DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Daffodil International University

Title

Feasibility Study of Biogas Energy in Bangladesh

A Thesis submitted to the Daffodil International University in fulfillment of the requirements for the degree of B. Sc in Electrical and Electronics Engineering.

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APPROVAL

This thesis titled **"Feasibility Study of Biogas Energy in Bangladesh",** submitted by **Md. Mahmudul Hasan** and **Md. Parvez Alam** to the Department of Electrical and Electronics Engineering, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Electrical and Electronics Engineering and approved as to its style and contents.

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DECLARATION

We do here by declare that, the work presented in this Research paper has been carried out by ours and has not been previously submitted to any other University/College for an academic qualification/certificate/diploma or degree. We here by warrant that work we have presented does not breach any exciting copyright. This report is the outcome of investigation performed by **Md. Mahmudul Hasan** and **Md. Parvez Alam**, under the supervision of **Ms. Rifat Abdullah, Senior Lecturer,** Department of EEE Daffodil International University. The work was spread over one semester course, EEE-499: Thesis/Project in accordance with the course curriculum of the Department for the Bachelor of Science in Electrical and Electronics Engineering program.

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ABSTRACT

Energy is a key determinant of socio economic development of any country. But the matter of fact is that Bangladesh faces an acute crisis in the energy sector. Being less expensive and free availability, biogas can be a very useful solution to the energy crisis. The objective of this project is to investigate two reasonably uncommon energy sources on biogas analyzes can provide of power biogas digesters and generation methods. A biogas plant is modern energy source and is suitable to the necessities of the future. Now a day's electricity demand is high of Bangladesh and here are biogas resources unused. Our project discussion is how to used biogas resources to produce electrical power generation. The use of biogas as an alternative fuel for electricity run by generator was studied. Lastly, this project concludes that there exists great potential for fuel and cost savings with these types of alternative energy sources

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Chapter01

Introduction

Renewable energy (sources) or RES capture their energy from existing flows of energy, from on-going natural processes, such as sunshine, wind, flowing water, biological processes, and geothermal heat flows. Most renewable energy, other than geothermal and tidal power, ultimately comes from the Sun. Some forms are stored solar energy such as rainfall and wind power which is considered short-term solar-energy storage, whereas the energy in biomass is accumulated over a period of months, as in straw, or through many years as in wood. Capturing renewable energy by plants, animals and humans does not permanently deplete the resource. Fossil fuels, while theoretically renewable on a very long time-scale, are exploited at rates that may deplete these resources in the near future. Renewable energy resources may be used directly, or used to create other more convenient forms of energy. Examples of direct use are solar ovens, geothermal heating, water heaters and windmills. Examples of indirect use which require energy harvesting are electricity generation through wind turbines or photovoltaic cells, or production of fuels such as methane from biogas.

This project will discuss the biogas production technology from house hold waste especially human manure; it contains three chapters to explain the process of biogas production systems and the potential of biogas production.

1. BIOGAS CONCEPT OF BIOGAS ENERGY

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Biogas originates from biogenic material and is a type of bio fuels [1]. It is mainly composed of methaneCH_4 & CO_2. The biogas typically has 60% methane & 35% CO_2. There is also some percentage of hydrogen, nitrogen, oxygen, ammonia, moisture etc. The feedstock that is used for biogas production is mainly animal dung and wastage materials. Biogas production can be aerobic (presence of oxygen) and anaerobic. In anaerobic decomposition (absence of oxygen) of biomass in presence of bacteria. The bacterial decomposition of biomass takes place in three phases. They are hydrolysis phase, acid phase, methane phase. The following are the three processes that take place in biogas formation.

Hydrolysis phase: $(C_5H_{10}O_5)n + H_2O \rightarrow n(C_5H_{12}O_6)$
Acid phase: $n(C_5H_{12}O_6) \rightarrow CH_3CH(OH)COOH$
Methane phase: $4H_2 + CO_2 \rightarrow 2H_2O + CH_4$
$CH_3CH(OH)COOH + H_2O + CO_2 \rightarrow CH_3COOH + CH_4$

These three phase run in parallel in a biogas plant. But for the efficient production of biogas, all three processes should happen in equal amount. The acid production should not occur in large amount as it seriously affects the production of biogas.
The pH value of the slurry in the digester tank should be between 6.8 & 7.2. The whole process of anaerobic decomposition of biomass into biogas takes several weeks. The retention period of biomass inside a biogas chamber varies between 20 to 50 days. For example the retention period of cow dung is 50 days.

