: The construction of slurry pit.

8.2.4 PIPELINING

The next step is pipelining of the plant which is necessary to distribute the produced gas for household uses. This step is shown in picture 8.10. Depending on the pipe types (GI pipe or flexible pipe) the cost of the step varies. This system uses GI pipes which cost is higher than the flexible pipes.

(a)

(b)

Picture 8.10: Pipelining of the system.

8.2.5 PAINTING AND FILLING UP THE DIGESTER

Painting is important for the digester dome, since the dome portion of the digester contains the biogas. It has three advantages-

- (i) It removes the vapor from the digester inner body
- (ii) It removes the leaking problems in digester inner body, and
- (iii) It helps to maintain the necessary gas pressure.

For the above reasons, the inner portion of the digester dome is painted twice as shown in picture 8.11(a). The name of the paint is Berger enamel paint. The paint should be enamel paint because it removes moisture easily than the other types.

(a)

(b)

Picture 8.11: The painting of digester dome and filling up the digester with cow dung.

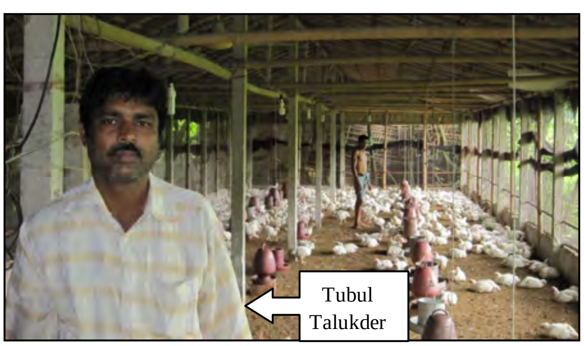
After the completion of digester construction, it is completely filled up with waste up-to the base level of hydraulic chamber. To fill up the digester initially cow dung is used, because the softness of the cow dung is more than the poultry waste. A total amount of cow dung used to fill up the digester is near about 40,000 kg. With cow dung methane is formed quickly which is essential to run the generator smoothly [39]. Pictures 8.11(b) and 8.12 express the filling up process of the digester initially with cow dung. The cow dung to water mixing ratio is 1:1 and the poultry waste to water mixing ratio is 1:2 [40]. By maintaining the mixing ratio the waste is given to the digester.

(a) (b)

Picture 8.12: The filling up process of digester with cow dung.

8.2.6 AVAILABILITY OF WASTE

In the selected area, the poultry waste is available. There are five poultry farms in this area. Three farms are based on broiler and two farms are of layer. The waste of layer is most suitable than the broiler. Among the five poultry farms, Mr. Tubul Talukder has two farms of his own. He supplies the waste to the system. He has a farm of layer and a farm of broiler. Some views of one of his farms are shown in picture 8.13.



(a) (b)

Picture 8.13: Some views of the Tubul Talukder's poultry farm.

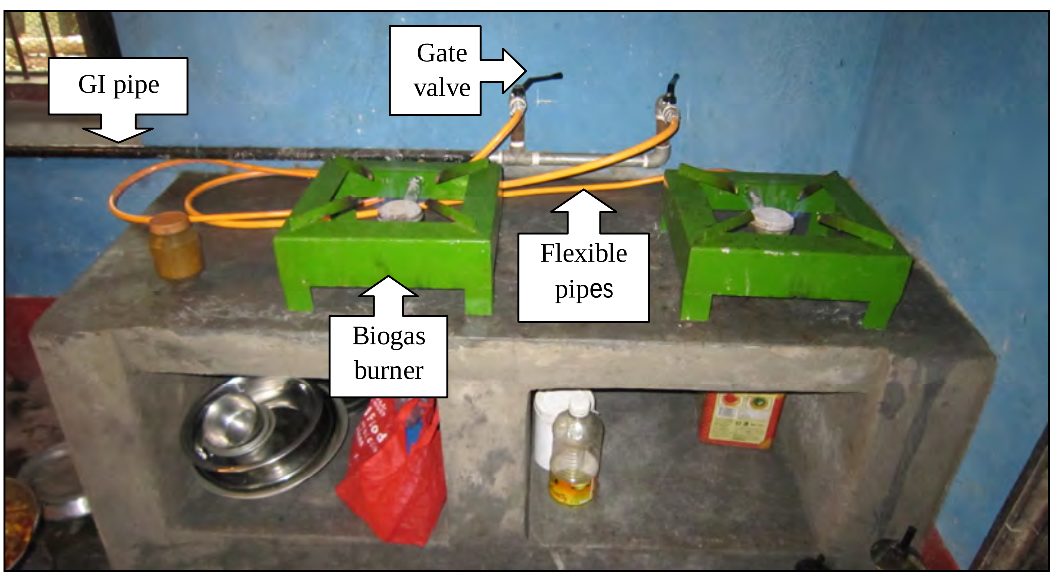
8.2.7 INSTALLATION OF THE OTHER ACCESSORIES

The energy requirements are divided into two parts. The first one is the generation of electricity and the second one is burning the gas burner. To fill up these energy requirements the following accessories are bought to set up an ENH system.

(i) Biogas burner
(ii) GI pipes and flexible gas distribution pipes
(iii) Gate valves and other gas pipe connectors
(iv) Gas generator
(v) Biogas purifier
(vi) Manometer or pressure gauge
(vii) Electrical energy (kWh) meter
(viii) Energy saving lamps
(ix) Circuit breakers, switches and other electrical accessories
(x) Electrical change over switch (From grid to biogas power and vice-versa).

8.2.7.1 SETTING UP OF THE BIOGAS BURNER

The biogas burner that is used in the ENH system is shown in picture 8.14. Two burners are used in the system as shown in picture 8.14. The gas nozzles of these burners are different from the normal gas burner. These are made with a larger shape because the biogas pressure is less than the other gas pressure.



Picture 8.14: The setting up of biogas burner.

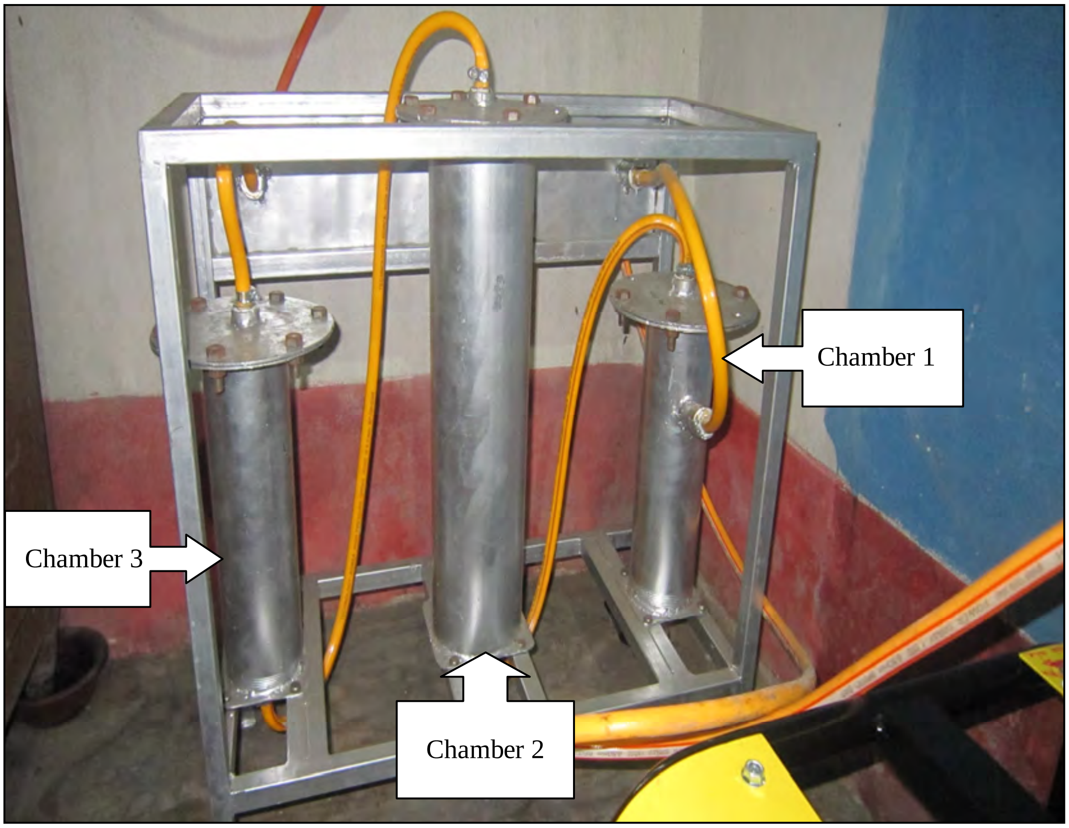
8.2.7.2 SETTING UP OF ACCESSORIES FOR ELECTRICITY GENERATION

8.2.7.2.1 THE BIOGAS PURIFIER

Biogas composition depends heavily on the feedstock, but mainly consists of methane (CH_4) and carbon dioxide (CO_2) with smaller amounts (ppm) of hydrogen sulfide (H_2S) and ammonia. Trace amounts of organic sulfur compounds, halogenated hydrocarbons, hydrogen, nitrogen, carbon monoxide, and oxygen are also occasionally present. Usually, the mixed gas is saturated with water vapor and may contain dust particles and siloxanes. Water-saturated biogas from dairy-manure digesters consists primarily of 50-60% methane, 40-50% carbon dioxide, and less than 1% sulfur impurities, of which the majority exists as hydrogen sulfide [42]. Hydrogen sulphide is formed in the biogas plant by the transformation of sulphur-containing protein, which can be from plants and fodder residues. However, when animal and human waste is used, bacteria excreted in the intestine are the main source of protein. Inorganic sulphur, particularly sulphates, can also be biochemically converted to H_2S in the fermentation chamber. While plant material introduces little H_2S into biogas, poultry droppings introduce, on average, up to 0.5 volume percent of H_2S, cattle and pig manure about 0.3 volume/percent [43].

Hydrogen sulfide is typically the most problematic contaminant because it is toxic and corrosive to most equipment. Hydrogen sulphide (H_2S) is particularly harmful when biogas is used in internal combustion engines. Its chemical reactions and those of its combustion product - sulphur dioxide - lead to corrosion and wear on engines. The acid which is formed corrodes engine parts in the combustion chamber, exhaust system and in various bearings. Hydrogen sulphide is a colourless, very poisonous gas. It is inflammable, and forms explosive mixtures with air (oxygen). Additionally, combustion of H_2S leads to sulfur dioxide emissions, which have harmful environmental effects. The combustion product, SO_2 combines with water vapor and badly corrodes the exhaust side of burners, gas lamps and engines. Burning biogas in stoves and broilers can also result in damage to the chimney [42], [43].

Removing H_2S as soon as possible is recommended to protect downstream equipment, increase safety, and enable possible utilization of more efficient technologies such as micro turbines and fuel cells. Because of these characteristics, hydrogen sulfide removal is usually performed directly at the gas-production site. Hence, it should be purified before using as input fuel of gas generator. The special type of biogas purifier used in the system is depicted in picture 8.15. This is made by GTZ (Deutsche Gesellschaft fur Technische Zusammenarbeit), Dhaka, Bangladesh.



Picture 8.15: Biogas purifier used in the ENH system.

This purifier is divided in three chambers as given below:-

(i) **Chamber 1-** It is known as water tap. It sucks the water contents from the biogas.

(ii) **Chamber 2-** It contains the iron chips. This chamber removes the dangerous gas H_2S from biogas. The removal of H_2S by ferrous is shown in below:

$$Fe + H_2S = FeS + H_2$$

(iii) **Chamber 3-** This chamber contains the silica gel. It removes vapors or moistures from biogas. Indicating Silica Gel is beads of clear Silica Gel that have been impregnated with a chemical that changes color when it comes into contact with moisture. When the color has changed, it means that the Silica Gel is fully saturated and needs to be replaced or reactivated. This can be useful when long term humidity control is needed [44].

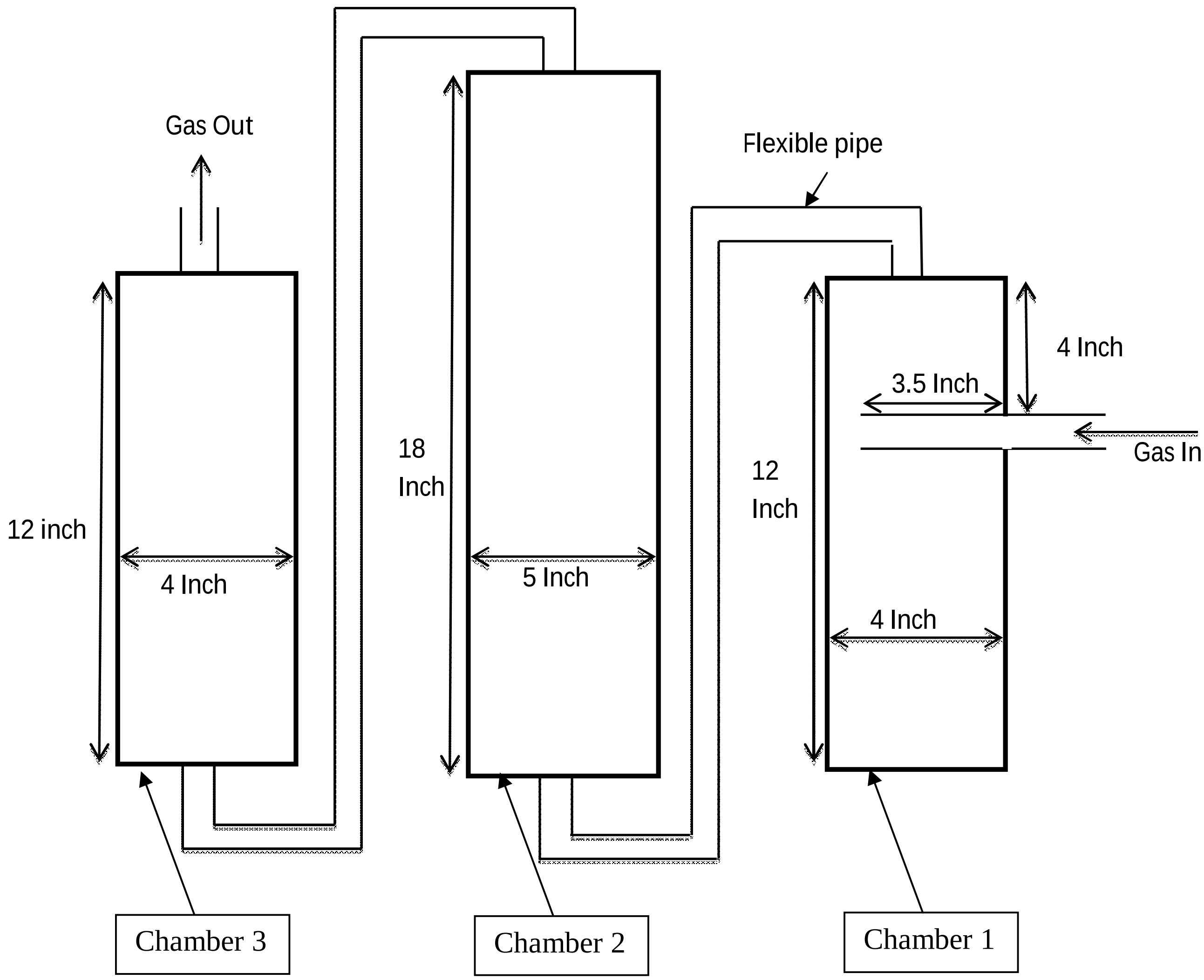
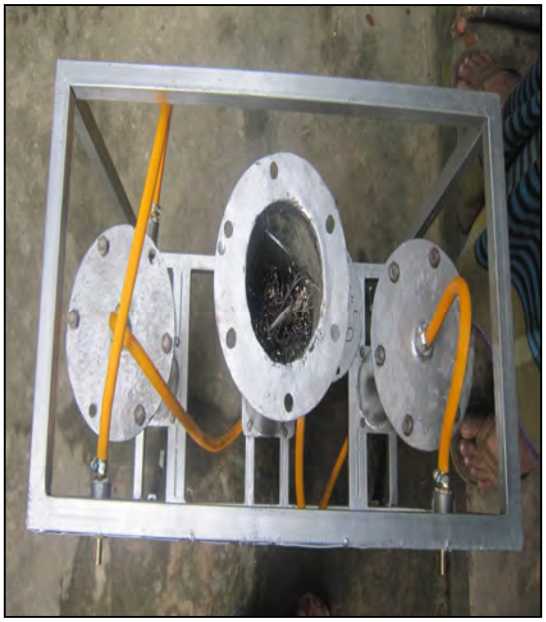
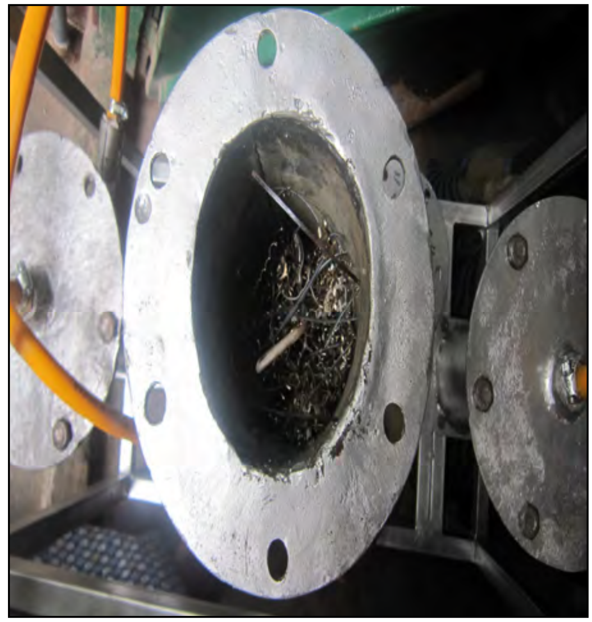


Figure 8.16: The schematic diagram of biogas purifier used in the ENH system.

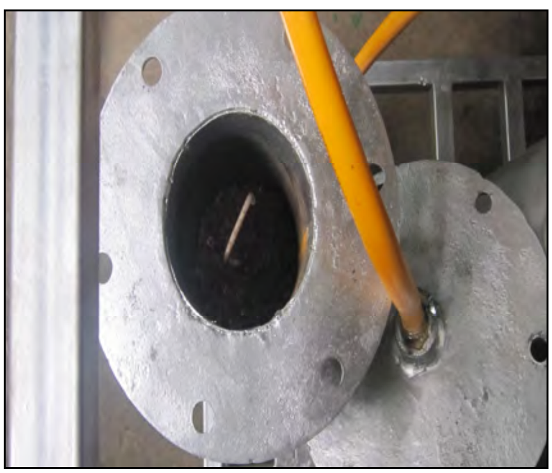
The schematic diagram of biogas purifier used in the ENH system is shown in figure 8.16 with all dimensions. The chamber 1 is a simple filter which has a pipe inside where the biogas from digester gets obstruction and hence the contained water in biogas is removed. There is a tap under this chamber. This tap is used to remove the stored water after six months. The view of chamber 2 and chamber 3 are shown in picture 8.17. The subfigures show the contained iron chips and silica gel in the chamber 2 and chamber 3.



(a): Top view of chamber 2



(b): The iron chips of chamber 2



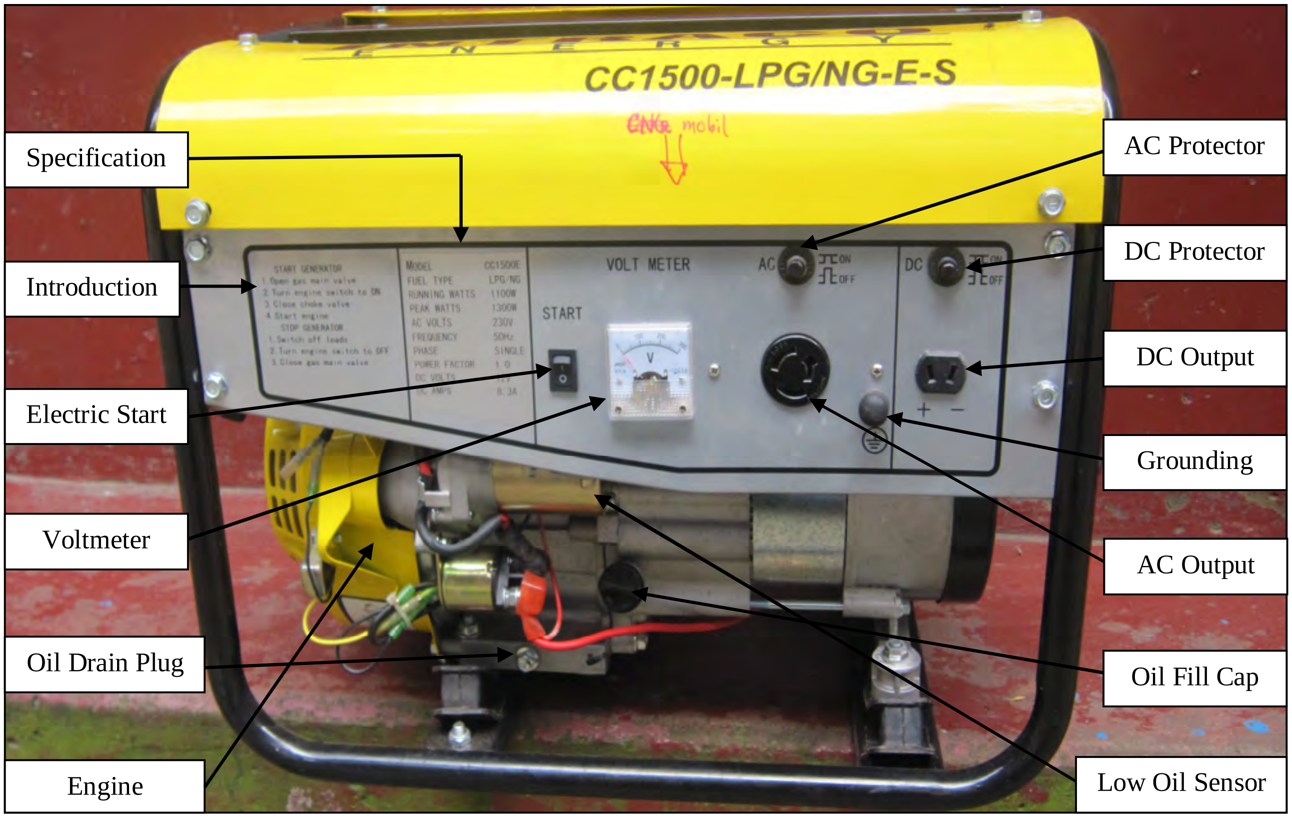
(c): Top view of chamber 3

(d): The silica gel of chamber 3

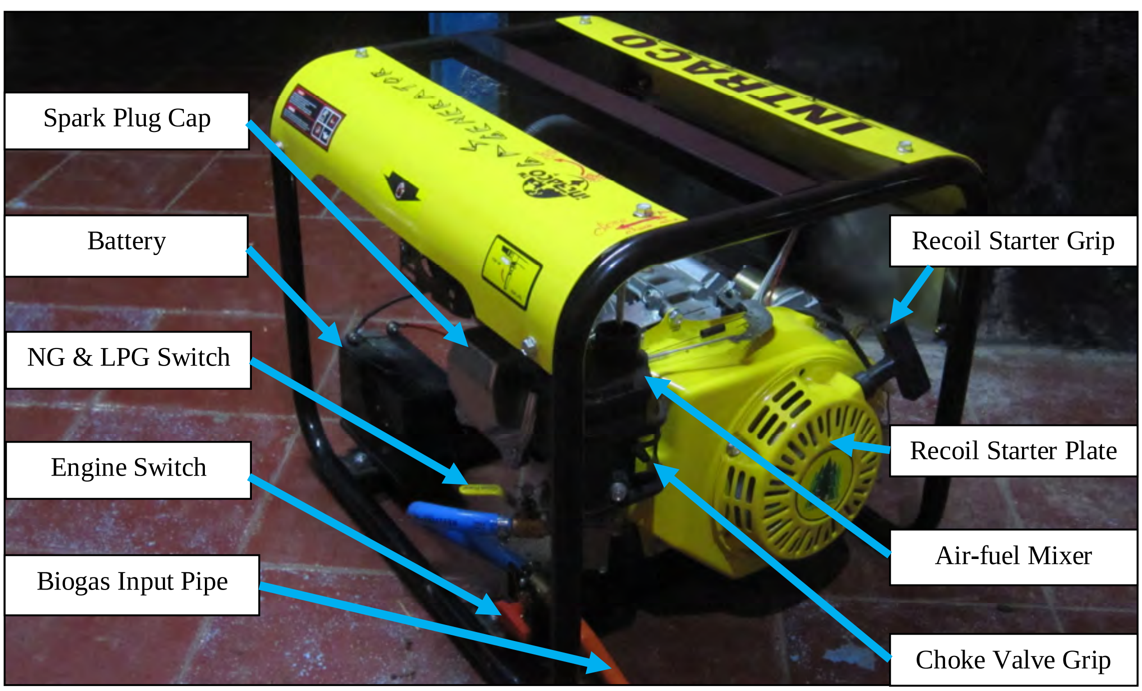
Picture 8.17: The different chambers of Biogas purifier used in the ENH system.

8.2.7.2.2 THE GAS GENERATOR

The gas generator used in the system is shown in picture 8.18. It is supplied by INTRACO ENERGY. It's model no CC1500-LPG/NG-E-S. It's features are tabulated in table 8.1.



(a):- The side view of gas generator.



(b):- The front view of gas generator.

Picture 8.18: The gas generator.

Table 8.1: The specifications of the INTRACO gas generator.

Description	Ratings
Model	CC1500S
Fuel	LPG/NG
Frequency (Hz)	50
Running Power(kW)	1.2/1.1
Peak Power(kW)	1.4/1.3
DC voltage (V) / Current (A)	12V/8.3A
Generator Type	Single Phase AC Synchronization With Brush
Bore x Stroke (mm)	68 x 45
Displacement(cc)	163
Starting Method	Recoil Start / Electric Start
Ignition System	Transistor Magneto (T.C.I)
Engine Oil Capacity (ounce)	0.60
Min. Fuel Consumption (LPG)	0.35kg/kWh
Min. Fuel Consumption (NG)	0.35m^3/kWh

The function of the different parts of gas generator is discussed below:-

(i) **Oil fill cap:-** It is used to check and fill engine oil level.

(ii) **Engine:-** This is used as power generator (alternator).

(iii) **Air cleaner:-** It protects the engine by filtering dust and debris from the intake air.

(iv) **Choke Valve Grip:-** It is used to control air flow rate.

(v) **Recoil starter:-** It is used to start the engine.

(vi) **Engine switch:-** It helps to supply fuel to the engine. It should be turned to "ON" position.

(vii) **Battery:-** It is used to start the engine.

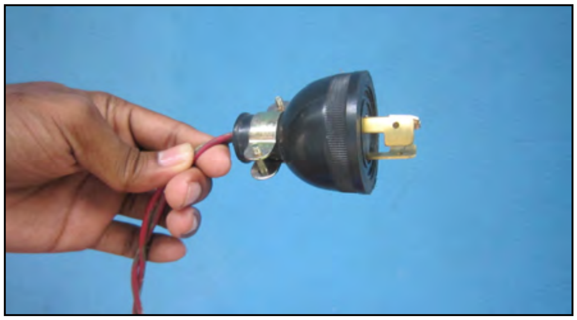
(viii) **Low oil sensor:-** It senses the level oil in the crankcase and shuts the engine down if the level falls too low.

(ix) **NG and LPG Switch:-** It is used to change the fuel supply mode i. e. to change NG or LPG supply mode.

(x) **Voltmeter:-** Displays the output voltage of the generator.

(xi) **AC / DC output:-** This generator can supply both AC and DC. With the DC output voltage a 12V automotive or utility style storage battery can be charged.

To use the generated electricity by the generator an AC output plug is used as shown in picture 8.19. It's one side should be connected to generator AC output and other side should be connected to the circuit breaker of the main supply board.



(a)

(b)

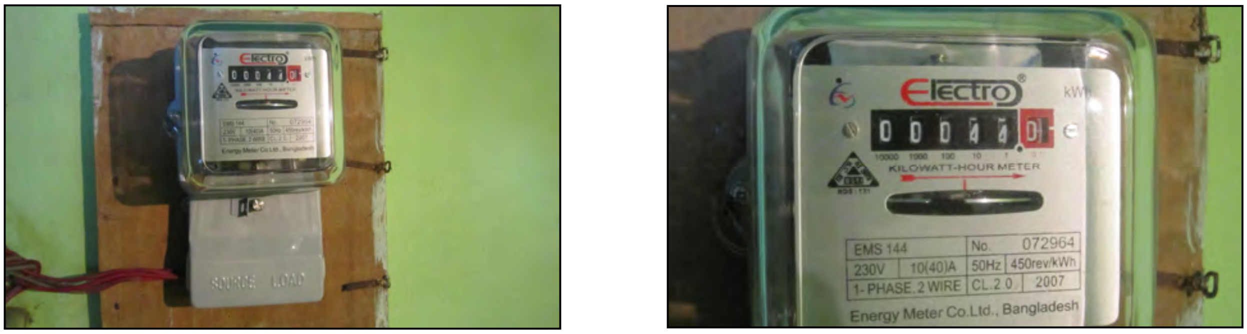
Picture 8.19: The AC output plug of generator.

The generator is set with the biogas purifier and is shown in picture 8.20.The biogas coming from digester is purified in purifier and then the purified gas is sent to the generator.

Picture 8.20: The gas generator with the biogas purifier.

8.2.7.2.3 THE ELECTRICAL ENERGY METER

To record the electricity used by the owner of the home, it is essential to have an electrical energy (kWh) meter. In this system, an analog energy meter is used to save cost that is shown in picture 8.21. Picture 8.21(b) reveals that the unit consumption of electricity is 44kWh. The digital energy meter also can be used to record the electricity usage.



(a) (b)

Picture 8.21: The electrical energy (kWh) meter reading in the ENH system.

8.2.7.2.4 THE ENERGY SAVING BULBS AND FANS

For the proper utilization of the produced electricity, the energy saving bulbs are used in this system. The loads are used according to the table 7.4. Here, energy saving fans are not used to save the cost because the cost of those are higher than the normal fans in the local market. If it is possible to use energy saving fans, then the more energy will be saved. Picture 8.22 shows the energy saving lamps (12W and 25W) used in this system. These are of SONOS company.

(a):- Energy saving bulb of 12W (b):- Energy saving bulb of 25W

Picture 8.22: The energy saving lamps used in the ENH system.

8.2.7.2.5 THE PRESSURE GAUGE

A pressure gauge of range 0-300 mbar (0-30 kPa, as we know, 1 kPa is equivalent to 10 mbars [45]) is used to measure the available gas pressure in the digester. The picture 8.23(a) reveals the condition without any gas pressure. On the other hand, picture 8.23(b) expresses that the system gas pressure is 34 mbar after running the generator about 3 hours. From the experiment it is found that the minimum initial gas pressure to start a gas generator is 10 kPa or 100 mbar. Above 100 mbar it starts and run smoothly but below this level it cannot start perfectly.

(a)

(b)

Picture 8.23: The pressure gauge reading in the ENH system.

8.2.7.2.6 THE CIRCUIT BREAKERS OR CHANGE OVER SWITCH

The house of Mr. Anil Kanti Das is divided into five rooms. Among those rooms, three are bed rooms, one dining plus drawing room and one kitchen. In the main electrical supply board, there are three circuit breakers. One is main circuit breaker and other two breakers are used to share the load equally. Picture 8.24 shows the circuit breakers. The option of circuit breaker or the change over switches are used if both the grid supply and generator supply is necessary.

Picture 8.24: The circuit breaker used in the system.

CHAPTER 9

RESULT, OBSERVATION AND COST ANALYSIS

9.1 THE RESULT AND OBSERVATION

9.1.1 OBSERVATION OF BIOGAS PRODUCTION AND OPENING THE DIGESTER GATE VALVE:

The biogas is produced after one day and the production of biogas is proved with the overflow of cow dung solution in the hydraulic chamber. Also the pressure gauge indicates the gas production. The gas pressure increased to 200- 250 mbar after 7th day of recharging the digester. After one week, all the produced gas is to be released to air because it contains moisture or water particles and thus are not ready for household uses. At that time, the main gate valve of digester is opened as shown in picture 9.1.

Picture 9.1: Opening of digester gate valve after one week.

9.1.2 BURNING THE BIOGAS BURNERS

After one week the waste is given daily as input to the digester. Up to the 20 days the cow dung is given as waste because the cow dung is soft and gets rotten easily than poultry waste [40]. After this period the poultry waste is given as input of digester by maintaining the proper waste to water mixing ratio. The gas burners start to run with biogas after10 days as shown in picture 9.2(a). The red flame of fire indicates that the methane has not formed yet. The blue flame of fire is observed after the HRT time (40 days in this case) i. e. at 45th days from the initial time and proves the presence of more methane than before. Picture 9.2(b) expresses that the food is cooking at biogas burner with biogas.

(a) (b)

Picture 9.2: Burning the biogas and cooking the food.

9.1.3 THE USE OF BIO-SLURRY

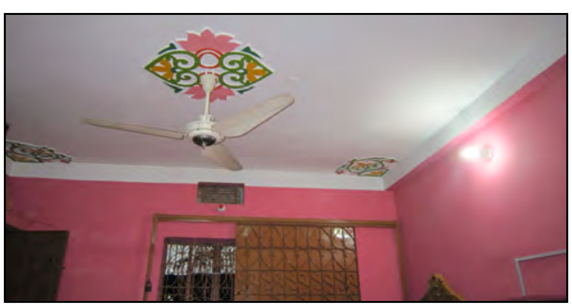
After one month the bio-slurry goes out to the slurry pit. This slurry is used as foods of fishes. Pictures 9.3reveals the scene of going out of slurry from hydraulic chamber and throwing out this slurry to the pond for fishes respectively. It is an excellent fertilizer for fishes.

(a) (b)

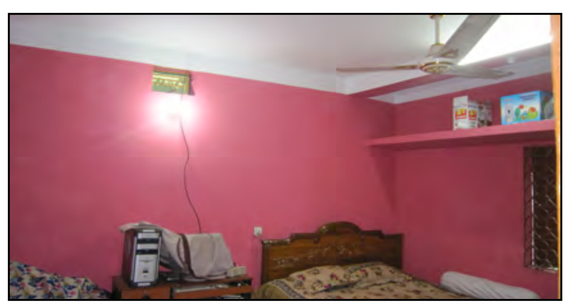
Picture 9.3: The bio-slurry used for fishes.

9.1.4 RUNNING THE ELECTRICAL LOADS WITH GENERATED ELECTRICITY

The electrical loads as given in table 7.4 are run with the generated electricity from biogas. Some views of running electrical loads with biogas of different rooms are shown in picture 9.4.



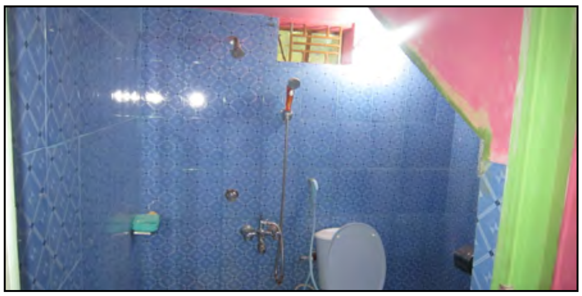
(a):- Uses of electricity in room1



(b):- Uses of electricity in room2

(c):- Uses of electricity in room3

(d):- Uses of electricity in room4



(e):- Uses of electricity in bath room

(f):-Uses of electricity in Kitchen

Picture 9.4: Running of electrical loads with biogas.

9.2 COST ANALYSIS OF THE IMPLEMENTATION

9.2.1 COST CALCULATION

The cost of the implemented system is divided into two parts as shown in table 9.1 and table 9.2.

Table 9.1: Cost of Digester, Inlet and Outlet

Description	Quantity	Rate (BDT)	Amount (BDT)
Bricks	2000 pcs	6.00	12,000.00
Cement	22 bags	350.00	7,700.00
Mass Rod	80 kg	50.00	4,000.00
Sand	170 CFT	20.00	3,400.00
Bricks chips	80 CFT	70.00	5,600.00
Paints	2 Liter	200.00	400.00
Appliances			1,500.00
Soil digging			4,000.00
Mason for construction			6,000.00
Total=			44,600.00

Table 9.2: The cost of other components of the system.

Description	Amount (BDT)
Cost of generator 1 (1.2kW) [Used as main generator]	26,890.00
Cost of generator 2 (1.2kW) [Used as back up generator]	26,890.00
Purification Unit Cost	10,000.00
Manometer, Range 0-300 mbar,water column	3000.00
Pipe Line, Special SS Ball Valves	3000.00
Electrical Change-over Switch (From grid to biogas power and vice-versa)	1400.00
Electrical Energy (kWh) Meter (Digital)	1200.00
Miniature Circuit Breakers	800.00
Electrical wiring	1000.00
Installation Cost	5,000.00
Total Cost of Digester, Inlet and Outlet from table 5	44,600.00
The overall cost	1,23,780.00

Operating time of generator in 20 years =8 × 365 × 20=58,500 hour

The overhauling cost of generator is 15% of total cost [46].

Top overhauling (3 times) cost = 3 × (15% of 26890) BDT

=12,100.50 BDT

Major Overhauling (3 times) cost = 3 × (50% of 26890)

= 40,335.00 BDT

Maintenance cost (Gen 1) = 12,100.50 + 40,335.00

= 52,435.50 BDT

Maintenance cost (Gen 2) = 52,435.50 BDT

Total maintenance cost of generator= 1, 04,871 BDT

Cost of system in 20 years = Installation cost + maintenance Cost = (1, 23,780 + 1, 04,871) BDT

=2, 28,651 BDT

9.2.2 PER UNIT COST

Electricity used in 20 years = 5.1 × 365 × 20 = 37,230 kWh [electricity used per day is 5.1 kWh as shown in figure 7.4]

Savings in Cooking = 500 × 12 × 20 = 120,000 BDT

Remaining Cost = (2, 28,651 - 1, 20,000) BDT = 108,651 BDT

Per unit cost = 108,651 / 37,230 = 2.92 BDT

The total life time of the biogas plant is 20 years. With this time no maintenance is required for digester. Considering the evaluated maintenance cost of generator, we have got per unit cost is only 2.92 BDT which is lower than the present determined unit price of electricity by the government of Bangladesh.

9.3 SCOPE OF ENERGY NEUTRAL TECHNOLOGY IN BANGLADESH

The designed energy neutral home system is very much important for the developing countries like Bangladesh for the following reasons:

a) To fulfill the energy requirements at the present situation of Bangladesh.
b) To preserve the non-renewable energy sources by the reduction of their household expenditures for energy services.
c) To create part-time job in each community for the operator of the plant by that way it reduce poverty.
d) To create and improve of small business policy.
e) To give the rural students a better condition with house lighting and more time for studying.
f) To reduce the greenhouse effect by creating a complete smoke free system.
g) To produce slurry that can be utilized as fertilizer for the land and fish.

9.4 LIMITATIONS OF THE SYSTEM

a) Adequate land space to implement the ENH system.
b) The initial cost of ENH system is high for rural people.
c) Long start up time to start the ENH system.

CHAPTER 10

DESIGN CALCULATION USING "C" PROGRAMMING

10.1 THE PROGRAM FOR DESIGN CALCULATION

A program is prepared in TURBO C to facilitate the design of the ENH system for more number of houses. The program is included in appendix A. It helps to find the design parameters of the ENH system easily. It saves time and labor in design process.

10.2 THE RESULT OF THE PROGRAM

The result of the program is shown in three steps.

(i) Step 1:- Design calculation for poultry waste only.

(ii) Step 2:- Design calculation for cow waste only.

(iii) Step 3:- Design calculation for mixed waste (both cow and poultry waste).

In this program, the inputs that should be given are number of home, electricity demand according to the time interval, number of gas burners, time of using gas burner, type of waste and the value of HRT. The output results of the program are total kWh to be used, amount of gas used in burners, amount of gas to generate electricity, total number of required hen, and the design parameters.

10.2.1 THE RESULT FOR POULTRY WASTE ONLY

The poultry waste is more suitable than the other waste because it produce more gas than the other waste. So it requires less volume than the other waste. In the software, the design parameter can be calculated easily as shown in the result of programming window 10.1. Here, the obtained volume (9.93 m^3) which is near to obtained volume in chapter 7 (10 m^3). Not only the volume but also the other parameters also matched with the result of chapter 7. Thus, the verification of software accuracy is checked.

```
C:\TC\BIN\JOURNAL.EXE
Enter number of home:1
Electricity demand of each house at differenttime(in KW):
TIME: 2 to 4: 0.3
TIME: 4 to 6: 0.3
TIME: 6 to 8: 0
TIME: 8 to 10: 0
TIME: 10 to 12: 0
TIME: 12 to 14: 0.25
TIME: 14 to 16: 0.3
TIME: 16 to 18: 0
TIME: 18 to 20: 0.4
TIME: 20 to 22: 0.4
TIME: 22 to 24: 0.3
TIME: 24 to 2: 0.3

kWh=5.100000
No of gas burner for cooking purpose:2

How much time you will use gas burner(in Hour):2.5

Gas Used in Burner= 2.000000 m3
To get 5.100000 kWh electricity per day we needs 3.642857 m3 biogas
What types of waste you want to use??
For poultry waste press 1,for cow waste press 2 and for mix of poultry & cow waste
press 3: 1
Total no of hen required = 794
What is the value of HRT=40 days

Digester Volume: 9.934608 cubic meter
Diameter=2.811413 m
H=1.125281 m f1=0.562283 m  f2=0.351427 m  R1=2.038274 m
R2=2.987126 m V1=1.837720 m3 Vc=0.496730 m3
Final pressure of Digester=12.784947 kPa
 Height of hydraulic chamber from manure level:0.303257 m
Assume height of hydraulic chamber:1 m

Diameter of Hydraulic chamber: 0.502973 m
```

Programming window 10.1:- Calculation of plant parameters for only poultry waste

10.2.2 THE RESULT FOR COW WASTE ONLY

On the other hand, the cow waste is softer than the other waste. So it requires more volume than the other waste to produce same amount of gas. In the software, the design parameter can be calculated easily as shown in the result of programming window 10.2. Here, the obtained volume (16 m^3) which is exactly same to obtained volume in chapter 7 (16 m^3). Not only the volume but also the other parameters also matched with the result of chapter 7. Thus, the verification of software accuracy is also checked.

```
C:\TC\BIN\JOURNAL.EXE
Enter number of home:1
Electricity demand of each house at differenttime(in kW):
TIME: 2 to 4: 0.3
TIME: 4 to 6: 0.3
TIME: 6 to 8: 0
TIME: 8 to 10: 0
TIME: 10 to 12: 0
TIME: 12 to 14: 0.25
TIME: 14 to 16: 0.3
TIME: 16 to 18: 0
TIME: 18 to 20: 0.4
TIME: 20 to 22: 0.4
TIME: 22 to 24: 0.3
TIME: 24 to 2: 0.3

kWh=5.100000
No of gas burner for cooking purpose:2

How much time you will use gas burner(in Hour):2.5

Gas Used in Burner= 2.000000 m3
To get 5.100000 kWh electricity per day we needs 3.642857 m3 biogas
What types of waste you want to use??
For poultry waste press 1,for cow waste press 2 and for mix of poultry & cow waste
press 3: 2
 How much waste we get from a cow (in Kg):10

Total no of cow required = 16.000000 (for elec. gen. 10.000000 cows required)
What is the value of HRT=40 days

Digester Volume: 16.000000 cubic meter
Diameter=3.295419 m
H=1.319007 m f1=0.659084 m f2=0.411927 m R1=2.389179 m
R2=3.501383 m  V1=2.959630 m3  Vc=0.800000 m3
Final pressure of Digester=12.785110 KPa
 Height of hydraulic chamber from manure level:0.303273 m
Assume height of hydraulic chamber:1 m

Diameter of Hydraulic chamber: 0.638307 m
```

Programming window 10.2:- Calculation of plant parameters for only cow waste

10.2.3 THE RESULT FOR MIXED WASTE (BOTH COW AND POULTRY WASTE)

For the mixed waste, the design calculation will be slightly different than before. In the software, the design parameter can be calculated easily as shown in the result of programming window 10.3.

```
C:\TC\BIN\JOURNAL.EXE
Enter number of home:1
Electricity demand of each house at differenttime(in kW):
TIME: 2 to 4: 0.3
TIME: 4 to 6: 0.3
TIME: 6 to 8: 0
TIME: 8 to 10: 0
TIME: 10 to 12: 0
TIME: 12 to 14: 0.25
TIME: 14 to 16: 0.3
TIME: 16 to 18: 0
TIME: 18 to 20: 0.4
TIME: 20 to 22: 0.4
TIME: 22 to 24: 0.3
TIME: 24 to 2: 0.3

kWh=5.100000
No of gas burner for cooking purpose:2

How much time you will use gas burner(in Hour):2.5

Gas Used in Burner= 2.000000 m3
To get 5.100000 kWh electricity per day we needs 3.642857 m3 biogas
What types of waste you want to use??
For poultry waste press 1,for cow waste press 2 and for mix of poultry & cow waste
press 3: 3
How much percentage of gas you want from poultry waste:66.66

 How much waste we get from a cow (in Kg):10

Total no of hen required = 529 (For electricity gen: 342)
Total no of cow required = 5.000000 (for electricity gen: 4.000000)
What is the value of HRT=40 days

Digester Volume: 11.622410 cubic meter
Diameter=2.962373 m
H=1.185704  f1=0.592475  f2=0.370297  R1=2.147720
R2=3.147521m  V1=2.149932m3 Vc=0.581120m3
 Final pressure of Digester=12.784948 KPa
 Height of hydraulic chamber from manure level:0.303257 m
Assume height of hydraulic chamber:1 m

Diameter of Hydraulic chamber: 0.544023m
```

Programming window 10.3:- Calculation of plant parameters for mixed waste

CHAPTER 11

DESIGN OF AN ENERGY NEUTRAL HOME (ENH) SYSTEM FOR AN AREA

11.1 DESIGN OF ENH SYSTEM FOR AN AREA OF 200 HOUSES

The implemented system is for neutralizing only a home. The cost analysis result of the implemented ENH system shows that the unit price of electricity is only 2.92 BDT for a home. If the system is designed for an area of 200 homes (capacity 85 kW) then by similar analysis we get the unit price of electricity is approximately 1.55 BDT as analyzed in this chapter. So, it can be said that the unit cost of electricity decreases with the increase of number of homes. The ENH system of 200 houses should have a farm containing 50 thousand layers and 140 cows to produce necessary amount of biogas.

11.2 BIOGAS PLANT DESIGN FOR A FARM

Suppose, the ENH system has a farm containing 50 thousand layers and 140 cows.

11.2.1 DESIGN OF DIGESTER

For 50 thousand layers the size of the digester will be too much large. To obtain the better performance we have to design several digesters. Let us design three digesters, where one will be designed for 20 thousand layers and other two will be designed for 15 thousand layers. The design parameters are calculated according to the chapter 7. The calculation of the design of an energy neutral home system for an area is given in appendix B.

11.2.1.1 DESIGN OF DIGESTER FOR 15 THOUSAND LAYERS:

With the similar calculation of chapter 7 (given in appendix B) the design layout of biogas plant for 15 thousand layers is shown in figure 11.1.

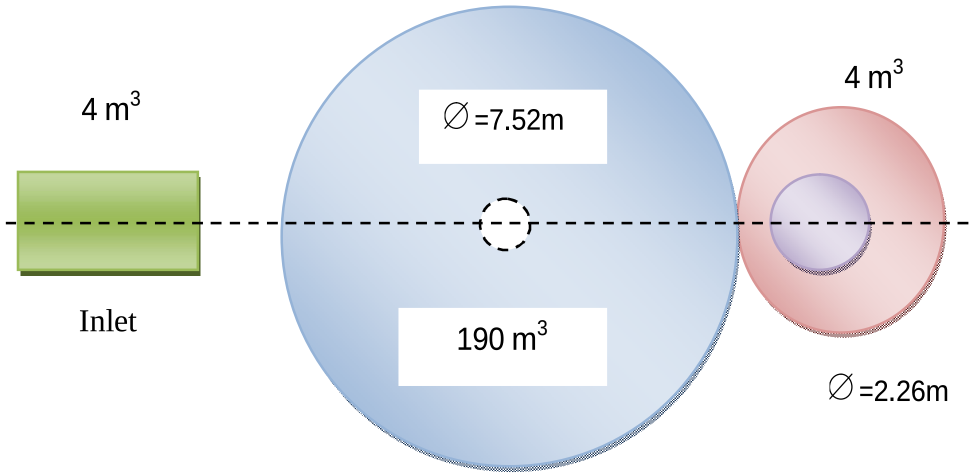


Figure 11.1: Top view of digester for 15 thousand layers

11.2.1.2 DESIGN OF DIGESTER FOR 20 THOUSAND LAYERS

With the similar calculation of chapter 7 (given in appendix B) the design layout of biogas plant for 20 thousand layers is shown in figure 11.2.

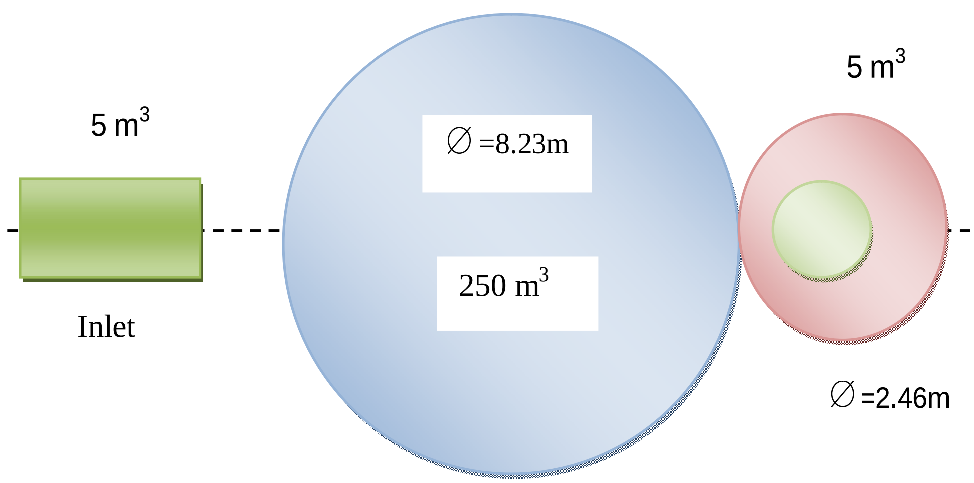


Figure 11.2: Top view of digester for 20 thousand layers

11.2.1.3 DESIGN OF DIGESTER FOR 140 COWS

With the similar calculation of chapter 7 (given in appendix B) the design layout of biogas plant for 140 cows is shown in figure 11.3.

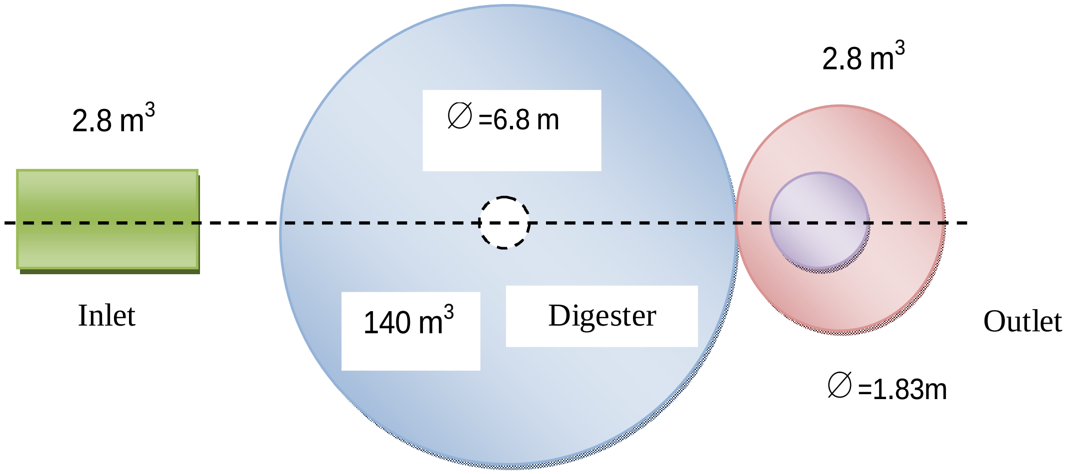


Figure 11.3: Top view of digester for 140 cows

11.3 TOTAL ELECTRICITY PRODUCTION

Total produced electricity for 200 homes are tabulated in table 11.1.

Table 11.1 : Electricity Generated from each digester.

Digester no.	Designed for	Gas production capacity(m^3)/day	Electricity production capacity/day (kW)	Time of electricity supply (Hour)	Unit of electricity (kWh)
1	15 thousand layer	105	15	10	150
2	15 thousand layer	105	15	10	150
3	20 thousand layer	140	20	10	200
4	140 number of cows	78.4	7	10	70

Total kWh generated = 150 + 150 + 200 + 70 = 570 kWh

11.4 LOAD CALCULATION

The load calculation is tabulated in table 11.2 and the load curve is shown in figure 11.4.

Load used in the system: Energy saving bulb, Ceiling fan, Color TV, Deep Freezer, Computer

Table 11.2: Demand of electricity in Watt at different times.

House	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
Energy Saving Bulb=5, Ceiling Fan=4, Color TV=1, Deep Freezer=1, Computer=1												
1	700	100	700	100	700	100	1000	500	750	600	200	600
2	100	700	100	700	100	700	500	1000	500	200	600	200
3	700	100	700	100	700	100	1000	500	750	600	200	600
4	100	700	100	700	100	700	500	1000	500	200	600	200
5	700	100	700	100	700	100	1000	500	750	600	200	600
6	100	700	100	700	100	700	500	1000	500	200	600	200
7	700	100	700	100	700	100	1000	500	750	600	200	600
8	100	700	100	700	100	700	500	1000	500	200	600	200
9	700	100	700	100	700	100	1000	500	750	600	200	600
10	100	700	100	700	100	700	500	1000	500	200	600	200
Total	40000	40000	4000	4000	4000	4000	7500	7500	6250	4000	4000	4000
Energy Saving Bulb=5, Ceiling Fan=4, Color TV=1												
11			100	150	100	150	450	450	350	200	200	200
12			150	100	150	100	450	450	350	200	200	200
13			100	150	100	150	450	450	350	200	200	200
14			150	100	150	100	450	450	350	200	200	200
15			100	150	100	150	450	450	350	200	200	200
16			150	100	150	100	450	450	350	200	200	200
17			100	150	100	150	450	450	350	200	200	200
18			150	100	150	100	450	450	350	200	200	200

House	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
19			100	150	100	150	450	450	350	200	200	200
20			150	100	150	100	450	450	350	200	200	200
21			100	150	100	150	450	450	350	200	200	200
22			150	100	150	100	450	450	350	200	200	200
23			100	150	100	150	450	450	350	200	200	200
24			150	100	150	100	450	450	350	200	200	200
25			100	150	100	150	450	450	350	200	200	200
26			150	100	150	100	450	450	350	200	200	200
27			100	150	100	150	450	450	350	200	200	200
28			150	100	150	100	450	450	350	200	200	200
29			100	150	100	150	450	450	350	200	200	200
30			150	100	150	100	450	450	350	200	200	200
31			100	150	100	150	450	450	350	200	200	200
32			150	100	150	100	450	450	350	200	200	200
33			100	150	100	150	450	450	350	200	200	200
34			150	100	150	100	450	450	350	200	200	200
35			100	150	100	150	450	450	350	200	200	200
36			150	100	150	100	450	450	350	200	200	200
37			100	150	100	150	450	450	350	200	200	200
38			150	100	150	100	450	450	350	200	200	200
39			100	150	100	150	450	450	350	200	200	200
40			150	100	150	100	450	450	350	200	200	200
Total			3750	3750	3750	3750	13500	13500	13500	6000	6000	6000
Energy Saving Bulb=4, Ceiling Fan=2												
41			70	100	70	100	300	300	200	150	150	150
42			100	70	100	70	300	300	200	150	150	150
43			70	100	70	100	300	300	200	150	150	150
44			100	70	100	70	300	300	200	150	150	150
45			70	100	70	100	300	300	200	150	150	150

House	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
46			100	70	100	70	300	300	200	150	150	150
47			70	100	70	100	300	300	200	150	150	150
48			100	70	100	70	300	300	200	150	150	150
49			70	100	70	100	300	300	200	150	150	150
50			100	70	100	70	300	300	200	150	150	150
51			70	100	70	100	300	300	200	150	150	150
52			100	70	100	70	300	300	200	150	150	150
53			70	100	70	100	300	300	200	150	150	150
54			100	70	100	70	300	300	200	150	150	150
55			70	100	70	100	300	300	200	150	150	150
56			100	70	100	70	300	300	200	150	150	150
57			70	100	70	100	300	300	200	150	150	150
58			100	70	100	70	300	300	200	150	150	150
59			70	100	70	100	300	300	200	150	150	150
60			100	70	100	70	300	300	200	150	150	150
Total			1700	1700	1700	1700	6000	6000	4000	3000	3000	3000
Energy Saving Bulb=4, Ceiling Fan=2												
61							300	300	200	150	150	150
62							300	300	200	150	150	150
63							300	300	200	150	150	150
64							300	300	200	150	150	150
65							300	300	200	150	150	150
66							300	300	200	150	150	150
67							300	300	200	150	150	150
68							300	300	200	150	150	150
69							300	300	200	150	150	150
70							300	300	200	150	150	150
71							300	300	200	150	150	150
72							300	300	200	150	150	150

House	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
73							300	300	200	150	150	150
74							300	300	200	150	150	150
75							300	300	200	150	150	150
76							300	300	200	150	150	150
77							300	300	200	150	150	150
78							300	300	200	150	150	150
79							300	300	200	150	150	150
80							300	300	200	150	150	150
Total							6000	6000	4000	3000	3000	3000
Energy Saving Bulb=4												
81							120	120	120	0	30	0
82							120	120	120	30	0	30
83							120	120	120	0	30	0
84							120	120	120	30	0	30
85							120	120	120	0	30	0
86							120	120	120	30	0	30
87							120	120	120	0	30	0
88							120	120	120	30	0	30
89							120	120	120	0	30	0
90							120	120	120	30	0	30
91							120	120	120	0	30	0
92							120	120	120	30	0	30
93							120	120	120	0	30	0
94							120	120	120	30	0	30
95							120	120	120	0	30	0
96							120	120	120	30	0	30
97							120	120	120	0	30	0
98							120	120	120	30	0	30
99							120	120	120	0	30	0

House	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
100							120	120	120	30	0	30
Total							2400	2400	2400	300	300	300
Energy Saving Bulb=3, Fan=2												
101							330	330	330	140	140	140
102							330	330	330	140	140	140
103							330	330	330	140	140	140
104							330	330	330	140	140	140
105							330	330	330	140	140	140
106							330	330	330	140	140	140
107							330	330	330	140	140	140
108							330	330	330	140	140	140
109							330	330	330	140	140	140
110							330	330	330	140	140	140
111							330	330	330	140	140	140
112							330	330	330	140	140	140
113							330	330	330	140	140	140
114							330	330	330	140	140	140
115							330	330	330	140	140	140
116							330	330	330	140	140	140
117							330	330	330	140	140	140
118							330	330	330	140	140	140
119							330	330	330	140	140	140
120							330	330	330	140	140	140
121							330	330	330	140	140	140
122							330	330	330	140	140	140
123							330	330	330	140	140	140
124							330	330	330	140	140	140
125							330	330	330	140	140	140
126							330	330	330	140	140	140

House	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
127							330	330	330	140	140	140
128							330	330	330	140	140	140
129							330	330	330	140	140	140
130							330	330	330	140	140	140
131							330	330	330	140	140	140
132							330	330	330	140	140	140
133							330	330	330	140	140	140
134							330	330	330	140	140	140
135							330	330	330	140	140	140
136							330	330	330	140	140	140
137							330	330	330	140	140	140
138							330	330	330	140	140	140
139							330	330	330	140	140	140
140							330	330	330	140	140	140
141							330	330	330	140	140	140
142							330	330	330	140	140	140
143							330	330	330	140	140	140
144							330	330	330	140	140	140
145							330	330	330	140	140	140
146							330	330	330	140	140	140
147							330	330	330	140	140	140
148							330	330	330	140	140	140
149							330	330	330	140	140	140
150							330	330	330	140	140	140
Total							16500	16500	16500	7000	7000	7000
Energy Saving Bulb=5												
151							150	150	150			
152							150	150	150			
153							150	150	150			

House	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
154							150	150	150			
155							150	150	150			
156							150	150	150			
157							150	150	150			
158							150	150	150			
159							150	150	150			
160							150	150	150			
161							150	150	150			
162							150	150	150			
163							150	150	150			
164							150	150	150			
165							150	150	150			
166							150	150	150			
167							150	150	150			
168							150	150	150			
169							150	150	150			
170							150	150	150			
171							150	150	150			
172							150	150	150			
173							150	150	150			
174							150	150	150			
175							150	150	150			
176							150	150	150			
177							150	150	150			
178							150	150	150			
179							150	150	150			
180							150	150	150			
181							150	150	150			
182							150	150	150			
183							150	150	150			

House	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
184							150	150	150			
185							150	150	150			
186							150	150	150			
187							150	150	150			
188							150	150	150			
189							150	150	150			
190							150	150	150			
191							150	150	150			
192							150	150	150			
193							150	150	150			
194							150	150	150			
195							150	150	150			
196							150	150	150			
197							150	150	150			
198							150	150	150			
199							150	150	150			
200							150	150	150			
Total							7500	7500	7500			

Table 11.3: Total Demand of electricity at different times.

Time	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
Load in Watt	4000	4000	9450	9450	9450	9450	59400	59400	54150	23300	23300	23300
Load in kW	4	4	9.45	9.45	9.45	9.45	59.4	59.4	54.15	23.3	23.3	23.3

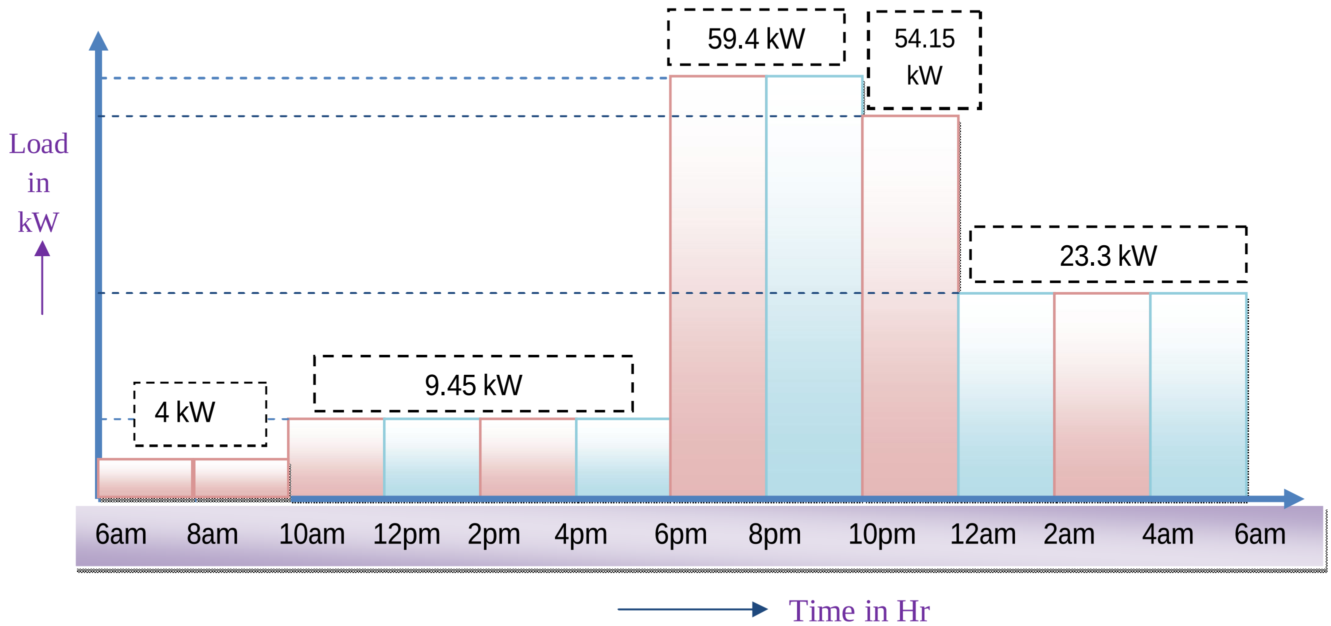


Figure 11.4: Load Curve of the ENH system for an area

11.5 CAPACITY SELECTION OF GENERATOR

The capacity selection of generator is given in table 11.4 and the running time according to the capacity is shown in table 11.5.

Table 11.4: Digester numbering and generator capacity selection.

Digester no.	Designed for	Gas production capacity(m^3)/day	Generator Capacity (kW)	Time of electricity supply (Hour)
1	15 thousand layer	105	10	15
2	15 thousand layer	105	5	10
			20	5
3	20 thousand layer	140	40	5
4	140 number of cows	52	10	7

So, five generators are required with capacity and running time as shown in below:

Table 11.5: Capacity and Running time of each generator

Generator no	Capacity (kW)	Running time (Hour)
1	10	15
2	40	5
3	10	7
4	20	5
5	5	10

11.6 GENERATOR SCHEDULING

The generator scheduling for this system is shown in table 11.6.

Table 11.6: Generator scheduling for the ENH system

Gen No.	6-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
1	Off	On	On	On	On	Off	Off	On	On	On	On
2	Off	Off	Off	Off	Off	On	On	On	Off	Off	Off
3	Off	Off	Off	Off	Off	Off	Off	Off	On	On	On
4	Off	Off	Off	Off	Off	On	On	On	Off	Off	Off
5	On	Off	Off	Off	Off	Off	Off	Off	On	On	On
Total generation	5 kW	10 kW	10 kW	10 kW	10 kW	60 kW	60 kW	70 kW	25 kW	25 kW	25 kW

11.7 COST CALCULATION

11.7.1 COST OF DIGESTERS

The cost of a 500 CFT Digester is about 55,000 BDT [48].

Cost of Digester no. 1 and 2:

The volume digester no.1 is 190 m^3= 190×3.28^3 CFT= 6,704.6 CFT

$$\text{So, The cost of Digester} = \frac{55{,}000}{500} \times 6{,}704.6 \text{ BDT} = 7{,}37{,}506 \text{ BDT}$$

Volume of hydraulic chamber and inlet recharge chamber = 2×4×3.28^3 CFT= 282 CFT

So, cost of hydraulic chamber and inlet recharge chamber = 282×110= 31,020 BDT

Total cost of digester no.1 = 7,37,506 + 31,020 BDT. = 7,68,526 BDT.

The size of digester no. 2 is same as digester no.1.

So, total cost of digester no, 1 and 2 = (7,68,526 + 7, 68,526) BDT = 15,37,052 BDT

Cost of Digester no. 3:

The volume digester no.3 is 250 m^3= 250×3.28^3 CFT= 8821.88 CFT

$$\text{So, The cost of Digester} = \frac{55{,}000}{500} \times 8821.88 \text{ BDT} = 9{,}70{,}406.8 \text{ BDT}$$

Volume of Hydraulic chamber and inlet recharge chamber = 2×5×3.28^3 CFT= 352 CFT

So, Cost of Hydraulic chamber and inlet recharge chamber = 352×110 = 38,720 BDT

Total cost of digester no.2 and 3 = (970406.8 + 38,720) BDT = 10,09,126 BDT.

Cost of Digester no.4:

The volume digester no.4 is 140 m^3= 140×3.28^3 CFT= 4,940 CFT

$$\text{So, The cost of Digester} = \frac{55{,}000}{500} \times 4940 \text{ BDT} = 5{,}43{,}400 \text{ BDT}$$

Volume of Hydraulic chamber and inlet recharge chamber = 2×2.8×3.28^3 CFT= 198 CFT

So, Cost of Hydraulic chamber and inlet recharge chamber = 198×110= 21,780 BDT

Cost of digester no.4 = (5,43,400 + 21,780) BDT. = 5,65,180 BDT.

Total Cost of Digesters = (15,37,052 +10,09,126 +5,65,180) BDT. = 31,11,358 BDT.

11.7.2 COST OF PURIFICATION UNITS AND PIPE LINE

Cost of Purification Unit = 40,000 BDT.

Pipe line and others = 20,000 BDT.

11.7.3 COST OF GENERATORS [46], [47]

Cost of 40 kW generator = 6,50,000 BDT

Cost of 20 kW generator = 3,00,000 BDT.

Cost of two 10 kW generator = 1,70,000×2 = 3,40,000 BDT.

Cost of 5 kW generator = 70,000 BDT.

Total Generator Cost = (6,50,000 +3,00,000+ 3,40,000 +70,000) BDT. = 13,60,000 BDT.

Subtotal Cost of Plant = (31,11,358 + 60,000 + 13,60,000) BDT. = 45,31,358 BDT.

11.7.4 TRANSMISSION LINE COST

Let, Transmission line Cost is 2% of the total plant cost.

So, Transmission line cost = 45, 31, 358 ×0.02 = 90, 627 BDT.

11.7.5 TOTAL COST OF THE SYSTEM

Total Cost of the system = (45, 31, 358 + 90,627) BDT. = 46, 21, 985 BDT.

11.8 MONTHLY INCOME

The monthly income of the ENH system can be expressed as shown in table 11.7.

Table 11.7: Per month income calculation

House no.	Electricity consumption/day (kWh)	Per Unit Cost (BDT)	Monthly Bill (BDT)
1-10	114.6	5	17,190
11-40	147	5	22,050
41-60	63.6	5	9,540
61-80	50	5	7,500
81-100	16.2	5	2,430
101-150	141	5	21,150
151-200	45	5	6,750
		Total	**86, 610**

11.9 COST ANALYSIS

Income per month = 86,610 BDT.

Two labors are necessary for operating the plant.

Per month Salary of the labors = 20,000 BDT.

Net income per month = (86,610-20,000) BDT. = 66,610 BDT.

Income per year = (66,610× 12) BDT. = 7,99,320 BDT.

Repairing cost of transmission line per year = 50,000 BDT.

Net income per year = (7,99,320 - 50,000) BDT. = 7,49,320 BDT.

Income per 20 years = (7,49,320×20) BDT = 1,49,86,400 BDT.

Overhauling Cost of Generator for 20 years:

Overhauling of a generator is required after 10,000 hours of operation which is called top overhauling. The cost of top overhauling is about 15% of the generator cost. Another overhauling has to be done after further 10,000 hour operation which is called major overhauling. Cost of major overhauling is about 50% of the generator cost [46].

1) **Overhauling cost of generator no.1**: Operating time will be (15×30×12×20) = 1,08,000 hours, if operates in 20 years. So six times top overhauling and 4 times major overhauling have to be done.

Top overhauling cost for one time = 15% of 1,70,000 = 25,500 BDT.

Total top overhauling cost = (25,500×6) BDT. = 1,53,000 BDT.

Major overhauling cost for one time = 50% of 1,70,000 = 85,000 BDT.

Total major overhauling cost = (85,000×4) BDT. = 3,40,000 BDT.

Total overhauling cost for generator no.1 = (1,53,000 + 3,40,000) BDT

= 4,93,000 BDT.

2) **Overhauling cost of generator no. 2:** Operating time will be (6×30×12×20) = 43,200 hours, if operates in 20 years. So two times top overhauling and one time major overhauling has to be done.

Top overhauling cost for one time = 15% of 6,50,000 = 97,500 BDT.

Major overhauling cost for one time = 50% of 6,50,000 = 3,25,000 BDT.

Total overhauling cost for generator no.2 = (1,95,000 + 3,25,000) BDT

= 5,20,000 BDT.

3) **Overhauling cost of generator no.3**: Operating time will be (7×30×12×20) = 50,400 hours, if operates in 20 years. So four times top overhauling and two times major overhauling have to be done.

Top overhauling cost for one time = 15% of 1,70,000 = 25,500 BDT.

Total top overhauling cost = (25,500×4) BDT. = 1,02,000 BDT.

Major overhauling cost for one time = 50% of 1,70,000 = 85,000 BDT.

Total overhauling cost for generator no.3 = (1,02,000 + 1,70,000) BDT

= 2,72,000 BDT.

4) **Overhauling cost of generator no.4**: Operating time will be (6×30×12×20) = 43,200 hours, if operates in 20 years. So 2 times top overhauling and 2 times major overhauling has to be done.

Top overhauling cost for one time = 15% of 3,00,000 = 45,000 BDT.

Total top overhauling cost = (45,000×2) BDT. = 90,000 BDT.

Major overhauling cost for one time = 50% of 3,00,000 = 1,50,000 BDT.

Total overhauling cost for generator no.4 = (90,000 + 3,00,000) BDT = 3,90,000 BDT.

5) **Overhauling cost of generator no.5**: Operating time will be (10×30×12×20) = 72,000 hours, if operates in 20 years. So 4 times top overhauling and 2 times major overhauling have to be done.

   Top overhauling cost for one time = 15% of 70,000 = 10,500 BDT.

   Total top overhauling cost = (10,500×4) BDT. = 42,000 BDT.

   Major overhauling cost for one time = 50% of 70,000 = 35,000 BDT.

   Total overhauling cost for generator no.5 = (42,000 + 70,000) BDT = 1,12,000 BDT.

Overhauling cost of all generators for 20 years = (4,93,000 + 5,20,000 + 2, 72, 000 + 3,90,000 + 1,12,000) BDT. = 17,87,000 BDT.

Total operating Cost = repairing cost + overhauling cost of generator = 50,000 + 17,87,000 = 18,37,000 BDT

So net income considering the overhauling cost of generator after 20 years

= (149,86,400 -18,37,000) BDT. = 131,49,400 BDT.

Net income per year = (131,49,400/20) BDT. = 6,57,470 BDT.

Total investment will be come out within (46,21,985 / 6,57,470) year or 7 years and 3 months.

Per Unit Cost:

Electricity used in a day = (4 x 4 + 9.45 x 8 + 59.4 x 4 + 54.15 x 2 + 23.3 x 6) kWh

= 16+75.6+237.6+108.3+139.8 = 577.3 kWh

Total electricity used in 20 years = 577.3 x 30 x 12 x 20 kWh = 41,56,560 kWh

Total cost = 46,21,985 + 18,37,000 = 64,58,985 BDT

Per Unit Cost = 64,58,985 / 41,56,560 BDT = 1.55 BDT

The analysis is done for a life time of 20 years. For this life time, the founded result of the unit price of electricity is only 2.92 BDT for a home. On the other hand, the result of the ENH system for an area of 200 homes (capacity 85 kW) shows that the unit price of electricity is approximately 1.55 BDT. So it can be concluded here that the unit price of electricity decreases with the increase of houses in the ENH system.

11.10 OVERVIEW OF THE ENH SYSTEM FOR AN AREA (200 HOUSES)

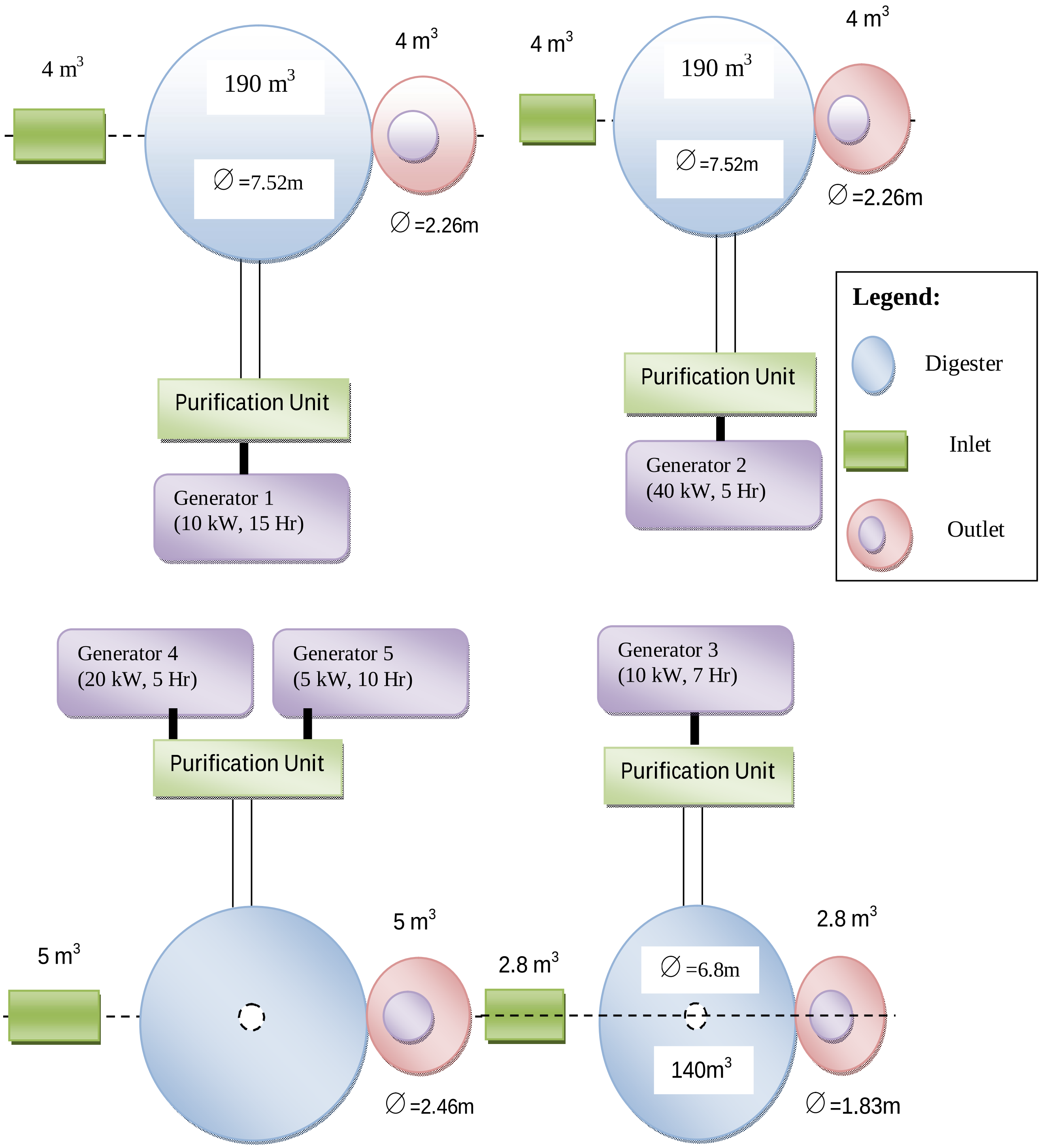


Figure 11.5: Overview of the ENH system for an area of 200 homes

CHAPTER 12

THE HYBRID ENH SYSTEM: DESIGN AND COST ANALYSIS

12.1 THE HYBRID ENH SYSTEM

When an ENH system is able to meet the energy requirements from more than one source then the power plant is called a hybrid ENH system. The aim of this research is to use only the renewable energy sources available in Bangladesh to develop the hybrid power plant. Offshore wind power plant is not suitable for Bangladesh and tidal energy conversion to electricity is still costly, so here the main considerations of the hybrid ENH system are the biogas and solar as input renewable energy sources. Photovoltaic power production and power from biogas are gaining more significance as a renewable energy source due to their many advantages. These advantages include everlasting pollution free energy production scheme, ease of maintenance, and generation of electricity. However, the high cost of PV installations still forms an obstacle for this technology. Moreover, the PV panel output power fluctuates due to some reasons such as the weather conditions, the insulation level and cell temperature. In the winter season the load demand decreases. Then the surplus power can be supplied to other places and also used the gas for cooking, lighting etc.

12.2 AIM OF THE HYBRID ENH SYSTEM

The aim of the Hybrid ENH system is to supply electricity continuously to the rural areas where grid connection is not possible such as Islands and Hilly regions and to facilitate the house hold uses such as cooking. The only requirement of the system is that the areas should have poultry farm or cow farm. In fact, most of the houses in the rural area have small farms. They use the waste of these farms as organic fertilizer. But they can use these waste to generate biogas which can produce electricity and after producing biogas the waste can be used as an organic fertilizer. This hybrid power plant can also be effectively used in metropolitan city. The solar panels can be installed at the roof of buildings. A small poultry farm can also be built in the roof or a specific land. From the farm waste the biogas can be produced. Also, biogas can be obtained from human waste. By combining the biogas collected from human waste and poultry waste with solar uninterrupted electricity supply is possible in the metropolitan city.

12.3 DESIGN OF A HYBRID ENH SYSTEM FOR 15 HOUSES

The commonly used loads in house hold are tabulated in table 12.1.The load curve is shown in figure 12.1.

Table 12.1: Some common load used in house hold and their ratings

S\N	Name of Appliance	Power consumed in watts
1	Bulb	40-250
2	Tube Light	20-40
3	Ceiling Fan	75-100
4	Color TV	70-100
5	PC	60-120
6	Refrigerator	100-150
7	Deep Freezer	500-700
8	Cordless Telephone	10-15
9	Calling Bell	15-25
10	Energy Saving Bulb	11-30

12.3.1 LOAD CALCULATION

The electrical load is calculated according to the demand of the houses and is depicted in table 12.2.

Load used for each house: Tube Light=2, Energy Saving Bulb=2, Color TV=1, Freeze=1, Ceiling Fan=3

Table 12.2: Demand of electricity in watt at different times.

House	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-4 am	4-6 am
1	500	150	500	150	500	150	800	350	700	200	700	200
2	150	500	150	500	150	500	350	800	300	700	200	700
3	500	150	500	150	500	150	800	350	700	200	700	200
4	150	500	150	500	150	500	350	800	300	700	200	700
5	500	150	500	150	500	150	800	350	700	200	700	200
6	150	500	150	500	150	500	350	800	300	700	200	700
7	500	150	500	150	500	150	800	350	700	200	700	200

8	150	500	150	500	150	500	350	800	300	700	200	700
9	500	150	500	150	500	150	800	350	700	200	700	200
10	150	500	150	500	150	500	350	800	300	700	200	700
11	500	150	500	150	500	150	800	350	700	200	700	200
12	150	500	150	500	150	500	350	800	300	700	200	700
13	500	150	500	150	500	150	800	350	700	200	700	200
14	150	500	150	500	150	500	350	800	300	700	200	700
15	500	150	500	150	500	150	800	350	700	200	700	200
Total	**4875**	**4875**	**4875**	**4875**	**4875**	**4875**	**8625**	**8625**	**7500**	**7500**	**6750**	**6750**

12.3.2 LOAD CURVE

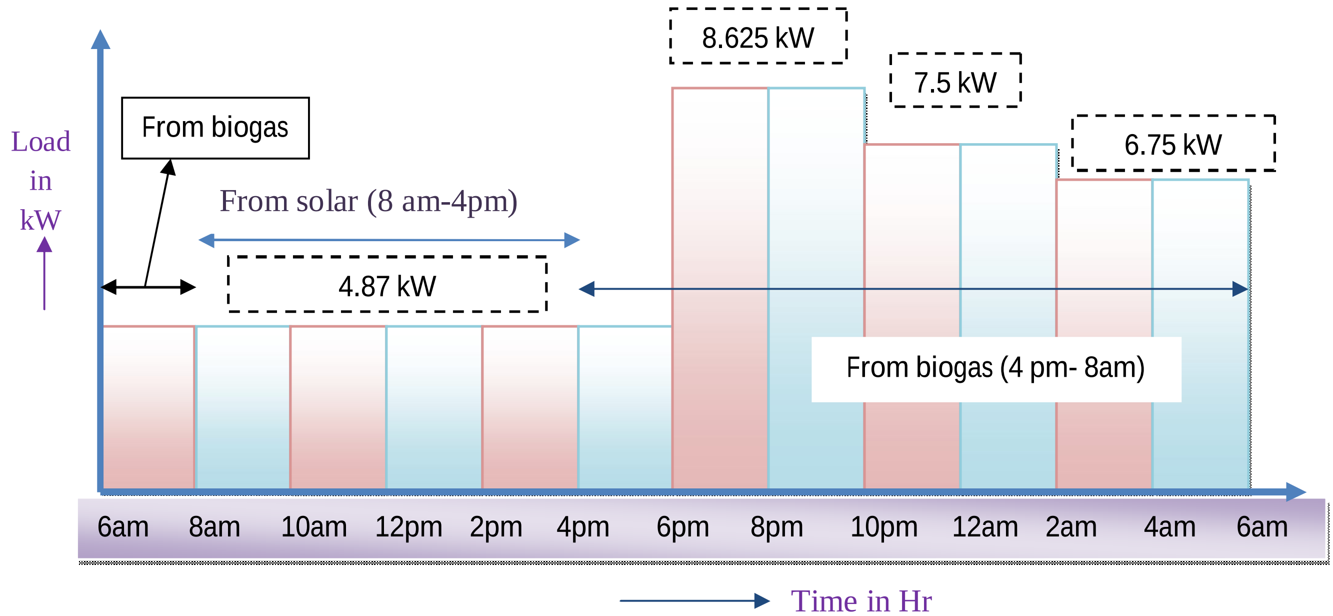


Figure 12.1: Load Curve of the hybrid ENH system

12.3.3 DESIGN AND ANALYSIS OF BIOGAS PLANT FOR THE HYBRID ENH SYSTEM

12.3.3.1 HENS REQUIRED IN THE FARM

(a) For electricity generation:

Total electricity demand from biogas plant

$$= (8.625 \times 2 \times 2 + 7.5 \times 2 \times 2 + 6.75 \times 2 \times 2 + 4.87 \times 4)\ \text{kWh}$$

$$= 110.98\ \text{kWh}$$

Let for 110.98 kWh electricity generations we required n number of hens. As an average each hen gives 100 gm of waste.

Total waste for n number of hens= 0.1n kg

Again, practically 0.07 m^3 of biogas can be obtained from 1 kg of waste [39], [40].

So, total biogas obtained from n number of broilers

$$= 0.1n \times 0.07\ m^3 = 0.007n\ \ m^3$$

From each cubic meter we get 1.4 kWh of electricity [39].

So, from n number of broilers the electricity obtained

$$= 0.007n \times 1.4 = .0098n \approx 0.01n\ kWh$$

This 0.01n kWh should be equals to the electricity demand for calculating the number of hen. So,

$$0.01n = 110.98\ or, n = \frac{110.98}{0.01} = 11{,}098 \approx 11{,}100$$

That means 11,100 number of hens is required to fulfill the demand of electricity of 15 houses. Each house should have poultry farm with 740 hens.

(b) For gas supply:

Each family needs two gas burners for cooking purpose and

Each gas burner consumes 0.4 m^3 gas per hour.

Total gas required for the system = $(15 \times 2 \times 2.5 \times 0.4)\ m^3 = 30\ m^3$

From n numbers of broiler the available biogas $0.007n\ \ m^3$.

So, to produce this gas required no of broiler, $n = \frac{30}{0.007} = 4{,}285.7$ = 4,286

Total broilers need for the system = (11,100 + 4,286) = 15,386

12.3.3.2 DESIGN OF DIGESTER

The design calculation of digester and hydraulic chamber of hybrid ENH system is given in appendix C. The design layout is shown in figure 12.2.

From the calculation of appendix C the following results are found:

$V = 140\ m^3, D = 6.79\ m, H = 2.72\ m$

$f_1 = D/5 = 6.79/5 = 1.358$ m

$f_2 = D/8 = 6.79/8 = 0.85$ m

$R_1 = 0.725D = 0.725 \times 6.79 = 4.92$ m

$R_2 = 1.0625D = 1.0625 \times 6.79 = 7.21$ m

$V_1 = 0.0827D^3 = 0.0827 \times (6.79)^3 = 25.9\ m^3 = 25.9\ m^3$

$V_c = 0.05V = 0.05 \times 140\ m^3 = 7\ m^3$

12.3.3 .3 VOLUME CALCULATION OF HYDRAULIC CHAMBER

From the calculation of appendix C the following results are found:

$h = 0.23$ m, $h_1 = H_H = 1.06$ m, $D_H = 2.82\ m$

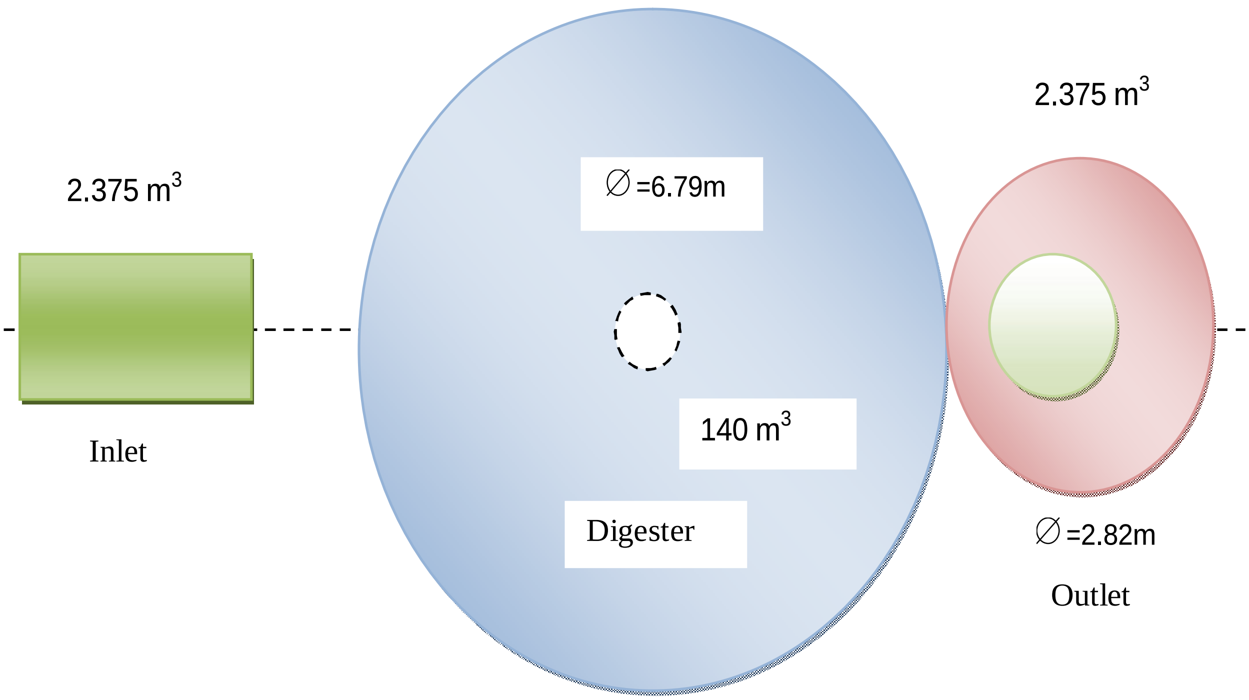


Figure 12.2: Volume and diameter of digester and hydraulic chamber

12.3.3 .4 DIGESTER SIZE FOR SUPPLYING GAS

By similar calculation,

Volume of digester = $53.575\ m^3$

Volume of inlet and outlet = $1.07\ m^3$

12.3.4 COST CALCULATION OF THE HYBRID ENH SYSTEM

12.3.4.1 INSTALLATION COST (FOR ELECTRICITY GENERATION)

The cost of a 500 CFT Digester is about 55,000 BDT [48].

The volume of digester is 140 m^3= 140×3.28^3 CFT= 4940 CFT

$$\text{So, The cost of Digester} = \frac{55{,}000}{500} \times 4940 \text{ BDT} = 5{,}43{,}400 \text{ BDT}$$

Volume of hydraulic chamber and inlet recharge chamber = 2×2.775×3.28^3 CFT= 195.8 CFT

So, cost of hydraulic chamber and inlet recharge chamber = 195.8×110 = 21,543 BDT

Cost of purification unit = 15,000 BDT

Pipe line and others = 20,000 BDT

In this design, two 5 kW generators and two 2 kW generators should be bought.

Cost of two 5kW generators = 1,40,000 BDT [46], [47].

And cost of two 2kW generator = 40,000×2 = 80,000 BDT

Total generator cost = 1,40,000 + 80,000 = 2,20,000 BDT

Table 12.3: Cost of biogas plant

Digester cost	5,43,400 BDT
Hydraulic chamber cost	21,443 BDT
Purification unit cost	15,000 BDT
Pipe line	20,000 BDT
Generator cost	2,20,000 BDT
Total	**8,19,843 BDT**

12.3.4.2 DESIGN OF SOLAR PANEL AND BATTERY SIZING

(a) Solar panel estimation [49], [50] and [51]:

We have run the loads eight hours per day.

Energy consumed by these loads = 4.87 × 8 kWh ⁄ day

= 38.96 kWh⁄day

Let select,

The days of autonomy is three (3) days and Depth of Discharge (DOD) = 70%.

Solar irradiation (G) = 4.2 kWh⁄m^2⁄day.

And η =55%

Now, Energy to load (kWh/day) = kW rating × G × η_p

=> 38.96 = kW rating ×4.2×0.55

=> kW rating = 16.86 kW

If 300 W rating module is selected,

Then the number of module will be required = 16.86 ÷ 0.300

= 56.2

≈ 57

(b) Battery estimation [49], [50] and [51]: If n is the number of days of autonomy, then

n×energy supplied to load (Wh/day) = Purchase capacity of battery(Wh) × DOD.

=> 3×38960 = Wh capacity of battery × 0.70

=> Wh capacity of battery = 166971.4

Again,

Wh capacity of battery = Ampere Hour (AH) capacity × Terminal Voltage (volt)

=> 166971.4 = AH×12

=> AH = 13914.3

If we select the following size of battery = 200AH@C10

Then the number of battery = 13914.3÷200

= 69.57

≈ 70

The function of battery in this system is optional because electricity cannot be supplied from battery during night. Battery requires only when solar radiation in insufficient.

Assuming, the number of batteries is 40% of the normal requirement.

Number of battery required = 28

Actual AH used = 28×200 = 5600 AH

Maximum current that could be supplied from the battery bank = 5600 ÷ 10

= 560 Amp

Now, load current = 4870 watt ÷ 12 volt

= 405.8 Amp

So the number of battery selection is correct.

12.3.4.3 COST OF PV SYSTEM

(a) Solar panel cost:

Recent market price of 300 W panel in Energy Bangla Company = 30,000 BDT [52]

So, total solar panel cost = 30,000 × 57 =17,10,000 BDT

(b) Battery bank cost:

Recent market price of 200 AH battery in Navana group = 18000 BDT [53].

So, total battery bank cost = 18000 × 28 = 5,04,000 BDT

(c) Inverter cost:

For this system, 3000 VA inverter with power factor of 0.8 is selected.

Recent market price of 3000 VA inverter in Solarpac company = 28000 BDT [54].

So, number of inverter needed = watt rating ÷ (3000 × 0.8) = 16860 ÷ (3000 × 0.8) ≈ 7

So, total inverter cost = 28,000 × 7 = 1,96,000 BDT

(d) Subtotal cost:

Solar panel cost + Battery bank cost + Inverter cost

= 17,10,000 + 5,04,000 + 1,96,000

= 24,10,000 BDT

(e) Miscellaneous cost:

This is the cost of charge controllers, wires, fuses, switches etc.

Estimating it by 5% of subtotal cost = 0.05 × 24,10,000 = 1,20,500 BDT

Total cost of PV system = 24,10,000 + 1,20,500 = 25,30,500 BDT

12.3.4.4 TOTAL INSTALLATION COST OF HYBRID ENH SYSTEM

Table 12.4: Total Cost of the Hybrid ENH system.

Cost of biogas plant	8,19,843 BDT
Cost of solar PV system	25,30,500 BDT
Total cost	**33,50,343 BDT**

12.3.4.5 INSTALLATION COST (FOR GAS SUPPLY)

The cost of a 500 CFT digester is about 55,000 BDT [48].

So the per CFT cost is 110 BDT.

The volume of digester is 53.575 m^3= 53.575 ×3.28^3 CFT= 1890.5 CFT

$$\text{So, The cost of Digester} = \frac{55{,}000}{500} \times 1890.5\ \text{BDT} = 2{,}07{,}955\ \text{BDT}$$

Volume of hydraulic chamber and inlet recharge chamber = 2×1.07 ×3.28^3 CFT = 75.5 CFT

So, cost of hydraulic chamber and inlet recharge chamber = 75.5×110 BDT = 8,306 BDT

Cost of purification unit = 10,000 BDT

Pipe line and others = 1, 00,000 BDT

Total cost= (1,07,955 + 8,306 + 10,000 + 1,00,000) BDT = 2,26,261 BDT

Maintenance cost for 20 years (for gas supply):

Maintenance cost of purification unit = 10,000 BDT

Repairing cost of pipelines = 50,000 BDT

Total maintenance cost = 10,000 + 50,000 = 60,000 BDT

Total cost for 20 years, including maintenance cost = (2,26,261 + 60,000) BDT = 2,86,261 BDT

Monthly cost of each family for using gas = 2,86,261/ (15×20×12) = 79.52 BDT

12.4 COST ANALYSIS FOR HYBRID AND NORMAL ENH SYSTEM

12.4.1 COST ANALYSIS FOR HYBRID ENH SYSTEM

Installation cost of hybrid plant = 33,50,343 BDT

(a) Maintenance cost of biogas plant per year:

Labor cost per year = 1,20,000 BDT

Repairing cost of transmission line per year = 10,000 BDT

Maintenance cost for 20 years = (1,20,000+10,000) ×20 BDT =26,00,000 BDT

Overhauling cost of generator for 20 years:

5 kW generators: Each 5 kW generator operates 12 hour per day. Total operating time for 20 years = (12×365×20) = 86,400 hours. So, five times top overhauling and four times major overhauling have to be done.

Top overhauling cost for one time = 15% of 50,000 = 7,500 BDT [46].

Total top overhauling cost = (7,500×5) BDT = 37,500 BDT

Major overhauling cost for four times = 50% of 50,000 = 25,000 BDT [46].

Total major overhauling cost = (25,000×4) BDT = 1,00,000 BDT

Total overhauling cost for two 5 kW generators = (37,500 +1,00,000) ×2 BDT = 2,75,000 BDT

Similarly, overhauling cost for two 2 kW generators = 1,65,000 BDT

Total maintenance cost considering overhauling cost = (26,00,000 +2,75,000+1,65,000) BDT

= 30,40,000 BDT

(b) Maintenance cost of solar PV system for 20 years:

Battery of PV system has to be changed after 10 years. There is no other maintenance required.

Battery bank cost = 5,04,000 BDT

Total maintenance cost of hybrid power plant = (30,40,000 +5,04,000) BDT = 35,44,000 BDT

Cost of operation with installation cost for 20 years = (33,50,343 +35,44,000) BDT

= 68,94,343 BDT

(c) Per unit cost calculation:

Electricity used per day in kWh = $8.625 \times 2 \times 2 + 7.5 \times 2 \times 2 + 6.75 \times 2 \times 2 + 4.87 \times 10$

= 140.2 kWh

Electricity used per year = (140.2×365) kWh = 51,173 kWh

Total electricity used in 20 years = 51,173×20 kWh = 10,23,460 kWh

Per unit cost = (68,94,343 /10,23,460) BDT = 6.74 BDT

12.4.2 COST ANALYSIS FOR ENH SYSTEM WITH ONLY BIOGAS

12.4.2.1 TOTAL COST OF THE SYSTEM WITHOUT OPERATING COST

(a) Cost of Digester:

The cost of a 500 CFT digester is about 55,000 BDT [48].

The volume digester is 188.556 m^3= 188.556 × 3.28^3 CFT= 6653.67 CFT

$$\text{So, The cost of digester} = \frac{55{,}000}{500} \times 6653.67 \text{ BDT} = 7{,}31{,}903.7 \text{ BDT}$$

Volume of hydraulic chamber and inlet recharge chamber = 2×4×3.28^3 CFT= 282 CFT

So, cost of hydraulic chamber and inlet recharge chamber = 282×110 BDT = 31,020 BDT

Total cost of digester = 7,31,903 + 31,020 BDT = 7,62,923 BDT

(b) Cost of purification units and pipe line:

Cost of purification unit = 10,000 BDT

Pipe line and others = 10,000 BDT

(c) Cost of generators: [46], [47]

Cost of 10 kW generator = 1,50,000 BDT

Cost of 6 kW generator = 90,00,000 BDT

Cost of 2 kW generator = 40,000 = 40,000 BDT

Total generator cost = (1,50,000 +90,000+ 40,000) BDT = 2,80,000 BDT

(d) Subtotal cost of system = (7,62,923 + 20,000 + 2,80,000) BDT = 10,62,923 BDT

(e) Transmission line cost:

Let, transmission line cost is 2% of the total plant cost.

So, transmission line cost = 10,62,923 ×0.02 = 21,258 BDT

(f) Total cost of system without operating cost:

Total cost of the system = (10,62,923 + 21,258) BDT = 10,84,181 BDT

12.4.2.2 TOTAL COST OF THE SYSTEM WITH OPERATING COST

Overhauling cost of generator for 20 years:

Overhauling of a generator is required after 10, 000 hours of operation which is called top overhauling. The cost of top overhauling is about 15% of the generator cost. Another overhauling has to be done after further 10,000 hour operation which is called major overhauling. Cost of major overhauling is about 50% of the generator cost [46].

(i) **Overhauling cost of generator no.1 (10 kW)**: Operating time will be (20×365×8) = 57,600 hours, if operates for 8 hours per day in 20 years. So, 3 times top overhauling and 2 time major overhauling have to be done.

Top overhauling cost for one time = 15% of 1,50,000 = 22,500 BDT

Total top overhauling cost = (22,500×3) BDT = 67,500 BDT

Total major overhauling cost =2 × 50% of 1,50,000 = 1,50,000 BDT

Total overhauling cost for generator no.1 = (67,500 + 1,50,000) BDT = 2,17,500 BDT

(ii) **Overhauling cost of generator no. 2 (6 kW):** Operating time will be (20×365×16) = 1,15,200 hours, if operates for 16 hours per day in 20 years. So, six times top overhauling and five times major overhauling have to be done.

Total top overhauling cost for one time = 6 ×15% of 90,000 = 81,000 BDT

Total major overhauling cost for one time = 5 × 50% of 90,000 = 2,25,000 BDT

Total overhauling cost for generator no.2 = (81,000 +2,25,000) BDT = 3,06,000 BDT

(iii) **Overhauling cost of generator no.3 (2 kW)**: Operating time will be (20×365×4) = 28,800 hours, if operates for 4 hours in 20 years. So, 1 time top overhauling and 1 time major overhauling have to be done.

Top overhauling cost for one time = 15% of 40,000 = 6,000 BDT

Major overhauling cost for one time = 50% of 40,000 = 20,000 BDT.

Total overhauling cost for generator no.3 = 26,000 BDT

Overhauling cost of all generators for 20 years = (2,17,500 +3,06,000 +26,000) BDT

= 5,49,500 BDT

Total operating cost = pipe line repairing cost + overhauling cost of generator

= 10,000+5,49,500= 5,59,000 BDT

Total cost of the system including operating cost for 20 years = (10,84,181+5,59,000) BDT

= 16,43,181 BDT

12.4.2.3 PER UNIT COST CALCULATION

Electricity used per day in kWh = 8.625 × 2 × 2 + 7.5 × 2 × 2 + 6.75 × 2 × 2 + 4.87 × 10

= 140.2 kWh

Electricity used per year = (140.2×365) kWh = 51173 kWh

Total electricity used in 20 years = 51173×20 kWh = 10, 23,460 kWh

Per Unit Cost = (16, 43, 181 /10, 23, 460) BDT = 1.6 BDT

12.5 EFFECTIVENESS OF HYBRID ENH SYSTEM IN URBAN AREAS

In rural areas there are available places for building poultry farm and cow farm. Availability of poultry waste and cow dung will make it easier to supply electricity only from biogas plant. Again solar PV system is very costly. Most of the rural people have no ability to install a solar PV system. From this chapter, it is clear that the per unit cost of hybrid ENH system is only 6.74 BDT, where for ENH system with biogas is only 1.6 BDT. So, the hybrid ENH system is not cost effective for rural areas. But it will be useful in urban areas because the required land space is less than the normal ENH system.

12.6 DISCUSSION

Per unit cost of hybrid ENH system is only 6.74 BDT. Also electricity supply is uninterrupted and there is no use of any conventional energy. So, this hybrid system is able to ensure continuous power supply within a reliable price only using renewable energy sources even in metropolitan city area. This is the time to implement this system throughout the country for removing such worst condition of electricity supply.

CHAPTER 13

ENH SYSTEM AS A LOAD SHEDDING BACKUP

13.1 LOAD SHEDDING BACKUP BY IPS

Now a day in Bangladesh IPS (Instant Power Supply) is very popular as a backup of load shedding. It can supply electricity during load shade from its battery storage. Its capacity is very limited (200-300 VA) most of the cases. The average cost of IPS available at the market is about 20-25 thousands. Moreover the lifetime of IPS is not more than 2 years. Another important problem, IPS itself is a load; it has no ability to generate electricity. If everyone starts using IPS as a load shedding backup, the duration of load shade must be increased. So, use of IPS as a load shading backup cannot be a solution. So, this is the time to search an alternative way.

Biogas from human waste can be a source of electricity generation. The generated electricity is not too large to supply throughout the day. It can supply electricity 3 to 4 hours in a day which is enough to backup load shade. It only requires a special type of commode design. This chapter consists of two case studies for the clarification of the concept.

13.2 CASE STUDY 1

13.2.1 CALCULATION OF WASTE, BIOGAS AND GENERATED ELECTRICITY FOR AN EXISTING 5 STORIED BUILDING

Mr. Jashim Uddin (House-"Rekha Bhovon, Lane-12, Road-2, Block-A, Halishahsr H/E, Chittagong") is the owner of a five storied building. The building contains 19 flats and the number of people in this building is tabulated in table 13.1.

Table 13.1: Number of people living in Mr. Jashim Uddins building

Floor	No. of flat	No. of people	No. of people / flat
Ground floor	3	6+4+6	16
1st floor	4	5+6+6+4	21
2nd floor	4	4+5+6+6	21
3rd floor	4	6+6+6+5	23
4th floor	4	7+5+6+6	24
		Total	105

On an average each person gives 0.5 kg of waste per day.

If we have n numbers of people then total waste $= 0.5n$ kg

At ordinary temperature (30°C) biogas obtained from human waste 0.365 m^3/ kg TS [41].

Again TS value of human waste = 20%

So, total biogas obtained from n numbers of people

$$= 0.5n \times 0.2 \times 0.365\ m^3 = 0.0365n\ m^3$$

From each cubic meter biogas we get 1.4 kWh electricity [39].

So, from n number of persons electricity obtained

$$= 0.0365n \times 1.4 = 0.0511n\ \text{kWh}$$

If we use electricity 3 hours/day then capacity of the farm for electricity generation can be obtained by the following equation

$$\text{Capacity} = \frac{0.0511n}{3}\ \text{kW, where n is the number of persons}$$

In this case number of person n = 105

$$\text{So, capacity of generator} = \frac{0.0511n}{3} = \frac{0.0511 \times 105}{3}\ \text{kW} = 1788\ \text{W for 3 hours}$$

13.2.2 DIGESTER VOLUME

Let HRT =40 days (for temperature 30°C)

Every layer or broiler gives 500 gm manure per day.

Total discharge=$105 \times 0.5\ \text{kg} = 52.5\ \text{kg}$

TS of fresh discharge=$0.2 \times 52.5\ \text{kg} = 10.5\ \text{kg}$

To make the TS value of 8% for favorable condition we have to mix some additional water with fresh discharge. The required water to be added can be calculated by the following way,

8 kg solid equivalent 100 kg of influent

$$\therefore\ 10.5\ \text{kg solid equivalent} = \frac{100 \times 10.5}{8} = 131.25\ kg$$

So, total influent required, Q= 131.25 kg.

Recharge in digester per day = 131.25 kg = 0.3125 m^3

Working volume of digester$= V_{gs} + V_f$

$$V_{gs} + V_f = Q \times HRT = 131.25 \frac{\text{kg}}{\text{day}} \times 40\ \text{days} = 5250\ \text{kg} = 5.25 m^3$$

From geometrical assumption:

$V_{gs} + V_f = 80\%V$

Or, 5.25 = 0.8V (Putting the value of $(V_{gs} + V_f)$)

Or, $V = 6.5625\ m^3$

13.2.3 INSTALLATION COST

a) Cost of digester:

The cost of a 500 CFT digester is about 55,000 BDT [48]

The volume of our digester is 6.5625 m^3= 6.5625×3.28^3 CFT= 231.57 CFT

$$\text{So, the cost of digester} = \frac{55{,}000}{500} \times 231.57\ \text{BDT} = 25{,}472\ \text{BDT}$$

b) Volume of Hydraulic chamber and inlet recharge chamber,

= 2× recharge per day×3.28^3

= 2×0.3125× 3.28^3CFT

= 22.05 CFT

So, cost of hydraulic chamber and inlet recharge chamber = 22.05×110 BDT = 2,425 BDT

c) Cost of purification unit = 10,000 BDT

d) Pipe line and others = 10,000 BDT

e) Generator cost: In this case a 2.6 kW generator is necessary

Cost of 2.6 kW generator = 44,000 BDT [47]

Total cost of the plant = (25,472+2,425+10,000+10,000+44,000) BDT = 91,897 BDT

13.2.4 MAINTENANCE COST FOR FIVE YEARS

Labor cost = 2,000 BDT per month.

Total labor cost = 2,000 × 5 × 12 = 1,20,000 BDT

Overhauling of generator is needed after operating 10,000 hours [46]. Total operating time within 5 years for our generator is 5,400 hours. So, overhauling cost of Generator is not required.

Pipeline repairing cost = 10,000 BDT

Maintenance cost of purification unit = 3,000 BDT

Total maintenance cost = (1,20,000 + 10,000 + 3,000) BDT

= 1,33,000 BDT

Cost for each house:

Total cost of the plant with maintenance cost for five years = (91,897 + 1,33,000) BDT

= 2,24,897 BDT

The generated 1788 watt electricity can be distributed within three houses so that each house will get about 500 watt electricity if 288 watt is considered as loss.

Cost for each user = (2,24,897 ÷ 3) = **74,966 BDT**

13.2.5 MAINTENANCE COST FOR TWENTY YEARS

Labor cost = 2,000 BDT per month

Total labor cost = 2,000 × 20 × 12 = 4,80,000 BDT

Overhauling of Generator is needed after operating 10,000 hours [46]. Total operating time within 20 years for our generator is 21,600 hours. So, generators need one time top overhauling and one time major overhauling.

Cost of top overhauling = 15% of generator cost = 6,600 BDT

Cost of major overhauling = 50% of generator cost = 22,000 BDT

Total overhauling cost = (6,600 + 22,000) BDT = 26,600 BDT

Pipeline repairing cost = 20,000 BDT

Maintenance cost of purification unit = 15,000 BDT

Total maintenance cost = (4,80,000+26,600+20,000+15,000) BDT

= 5,41,600 BDT

Cost for each house (for 20 years):

Total Cost of the Plant with maintenance cost for five years = (91,897 + 5,41,600) BDT

= 6,33,497 BDT

Cost for each user = (6,33,497 ÷ 3) = **2,11,166 BDT**

13.3 CASE STUDY 2

13.3.1 CALCULATION OF WASTE, BIOGAS AND GENERATED ELECTRICITY FOR FIVE EXISTING 5 STORIED BUILDINGS

To investigate the concept of loadshedding backup using biogas, another case is considered with five buildings. Mr. Jamil Hossain who is the owner of another five storied building is the neighbor of Mr. Jashim Uddin. Besides Mr. Anwar Molla, Mr. Kobir Khan and Mr. Amzad Hossain are also neighbors of Mr. Jashim Uddin and all of them have their own buildings. Total number of people living in their buildings is listed in table 13.2.

Table 13.2: Number of people living in adjacent five buildings.

House owner	Total no of flat	No. of people
Mr. Jashim Uddin	19	105
Mr. Jamil Hossain	19	95
Mr. Anwar Molla	10	75
Mr. Kobir Khan	20	113
Mr. Amzad Hossain	15	80
	Total	**468**

On an average each person gives 0.5 kg of waste per day.

From 468 number of people total waste $= 0.5 \times 468 \text{ kg} = 234 \text{ kg}$

At ordinary temperature (30°C) biogas obtained from human waste 0.365 m^3/ kg TS [41].

Again TS value of human waste= 20%

So, total biogas obtained from 468 numbers of peoples

$$= 0.5 \times 468 \times 0.2 \times 0.365\, m^3 = 17.082\ \ m^3$$

From each cubic meter biogas we get 1.4 kWh electricity [39].

So, from 468 numbers of person electricity obtained

$$= 17.082 \times 1.4 = 23.915 \approx 24\, kWh$$

If we use electricity 3 hours/day then capacity of the generator will be

$$\text{capacity of generator} = \frac{24}{3} = 8 \text{ kW}$$

So, each house will get 1.6 kW (8kW ÷ 5 flat) for three hours per day.

13.3.2 DIGESTER VOLUME

Let HRT =40 days (for temperature of 30°C)

We know from every layer 500 gm manure is obtained per day.

Total discharge = $468 \times 0.5\ \text{kg} = 234\ \text{kg}$

TS of fresh discharge = $0.2 \times 234\ \text{kg} = 46.8\ \text{kg}$

To make the TS value of 8% for favorable condition some additional water has to mix with fresh discharge. The required water to be added can be calculated by the following way,

8 kg solid equivalent 100 kg of influent

$$\therefore\ 46.8\ \text{kg solid equivalent} = \frac{100 \times 46.8}{8} = 585\ kg$$

So, total influent required, Q = 585 kg.

Recharge in digester per day = 585 kg = 0.585 m^3

Working volume of digester = $V_{gs} + V_f$

$$V_{gs} + V_f = Q \times HRT = 585\frac{kg}{day} \times 40\ days = 23400\ kg = 23.4\ m^3$$

From geometrical assumption:

$V_{gs} + V_f = 80\%V$

Or, 23.4 = 0.8V (Putting the value of ($V_{gs} + V_f$))

Or, $V = 29.25m^3 \approx 30\ m^3$

13.3.3 INSTALLATION COST

a) Cost of digester:

The cost of a 500 CFT digester is about 55,000 BDT [48].

The volume of digester is 30 m^3= 30×3.28^3 CFT= 1058.6 CFT

$$\text{So, The cost of digester} = \frac{55{,}000}{500} \times 1058.6\ \text{BDT} = 1{,}16{,}448.92\ \text{BDT}$$

b) Volume of hydraulic chamber and inlet recharge chamber = 2× recharge per day×3.28^3

= 2×0.585× 3.28^3 CFT

= 41.28 CFT

So, cost of hydraulic chamber and inlet recharge chamber = 41.28×110 BDT= 4540.8 BDT

c) Cost of purification unit = 10,000 BDT

d) Pipe line and others = 40,000 BDT

e) Generator cost: This system needs two 5 kW generators.

Cost of 5 kW generator=70,000 BDT [47].

Total cost of Generator = (70,000+70,000) BDT = 1, 40, 000 BDT

Total cost of the plant = (1,16,488.92 + 4,540.8+10,000 + 40,000 + 1,40,000) BDT

= 3,11,029.72 BDT ≈ 3,11,030 BDT

13.3.4 MAINTENANCE COST FOR FIVE YEARS

Labor cost = 5,000 BDT per month

Total labor cost = 12 × 5 × 5,000 = 3,00,000 BDT

Overhauling of Generator needs after operating 10,000 hours [46]. Total operating time within 5 years for our generator is 5,400 hours. So, overhauling of Generator is not required.

Pipeline repairing cost = 20,000 BDT

Maintenance cost of purification unit = 20,000 BDT

Total maintenance cost = (3,00,000 + 20,000 + 20,000) BDT

= 3,40,000 BDT

Cost for each house:

Total cost of the plant with maintenance cost for five years = (3,11,030+ 3,40,000) BDT

= 6,51,030 BDT

Cost for each building = (6,51,030 ÷ 5) = 1,30,206 BDT

Again each building will get 1.6 kW electricity. It can be distributed within four families.

Cost required per family= (1,30,206 ÷ 4) BDT = 32,551 BDT

13.3.5 MAINTENANCE COST FOR TWENTY YEARS

Labor cost = 5,000 BDT per month

Total labor cost = 12 × 20 × 5,000 = 12,00,000 BDT

Overhauling of generator needs after operating 10,000 hours [46]. Total operating time within 20 years for our generator is 21,600 hours. So generators need one time top overhauling and one time major overhauling.

Cost of top overhauling = 15% of generator cost (5 kW) = 10,500 BDT

Cost of major overhauling = 50% of generator cost (5 kW) = 35,000 BDT

Total overhauling cost for two generators = (10,500 + 35,000) × 2 BDT = 91,000 BDT

Pipeline repairing cost = 50,000 BDT

Maintenance cost of purification unit = 40,000 BDT

Total maintenance cost = (12,00,000 + 91,000 + 50,000 + 40,000) BDT

= 13,36,000 BDT

Cost for each house (for 20 years):

Total cost of the plant with maintenance cost for twenty years = (3,11,030 + 13,36,000) BDT

=16,47,030 BDT

Cost for each building = (16,47,030 ÷ 5) = 3,29,406 BDT

Again each building will get 1.6 kW electricity. It can be distributed within four families.

Cost required per family = (3,29,406 ÷ 4) BDT = 82,351.5 BDT

Cost will be minimized considerably if more buildings are included under the project.

13.4 COMPARISON BETWEEN CASE STUDY 1 AND CASE STUDY 2

In case study 1, the cost of ENH load shedding backup system is calculated for only a building. The calculated cost of the system for five years is 74,966 BDT and for twenty years is 2, 11,166 BDT for each house.

In case study 2, the same calculation is done for five buildings. In this case, cost for each house is 32,551 BDT for five years life time and 82,351.5 BDT for twenty years life time. So it can be concluded here that if more buildings are included under the project cost will be minimized considerably.

13.4.1 COST OF IPS FOR FIVE YEARS BACKUP

Retail price List of Rahimafrooz IPS [55], which is effective from April 6, 2009, is shown in table-13.3.

Table 13.3: Price list of different model of IPS

IPS Model	Watt	Total Price (BDT)
Radiant 350 VA	280	17711.75
Radiant 550 VA	400	24,766.00
Volta 250 VA	160	14,717.50
Volta 400 VA	280	19,843.25
Computer VLX 600 VA	600 VA	30,470.30
DB Sine Wave 800	600	39,965.63
JUMBO	6.0 KVA	279,886.25
• Warranty for IPS control unit and battery: 1 (one) year from the date of first installation. • Backup time= 2 hours for every model.		

Considering the life time of IPS is 2.5 years. So, for five years backup we need 2 IPS's. Cost of two IPS's with a capacity of 400 watt = (24,766 ×2) BDT = 49,532 BDT

13.4.2 COMPARISON BETWEEN IPS AND ENH SYSTEM

13.4.2.1 CONSIDERING COST

From observation (case study-2) it is clear that, the cost of ENH load shedding backup system is 32,551 BDT. But for IPS this cost is 49,532 BDT for five years life span. The result shows that the cost discrimination will increase in favor of this system if more buildings are included under the project and if the considered time for comparison is equal to the life time of the biogas electricity backup system (about twenty years). The savings of the biogas load shedding backup system is depicted in table 13.4.

Table 13.4: The comparison of IPS with ENH load shedding backup system

Life Time	**Cost of ENH Load Shedding Backup System for one building (Case Study1-600W for each home)**	**Cost of IPS (600W for each home)**		**Cost of ENH Load Shedding Backup System for five buildings (Case Study2-400W for each home)**	**Cost of IPS (400W for each home)**
5 years	74,824 BDT	(39,966 x 2) = 79,932 BDT		32,551 BDT	(24,766 x 2) = 49,532 BDT
20 years	2,05,357 BDT	(79,932 x 4) = 3,19,728 BDT		81,351.5 BDT	(49,532 x 4) = 1,98,128 BDT

13.4.2.2 CONSIDERING BACKUP TIME

Backup time is 3 hours for ENH system with biogas where for IPS it is two hours.

13.4.2.3 CONSIDERING CONTRIBUTION OF ELECTRICITY GENERATION

IPS is itself a load and it has no generation capacity. But the ENH system generates electricity.

13.4.2.4 CONSIDERING SALVAGE VALUE

After five years, salvage value of IPS will be zero. But ENH load shedding backup system can be used after five years because the lifetime of the system is about 20 years. Only the generators have to change after five years for our system or overhauling should be done.

13.4.2.5 CONSIDERING POWER QUALITY

Electricity produced by generator is approximately sinusoidal. But in IPS, electricity is supplied from battery and an inverter is used to convert dc to ac. As a result, it contains many harmonics. Obviously, power quality of ENH load shedding system is better than IPS.

CHAPTER 14

CONCLUSION AND FUTURE SUGGESTION

14.1 CONCLUSION

In the designed system, the energy neutrality is proved by fulfilling the energy requirement without taking any electricity from grid. The implemented system can produce net 1kW (200w is considered as system loss) of electricity which is sufficient for a home if the full proportion of gas is used for the generation of electricity only. The system also supplies necessary gas for a home. The slurry of the system can be used in land as fertilizer. Thus the designed system is very fruitful for fulfilling the energy requirement with renewable energy source. Other natural resources like oil, gas etc. are limited and will be exhausted in course of time. So, the developed and developing countries consider their natural resources very precious and are cautious about extracting those. For this reason, this research is very much important for a country like Bangladesh where the people are facing great power crisis at present. The ENH system is valuable for the promising potentials it holds within, ranging from the long run economical benefits to the important environmental advantages. It will mark one of the few attempts and contributions in the field of renewable energy; where such system could be implemented extensively. With the increasing improvements in solar cell technologies and power electronics and price of generators, this system would have more value added and should receive more attention and support.

14.2 SUGGESTIONS FOR FUTURE WORK

(i) The ENH system can be implemented all over the Bangladesh for an area of 200 houses or more with the help of Government or any private organization.

(ii) The ENH system can be implemented with hybrid energy source inputs.

(iii) The ENH Load shedding backup system can also be implemented.

REFERENCES

[1]: Badrud Doza's profile in Bangladesh, Budget, Economy, and Governance "power crisis and Bangladesh Budget 2008-2009''August 3, 2008.

[2]: Islam M. A., finance and planning adviser ,Government of Bangladesh ''Load Shedding condition in Bangladesh " Dhaka ,Bangladesh April 12, 2009.

[3]: BPDB-Bangladesh power Development Board,"key Statistics ", 2006.

[4]: Kanama D. and Kawamoto H., "Research and development trends of solar cell for highly efficiency" from Nanotechnology and Material Research Unit, July, 2008.

[5]: Davies M. C., "Use of GEF Funds for Renewable Energy Investment", World Bank Asia Alternative Energy Units, 1997.

[6]: Akter N., "A Tentative situation in Bangladesh, country review" July, 1997.

[7]: Alamgir D. A. H., "Utilization of Wind Energy of Costal Areas of Bangladesh by Using Hybrid Power generation System: A Challenging Alternative" –national seminar on utilization of renewable and alternative energy sources for sustainable development, 10-11th March 1998, Khulna.

[8]: The Energy-Neutral Home, by Kerry A. Dolan. Available online, March 12, 2011, at: http://www.forbes.com/2009/11/06/net-zero-energy-technology-breakthroughs-house.html

[9]: Zero-energy building, Available online, March 12, 2011, at: http://en.wikipedia.org/wiki/Zero-energy_building

[10]: An Example of Net Zero-energy Home System, Available online, March 12, 2011, at: http://www.popsci.com/environment/article/2009-07/ge-wants-our-smart-grid-equipped-homes-consuming-zero-net-energy-2015.

[11]: Nasiruddin M., Bathan G., "Clean Air in Bangladesh: Summary of progress on improving air quality", Clean air initiative for asian citizen, pp. 4, November 2008.

[12]: Qurashi M. M. and Hussain T., "Renewable Energy Technologies for Developing Countries Now and to 2023", Publications of the Islamic Educational, Scientific and Cultural Organization –ISESCO, pp. 7 & 52, 2005.

[13]: Islam A. K. M. S. and Islam M. "Status of renewable energy technology in Bangladesh" ISESCO Science and Technology Vision, Vol-1, pp. 51-60, May 2005.

[14]: Renewable energy projects, Available online March 15, 2011, at: http://www.idcol.org/energyProject.php

[15]: National Domestic Biogas and Manure Programme Implementation Plan 2010-12 (NDBMP IP 2010-12), pp. i, ii & 15, Bangladesh, December 10, 2009.

[16]: Saleque K. A., "Natural Gas Crisis in Bangladesh- Possible Remedy" January, 2010. Available online, June 12, 2011, at: http://www.energybangla.com/index.php?mod=article&cat=SomethingtoSay&article=2359.

[17]: Uddin M. and Ahsan Q., "Expected status of natural gas in Bangladesh in meeting the electricity demand in the next twenty five years", **3**rd International Conference on Electrical & Computer Engineering ICECE 2004, Dhaka, Bangladesh, December 28-30, 2004.

[18]: Kossmann W., Ponitz U., "Biogas Digest", Information and Advisory Service on Appropriate Technology (ISAT), vol. 1, pp. 04.

[19]: Milono P., Lindajati T. and Aman S., "Biogas production from agricultural organic residues", The First ASEAN Seminar-Workshop on Biogas Technology, Working Group on Food waste Materials, pp. 52-65, 1981.

[20]: Cheremisinoff N. P., "Landfill operations and gas energy recovery", Handbook of Solid Waste Management and Waste Minimization Technologies, pp 109-117, Elsevier, 2003.

[21]: Cenex, "Biomethane Toolkit: A Guide to the Production and Use of Biomethane as a Road Transport Fuel", Cenex, Loughborough, UK, 2009.

[22]: Dennis A. and Burke P.E., **"**Dairy Waste Anaerobic Digestion Handbook"**,** Environmental Energy Company, June, 2001.

[23]: Jigar E., "Study on renewable biogas energy production from cladodes of opuntia ficus-indica", M. Sc. Thesis, school of graduate study, Addis Ababa University, pp. 9-21, July 2010.

[24]: Audra A. O. and Aryati V. D., “Biogas production using anaerobic biodigester from cassava starch effluent with ruminant bacteria as biocatalyst” M. Sc. thesis, chemical engineering department, Diponegoro University, Semarang, pp. 14-16, January 19, 2010.

[25]: Juanka J., Kuruparan P. and Visvanathan C., ‘’Optimizing Combined Anaerobic Digestion Process of Organic Fraction of Municipal Solid waste (MSW)’’, 2005.

[26]: Rozdilsky J. L., ‘’Farm-based Anaerobic Digestion in Michigan History, Current Status and Future Outlook’’, Report of Michigan Biomass Energy Program, September, pp. 2-8, 1997.

[27]: Nelson C. and Lamb J., “Final Report: Haubenschild Farms Anaerobic Digester”, the Minnesota project, pp 9-13, August 2002.

[28]: National Academy of Sciences, “Methane Generation from Human, Animal and Agricultural Wastes”, NTIS Accession No. PB-276-469, NAS, Washington, D. C., 1977.

[29]: McGarry M. J. and Stainforth J., “Compost, Fertilizer and Biogas Production in the People's Republic of China”, International Development Research Centre, Ottawa, IDRC-TS8e, pp. 94, 1978.

[30]: Singh R. B., “Bio-gas Plant: Generating Methane from Organic Wastes”, Gobar-Gas Research Station, Ajitmal, Etawah, India, 1971.

[31]: ESCAP Document RAS/74/041/A/01/01, "Biogas Technology and Utilization," ESCAP, Bangkok,1975.

[32]: Bell C., Boulter S., Dunlop D., and Keiller P., “Methane: Fuel of the Future”, Andrew Singer, Cambridgeshire, U.K., 1973.

[33]: Fry L. G., “Practical Building of Methane Power Plants for Rural Energy Independence”, L.G. Fry, Santa Barbara, California, 1974.

[34]: Loll U., Schiegel H. G. and Barnea J. (eds.), “Microbial Conversion”, pp. 361 - 378, Erich Gottze KG, Gottingen, W. Germany, 1976.

[35]: DaSilva E. J. “Biogas generation: developments, problems, and tasks - an overview” Division of Scientific Research and Higher Education, Unesco, Paris, France.

[36]: Islam M. S., “Use of Bioslurry as Organic Fertilizer in Bangladesh Agriculture”, International Workshop on the Use of Bioslurry, Domestic Biogas Programmes, September 27-28, 2006, Bangkok, Thailand.

[37]: Chu L., Yang G., Li Y., Ren G. and Feng Y., “The Biogas Production Efficiency of Anaerobic Fermentation of Different Dung and Straws” Transactions of the CSAE, Vol. 26 No.7, July 2010.

[38]: Biogas-Project, Training material of LGED (Local Government Engineering Development), Bangladesh, 1999.

[39]: Islam K. U., Senior Advisor, Sustainable Energy for Development (SED), GTZ (Deutsche Gesellschaft fur Technische Zusammenarbeit), Gulshan 2, Dhaka 1212, Bangladesh.

[40]: Gofran M. A., Asrafuzzaman M., “IDCOL Biogas Plant Construction Mannual”, IDCOL Infrastructure Development Company Limited, Bangladesh, April 2007.

[41]: Booklets and Research materials of Biogas Training Centre (BRC), Chendu, Sichum, China.

[42]: Zicari S. M., “Removal of hydrogen sulfide from biogas using cow-manure compost” M. Sc. Thesis, Faculty of the Graduate School, Cornell University, pp. 01-09, January 2003.

[43]: Biogas process for sustainable development, “FAO Corporate Document Repository”, available online April 14, 2011, at:

http://www.fao.org/docrep/T0541E/T0541E0b.htm

[44]: About silica gell, available online June 10, 2011, at:
http://wiki.answers.com/Q/How_silica_gel_absorb_moisture#ixzz1bIfGS000

[45]: Gobel E., Mills I. M. and Wallard A. J., “The International System of Units (SI)” 8th edition, ISBN 92-822-2213-6, pp. 127.

[46]: Sorkaar A. A., Service Engineer, Bangla Power Company Ltd., Chittagong branch, Bangladesh, 2010.

[47]: Ali M. A., Managing Director, INTRACO GROUP, 69, Suhrawardy Avenue, Baridhara, Dhaka –1212, Bangladesh.

[48]: Rahman Renewable Energy Co. Ltd, Local Office of IDCOL (Infrastructure Development Company Limited), Joydebpur, Gajipur, Bangladesh, December 2010.

[49]: Fahmy F. H., Sadek S. M., Ahamed N. M., Zahran M. B. and Nafeh A. E. S. A. “Microcontroller-Based Moving Message Display Powered by Photovoltaic Energy” International Conference on Renewable Energies and Power Quality (ICREPQ’10), Granada (Spain), March 23-25, 2010.

[50]: Opara F.K., Efemena O. E. and Felix E., “Solar solution for mobile charging centers in Nigeria” international journal of academic research, Vol. 3, No.1, Part II, January, 2011.

[51]: Gwamuri J. and Mhlanga S., “Design of PV solar home system for use in urban Zimbabwe” Applied Physics and Radiography Department, Faculty of Applied Sciences, National University of Science and Technology, Bulawayo, Zimbabwe, January 31, 2009.

[52]: Recent market price of 300W panel in Energy Bangla Company, Available online, September 11, 2011, at: http://www.energybangla.com/index.php?mod=article&cat=GreenPage&article=2751.

[53]: Leaflets, Navana Group Limited, Navana Toyota 3S Center, 205-207, Tejgaon Industrial Area, Dhaka- 1208, Bangladesh, April 2011.

[54]: Leaflets, Solarpac company Limited, 277, Shahid Janani Jahanara Imam Sarani (Elephant Road), Dhaka 1205, Bangladesh, May 2011.

[55]: Price List of Rahimafrooz IPS; Available online April 10, 2011, at: http://www.travelbangla.com/ra2/ra_downloads/IPS%20Price%20List_06%2004%2009.pdf

APPENDIX A

Codes of the “C” Programming:

```
#include<stdio.h>
#include<conio.h>
#include<math.h>
main()
{
clrscr();
int home,i,n,sum,time,cooking,cif,hrt,cwaste;
float elc[20],prcnt,prcnt1,btime,gcapacity,gburner,hen1,gaspcow,sdis,hh1,dh,h1,hh;
float hen,kwh,kwh1,cow,cow1,egas,tgas,q,dvol,d,h,f1,f2,r1,r2,v1,vc,vgs,vdis,pf;
printf("Enter number of home:");
scanf("%d",&home);
printf("Electricity demand of each house at differenttime(in kW):");
printf("\n");
sum=2;
kwh=0;
for(i=1;i<=12;i++)
{
n=0;
if(sum==24)
n=-24;
printf("TIME: %d to %d: ",sum,(sum+2+n));
scanf("%f",&elc[i]);
sum=i+i+2;
```

```
kwh+=(elc[i]*2);
}
kwh1=kwh*home;
printf("\nkWh=%f",kwh1);
printf("\nNo of gas burner for cooking purpose:");
scanf("%d",&cooking);
printf("\nHow much time you will use gas burner(in Hour):");
scanf("%f",&btime);
gburner=cooking*btime*0.4;
printf("\nGas Used in Burner= %f m3",gburner);
egas=(1/1.4)*kwh1;
printf("\nTo get %f kWh electricity per day we needs %f m3 biogas",kwh1,egas);
tgas=gburner+egas;
printf("\nWhat types of waste you want to use??");
printf("\nFor poultry waste press 1,for cow waste press 2 and for mix of poultry & cow waste
press 3: ");
scanf("%d",&cif);
if(cif==1)
{
hen=(tgas/0.0071);
printf("\nTotal no of hen required = %d",int(hen));
printf("\nWhat is the value of HRT=");
scanf("%d",&hrt);
sdis=(0.2*hen*0.1);
q=(100*sdis)/8;
```

```
dvol=(q*hrt)/(1000*0.8);

printf("\nDigester Volume: %f cubic meter",dvol);

d=1.3078*pow(dvol,(0.333333));

printf("\nDiameter=%f",d);

h=(4*0.3142*d)/3.14;

f1=d/5;

f2=d/8;

r1=0.725*d;

r2=1.0625*d;

v1=0.0827*pow(d,3);

vc=0.05*dvol;

printf("\nH=%f m f1=%f m  f2=%f m  R1=%f m",h,f1,f2,r1);

printf("\nR2=%f m V1=%f m3  Vc=%f m3",r2,v1,vc);

vgs=sdis*0.35;

vdis=q/1000;

pf=(4*(v1+vc+vdis+vgs))/(v1+vc+vdis);

printf("\nFinal pressure of Digester=%f kPa",pf);

hh1=pf/9.81;

h1=hh1-int(hh1);

printf("\n Height of hydraulic chember from manure level:%f m",h1);

printf("\nAssume height of hydraulic chember:");

scanf("%f",&hh);

dh=sqrt((4*vdis)/(3.1416*hh));

printf("\nDiameter of Hydraulic chember: %f m",dh);

}
```

```
else if(cif==2)
{
printf("\n How much waste we get from a cow (in Kg):");
scanf("%d",&cwaste);
gaspcow=0.037*cwaste;
cow=(tgas/gaspcow);
if((cow-int(cow))>0.1)
cow=int(cow)+1;
else
cow=int(cow);
cow1=(egas/gaspcow);
if((cow1-int(cow1))>0.1)
cow1=int(cow1)+1;
else
cow1=int(cow1);
printf("\nTotal no of cow required = %f (for elec. gen. %f cows required)",cow,cow1);
printf("\nWhat is the value of HRT=");
scanf("%d",&hrt);
sdis=(0.16*cow*cwaste);
q=(100*sdis)/8;
dvol=(q*hrt)/(1000*0.8);
printf("\nDigester Volume: %f cubic meter",dvol);
d=1.3078*pow(dvol,(0.33333));
printf("\nDiameter=%f",d);
h=(4*0.3142*d)/3.14;
```

```
f1=d/5;

f2=d/8;

r1=0.725*d;

r2=1.0625*d;

v1=0.0827*pow(d,3);

vc=0.05*dvol;

printf("\nH=%f m f1=%f m f2=%f m R1=%f m",h,f1,f2,r1);

printf("\nR2=%f  V1=%f m^3 Vc=%f m^3 ",r2,v1,vc);

vgs=sdis*0.35;

vdis=q/1000;

pf=(4*(v1+vc+vdis+vgs))/(v1+vc+vdis);

printf("\nFinal pressure of Digester=%f kPa",pf);

hh1=pf/9.81;

h1=hh1-int(hh1);

printf("\n Height of hydraulic chember from manure level:%f m",h1);

printf("\nAssume height of hydraulic chember:");

scanf("%f",&hh);

dh=sqrt((4*vdis)/(3.1416*hh));

printf("\nDiameter of Hydraulic chember: %f m",dh);

}

else if(cif==3)

{

printf("\nHow much percentage of gas you want from poultry waste:");

scanf("%f",&prcnt);

prcnt1=prcnt/100;
```

```
hen=((tgas*prcnt1)/0.0071);
printf("\n How much waste we get from a cow (in kg):");
scanf("%d",&cwaste);
gaspcow=0.037*cwaste;
cow=((tgas*(1-prcnt1))/gaspcow);
cow1=((egas*(1-prcnt1))/gaspcow);
hen1=((egas*prcnt1)/0.0071);
if((cow-int(cow))>0.1)
cow=int(cow)+1;
else
cow=int(cow);
if((cow1-int(cow1))>0.1)
cow1=int(cow1)+1;
else
cow1=int(cow1);
printf("\nTotal no of hen required = %d (For electricity gen: %d)",int(hen),int(hen1));
printf("\nTotal no of cow required = %f (for electricity gen: %f)",cow,cow1);
printf("\nWhat is the value of HRT=");
scanf("%d",&hrt);
sdis=(0.2*hen*0.1)+(0.16*cow*10);
q=(100*sdis)/8;
dvol=(q*hrt)/(1000*0.8);
printf("\nDigester Volume: %f cubic meter",dvol);
d=1.3078*pow(dvol,(0.333333));
printf("\nDiameter=%f",d);
```

```
h=(4*0.3142*d)/3.14;
f1=d/5;
f2=d/8;
r1=0.725*d;
r2=1.0625*d;
v1=0.0827*pow(d,3);
vc=0.05*dvol;
printf("\nH=%f m  f1=%f m  f2=%f m  R1=%f m ",h,f1,f2,r1);
printf("\nR2=%f m  V1=%f m3 Vc=%f m3",r2,v1,vc);
vgs=sdis*0.35;
vdis=q/1000;
pf=(4*(v1+vc+vdis+vgs))/(v1+vc+vdis);
printf("\n Final pressure of Digester=%f kPa",pf);
hh1=pf/9.81;
h1=hh1-int(hh1);
printf("\n Height of hydraulic chember from manure level:%f m",h1);
printf("\nAssume height of hydraulic chember:");
scanf("%f",&hh);
dh=sqrt((4*vdis)/(3.1416*hh));
printf("\nDiameter of Hydraulic chember: %f m",dh);
}
else
printf("Unknown Application");
getch();
return 0;}
```

APPENDIX B

CALCULATION OF DESIGN PARAMETERS OF AN ENERGY NEUTRAL HOME (ENH) SYSTEM FOR AN AREA OF 200 HOUSES.

11.2.1.1 DESIGN OF DIGESTER FOR 15 THOUSAND LAYERS:

11.2.1.1.1 VOLUME CALCULATION OF DIGESTER CHAMBER:

From figure 7.5, figure 7.6 and table 7.6 the design parameters are calculated as follows:

Let HRT = 40 days (for temperature 30℃)

We know from every layer 100 gm manure is obtained per day.

Total discharge=$15000 \times 0.1\ kg = 1500\ kg$

TS of fresh discharge = $0.2 \times 1500 kg = 300\ kg$

To make the TS value of 8% for favorable condition we have to mix some additional water with fresh discharge. The required water to be added can be calculated by the following way,

8 kg solid equivalent 100 kg of influent

$$\therefore\ 300 \text{ kg solid equivalent } = \frac{100 \times 300}{8} = 3750\ kg$$

So, total influent required, Q= 3750 kg per day.

Required water to be added to make TS value 8% =$3750 - 1500 kg = 2250\ kg$

Working volume of digester$= V_{gs} + V_f$

$$V_{gs} + V_f = Q \times HRT = 3750 \frac{kg}{day} \times 40\ days = 150000\ kg = 150\ m^3$$

From geometrical assumption:

$V_{gs} + V_f = 80\% V$

Or, 150 = 0.8V (Putting the value of $(V_{gs} + V_f)$)

Or, $V = 187.5\, m^3 \approx 190\, m^3$

And $D = 1.3078 V^{1/3} = 7.518\, m \approx 7.52\, m$

Again,

$$V_3 = \frac{3.14 \times D^2 \times H}{4}$$

$$or, 0.3142 D^3 = \frac{3.14 \times D^2 \times H}{4}$$

$$\therefore H = \frac{4 \times 0.3142 \times D}{3.14} = 3\, m$$

Now from assumption the following values are calculated as the value of 'D' and 'H' are known:

f_1= D/5 =7.52/5 = 1.5 m

f_2= D/8=7.52/8 = 0.94 m

R_1 = 0.725D = 0.725×7.52 = 5.452 m

R_2 = 1.0625D = 1.0625×7.52 = 8 m

V_1= $0.0827D^3$= $0.0827\times(7.52)^3$= 35.17 m^3=35.2 m^3

V_c= 0.05V= 0.05×190 m^3= 9.5 m^3

The value of inclined angle of inlet pipe, $\theta = 60^0$ [40]

11.2.1.1.2 VOLUME CALCULATION OF HYDRAULIC CHAMBER

From assumptions,

$V_c = 0.05V = 9.5\, m^3$

$V_s = V - (V_{gs} + V_f + V_c) = 190 - (150 + 9.5) = 30.5\, m^3$.

Now the volume of gas storage chamber should be 50% of the gas produced in a day.

So, $V_{gs} = Amount\ of\ the\ daily\ gas\ yield$

$= TS \times gas\ production\ rate\ per\ Kg\ TS$

$= 300 \times 0.35 = 105\ m^3$

$V_c + V_1 = 9.5 + 35.2 = 44.7\ m^3 \approx 48\ m^3$

Now, the discharge of outlet should be the same of inlet recharge.

So, out let discharge

$$V_{dis} = \frac{3750}{1000} = 3.75\ m^3 \approx 4m^3\ (\ as\ 3750\ kg\ \approx 3750\ liter)$$

Total volume of the gas staying chamber $= V_c + V_1 + V_{dis} = 48 + 4 = 52\ m^3$

Now, we can calculate the pressure of digester.

Let the normal pressure of the digester is $P_i = 4\ kPa$.

and final pressure after gas being stored = P_f

The produced gas should have to stay within 52 cubic meters volume. So, according to Boyle's law, $P_i \times (total\ gas\ produced + 52) = P_f \times 52$

$$Or,\ P_i \times (105 + 52) = P_f \times 52$$

$$Or,\ P_f \times 52 = 4 \times (105 + 52)\quad Or, P_f = 12.08\ kPa$$

Let, height of the hydraulic chamber is h. The pressure of the hydraulic chamber should be 12.08 kPa so that only the inlet recharge will be discharge.

$$P_f + H\rho g = H\rho g + h_1\rho g + h\rho g$$

$$Or, h + h_1 = \frac{P_f}{\rho g} = \frac{12.08 \times 1000}{1000 \times 9.81} = 1.23\ m$$

Let, height of the hydraulic chamber from digester manure level, $h_1 = 0.23\ m$

So, height of the hydraulic chamber, $h = 1.23 - 0.23 = 1m$

Now, the volume of the hydraulic chamber is equal to the discharge per day.

If D_H is the diameter of the hydraulic chamber then, and H_H = h = 1 m

$$\pi \left(\frac{D_H}{2}\right)^2 h = 4$$

$$Or, D_H = \sqrt{\frac{4 \times 4}{\pi \times H_H}} = \sqrt{\frac{16}{3.1416 \times 1}} = 2.26\, m$$

11.2.1.2 DESIGN OF DIGESTER FOR 20 THOUSAND LAYERS

HRT =40 days (for temperature 30°C)

We know from every layer 100gm manure is obtained per day.

Total discharge=$20{,}000 \times 0.1\, kg = 2000 kg$

TS of fresh discharge=$0.2 \times 2000kg = 400kg$ [Table 7.2]

To make the TS value of 8% for favorable condition we have to mix some additional water with fresh discharge. The required water to be added can be calculated by the following way,

8 kg solid equivalent 100 kg of influent

$$\therefore \text{ 400 kg solid equivalent } = \frac{100 \times 400}{8} = 5000\, kg$$

So, total influent required, Q = 5000 kg.

Required water to be added to make TS value 8% = $5000 - 2000kg = 3000\, kg$

Working volume of digester = $V_{gs} + V_f$

$$V_{gs} + V_f = Q \times HRT = 5000 \frac{kg}{day} \times 40\, days = 200000\, kg = 200\, m^3$$

From geometrical assumption:

$V_{gs} + V_f = 80\%V$

Or, 200=0.8V (Putting the value of $(V_{gs} + V_f)$)

Or, $V = 250\ m^3$

And $D = 1.3078V^{1/3} = 8.23\ m$

Again,

$$V_3 = \frac{3.14 \times D^2 \times H}{4}$$

$$or, 0.3142D^3 = \frac{3.14 \times D^2 \times H}{4}$$

$$\therefore H = \frac{4 \times 0.3142 \times D}{3.14} = 3.3\ m$$

Now we find from assumption as we know the value of 'D' and 'H'

f_1 = D/5 = 8.23/5 = 1.65m

f_2 = D/8 = 8.23/8 = 1.02m

R_1 = 0.725D = 0.725×8.23 = 6m

R_2 = 1.0625D = 1.0625×8.23 = 8.74m

$V_1 = 0.0827D^3 = 0.0827\times(8.23)^3 = 46.1\ m^3$

$V_c = 0.05V = 0.05\times250\ m^3 = 12.5\ m^3$

The value of inclined angle of inlet pipe, $\theta = 60^0$ [40]

Volume calculation of hydraulic chamber:

From assumptions,

$V_c = 0.05V = 12.5\ m^3$

$V_s = V - (V_{gs} + V_f + V_c) = 250 - (200 + 12.5) = 37.5\ m^3$.

Now the volume of gas storage chamber should be 50% of the gas produced in a day.

So, $V_{gs} = Amount\ of\ the\ daily\ gas\ yield$

$= TS \times gas\ production\ rate\ per\ Kg\ TS$

$= 400 \times 0.35 = 140\ m^3$

$V_c + V_1 = 12.5 + 46.1 = 58.6\ m^3 \approx 60\ m^3$

Now, the discharge of outlet should be the same of inlet recharge.

So, out let discharge

$$V_{dis} = \frac{5000}{1000} = 5\ m^3 (\ as\ 5000\ kg\ \approx 5000\ liter)$$

Total volume of the gas staying chamber = $V_c + V_1 + V_{dis} = 60 + 5 = 65\ m^3$

Now, we can calculate the pressure of digester.

Let the normal pressure of the digester is $P_i = 4\ kPa$.

and final pressure after gas being stored = P_f

The produced gas should have to stay within 65 cubic meters volume. So, according to boyle's law,

$$P_i \times (140 + 65) = P_f \times 65$$

$$Or, P_f = \frac{4 \times 205}{65} = 12.61\ kPa$$

Let, height of the hydraulic chamber is h. The pressure of the hydraulic chamber should be 12.61 kPa so that only the inlet recharge will be discharge.

$$P_f + H\rho g = H\rho g + h_1 \rho g + h\rho g$$

$$Or, h + h_1 = \frac{P_f}{\rho g} = \frac{12.61 \times 1000}{1000 \times 9.81} = 1.285\ m$$

Let, height of the hydraulic chamber from digester manure level, $h_1 = 0.23\ m$

So, height of the hydraulic chamber, $h = 1.285 - 0.23 = 1.05m$ = H_H

Now, the volume of the hydraulic chamber is equals to the discharge per day.

If D_H is the diameter of the hydraulic chamber then,

$$\pi\left(\frac{D_H}{2}\right)^2 h = 5$$

$$Or, D_H = \sqrt{\frac{4 \times 5}{\pi \times H_H}} = \sqrt{\frac{20}{3.1416 \times 1.05}} = 2.46\ m$$

11.2.1.3 DESIGN OF DIGESTER FOR 140 COWS

HRT =40 days (for temperature 30℃)

We know from every layer 10 kg manure is obtained per day.

Total discharge=140×10 kg = 1400 kg

TS of fresh discharge= (0.16×1400) kg = 224 kg

To make the TS value of 8% for favorable condition we have to mix some additional water with fresh discharge. The required water to be added can be calculated by the following way,

8 kg solid equivalent 100 kg of influent

$$\therefore\ 224\text{ kg solid equivalent} = \frac{100 \times 224}{8} = 2800\ kg$$

So, total influent required, Q= 2800 kg.

Required water to be added to make TS value 8% =2800-1400 kg = 1400 kg

Working volume of digester= $V_{gs} + V_f$

$$V_{gs} + V_f = Q \times HRT = 2800\frac{kg}{day} \times 40\ days = 112000kg = 112\ m^3$$

From geometrical assumption:

$V_{gs} + V_f = 80\%V$

Or, 112=0.8V (Putting the value of ($V_{gs} + V_f$))

Or,$V = 140\,m^3$

And $D = 1.3078V^{1/3} = 6.8\,m$

Again,

$$V_3 = \frac{3.14 \times D^2 \times H}{4}$$

$$or, 0.3142D^3 = \frac{3.14 \times D^2 \times H}{4}$$

$$\therefore H = \frac{4 \times 0.3142 \times D}{3.14} = 2.72\,m$$

Now from assumption the following values are calculated as the value of ‘D’ and ‘H’ are known:

f_1 = D/5 = 6.8/5 =1.36 m

f_2 = D/8 = 6.8/8 = 0.85 m

R_1 = 0.725D = 0.725×6.8 = 4.93 m

R_2 =1.0625D =1.0625×6.8 = 7.23 m

V_1= $0.0827D^3$ = $0.0827\times(6.8)^3$ =26 m^3

V_c = 0.05V = 0.05×140 m^3 = 7 m^3

The value of inclined angle of inlet pipe, $\theta = 60^0$ [40]

Volume calculation of hydraulic chamber:

From assumptions,

$V_c = 0.05V = 7\,m^3$

$V_s = V - (V_{gs} + V_f + V_c) = 140 - (112 + 7) = 21\, m^3$.

Now, the volume of gas storage chamber should be 50% of the gas produced in a day.

So, $V_{gs} = Amount\ of\ the\ daily\ gas\ yield$

$= TS \times gas\ production\ rate\ per\ Kg\ TS$

$= 224 \times 0.35 = 78.4\, m^3$

$V_c + V_1 = 7 + 26 = 33\, m^3$

Now, the discharge of outlet should be the same of inlet recharge.

So, outlet discharge

$$V_{dis} = \frac{2800}{1000} = 2.8\, m^3 (\ as\ 2800\, kg \approx 2800\, liter)$$

Total volume of the gas staying chamber $= V_c + V_1 + V_{dis} = 33 + 2.8 = 35.8\, m^3$

Now, we can calculate the pressure of digester.

Let the normal pressure of the digester is $P_i = 4\, kPa$.

and final pressure after gas being stored = P_f

The produced gas should have to stay within 35.8 cubic meters volume. So, according to boyle's law,

$$P_i \times (78.4 + 35.8) = P_f \times 35.8$$

$$Or, P_f = \frac{4 \times 114.2}{35.8} = 12.76\, kPa$$

Let, height of the hydraulic chamber is h. The pressure of the hydraulic chamber should be 12.76 kPa so that only the inlet recharge will be discharge.

$$P_f + H\rho g = H\rho g + h_1 \rho g + h\rho g$$

$$Or, h + h_1 = \frac{P_f}{\rho g} = \frac{12.76 \times 1000}{1000 \times 9.81} = 1.3\, m$$

Let, height of the hydraulic chamber from digester manure level, $h_1 = 0.23\, m$

So, height of the hydraulic chamber, $H_H = 1.3 - 0.23 = 1.07m = h$

Now, the volume of the hydraulic chamber is equals to the discharge per day.

If D_H is the diameter of the hydraulic chamber then,

$$\pi \left(\frac{D_H}{2}\right)^2 h = 2.8$$

$$Or, D_H = \sqrt{\frac{4 \times 2.8}{\pi \times H_H}} = \sqrt{\frac{11.2}{3.1416 \times 1.07}} = 1.83\, m$$

APPENDIX C

CALCULATION OF DESIGN PARAMETERS OF THE HYBRID ENH SYSTEM.

12.3.3.2 DESIGN OF DIGESTER

The design of digester is depicted in figure 7.5 and 7.6.

Let HRT = 40 days (for temperature 30°C)

We know from every layer 100 gm manure is obtained per day.

Total discharge = $11{,}100 \times 0.1 \text{ kg} = 1{,}110 \text{ kg}$

TS of fresh discharge = $0.2 \times 1{,}110 \text{ kg} = 222 \text{ kg}$

To make the TS value of 8% for favorable condition we have to mix some additional water with fresh discharge. The required water to be added can be calculated by the following way,

8 kg solid equivalent 100 kg of influent

$$\therefore\ 222 \text{ kg solid equivalent} = \frac{100 \times 222}{8} = 2{,}775 \text{ kg}$$

So, total influent required, Q = 2,775 kg.

Required water to be added to make TS value 8% = $2{,}775 - 1{,}110 \text{ kg} = 1{,}665 \text{ kg}$

Working volume of digester = $V_{gs} + V_f$

$$V_{gs} + V_f = Q \times HRT = 2{,}775 \frac{\text{kg}}{\text{day}} \times 40 \text{ days} = 1{,}11{,}000 \text{ kg} = 111 \text{ m}^3$$

From geometrical assumption: [Table 7.6]

$V_{gs} + V_f = 80\% V$

Or, 111 = 0.8V (Putting the value of ($V_{gs} + V_f$))

Or, $V = \frac{111}{0.8} = 138.75 \text{ m}^3 \approx 140 \text{ m}^3$

And $D = 1.3078 V^{1/3} = 6.79\ m$

Again,

$$V_3 = \frac{3.14 \times D^2 \times H}{4}$$

$$or,\ 0.3142 D^3 = \frac{3.14 \times D^2 \times H}{4}$$

$$\therefore H = \frac{4 \times 0.3142 \times D}{3.14} = 2.72\ m$$

Now from assumption and the value of 'D' and 'H' the following values are found:

$f_1 = D/5 = 6.79/5 = 1.358$ m

$f_2 = D/8 = 6.79/8 = 0.85$ m

$R_1 = 0.725D = 0.725\times6.79 = 4.92$ m

$R_2 = 1.0625D = 1.0625\times6.79 = 7.21$ m

$V_1 = 0.0827D^3 = 0.0827\times(6.79)^3 = 25.9\ m^3 = 25.9\ m^3$

$V_c = 0.05V = 0.05\times140\ m^3 = 7\ m^3$

12.3.3 .3 VOLUME CALCULATION OF HYDRAULIC CHAMBER

From assumptions, [Table 7.6]

$V_c = 0.05V = 7\ m^3$

$V_s = V - (V_{gs} + V_f + V_c) = 140 - (111 + 7) = 22\ m^3$.

Now the volume of gas storage chamber should be 50% of the gas produced in a day.

So, $V_{gs} =$ Amount of the daily gas yield

$= TS \times$ gas production rate per Kg TS

$= 222 \times 0.35 = 77.7\ m^3$

$V_c + V_1 = 7 + 25.9 = 32.9\ m^3 \approx 33\ m^3$

Now, the discharge of outlet should be the same of inlet recharge.

So, out let discharge,

$$V_{dis} = \frac{2775}{1000} = 2.775\ m^3$$

Total volume of the gas staying chamber = $V_c + V_1 + V_{dis} = 33 + 2.775 = 35.775\ m^3$

Now, we can calculate the pressure of digester.

Let the normal pressure of the digester is $P_i = 4$ kPa.

And final pressure after gas being stored = P_f

The produced gas should have to stay within 35.775 cubic meters volume. So, according to Boyle's law,

$$P_i \times (\text{total gas produced} + 35.775) = P_f \times 35.775$$

$$\text{Or, } P_i \times (77.7 + 35.775) = P_f \times 35.775$$

$$\text{Or, } 4 \times (77.7 + 35.775) = P_f \times 35.775$$

$$Or, P_f = 12.68 \text{ kPa}$$

Let, height of the hydraulic chamber is h. The pressure of the hydraulic chamber should be 12.68 kPa so that only the inlet recharge will be discharge.

$$P_f + H\rho g = H\rho g + h_1\rho g + h\rho g$$

$$Or, h + h_1 = \frac{P_f}{\rho g} = \frac{12.68 \times 1000}{1000 \times 9.81} = 1.29 \text{ m}$$

Let, height of the hydraulic chamber from digester manure level, $h = 0.23$ m

So, height of the hydraulic chamber, $h_1 = H_H = 1.29 - 0.23 = 1.06$ m

Now, the volume of the hydraulic chamber is equals to the discharge per day.

If D_H is the diameter of the hydraulic chamber then,

$$\pi \left(\frac{D_H}{2}\right)^2 H_H = 2.775$$

$$Or, D_H = \sqrt{\frac{4 \times 2.775}{\pi \times H_H}} = \sqrt{\frac{16}{3.1416 \times 1.06}} = 2.82\, m$$