1.1 Sources of Energy

Two kinds of energy source in the world there are

Primary

Primary electricity is obtained from natural sources, such as hydro, wind, solar and tide and wave power.
Already exists in the nature forms of primary energy

Electrical energy is produced from of different energy sources. The sources of energy are used for generation of electrical energy are commonly.

Secondary

Electricity is produced as primary as well as secondary energy.

Secondary electricity is produced from heat of nuclear fission of nuclear fuels, from
The geothermal heat and solar thermal heat and by burning primary combustible fuels such as coal, natural gas, oil and renewable and wastes.[1]

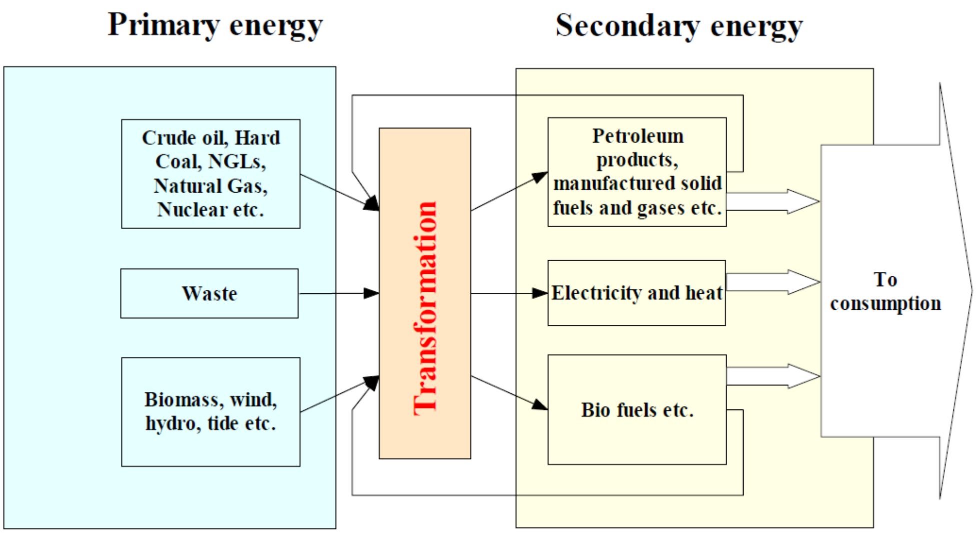

Fig:1 Primary and secondary energy

Sources of Energy:

Conventional l sources of energy
Unconventional sources of energy

1. Conventional Sources of Energy:
Conventional sources of energy e.g., fossil fuels (gaseous, solids and liquids), nuclear energy and water are used for much generation of electrical energy. Existing sources of energy such as coal, oil, uranium and water may not be sufficient to meet the ever increasing energy demands. Large amounts of electrical power can be produced through the use of conventional technology. The use of conventional technology to produce electrical power normally results in pollution that affects everyone. The major hazards of conventional energy are as following [18, 20]:
Nuclear energy is an inherently dangerous.
People and animals breathe in the polluted air and plants absorb the pollution. It is very expensive, because it is becoming increasingly rare. The burning of coal releases a high amount of sulphur .

2. Unconventional Sources of Energy

Unconventional sources of energy used for electrical energy in lesser magnitude which comes from renewable sources of energy. Renewable energy comes from natural resource such as sunlight, wind, rain, tidal energy, and geothermal heat, which are renewable. The various unconventional sources of energy are as following [2]:

- **Solar energy**
- **Wind energy**
- **Biomass**
- **Bio-gas**
- **Hydropower and**
- **Geothermal energy**

Solar energy:

Solar energy is the energy received by the earth from the sun. This energy is in the form of solar radiation, which makes the production of solar electricity possible. Solar energy is vital to support life on earth, it helps to grow our food, light our days, influence weather patterns, provide heat, and can be used to generate solar electricity. Solar electricity relies upon man-made devices such as solar panels or solar cells in order to provide a source of clean, and low cost renewable energy. We have used energy from the sun to provide electricity for many years, in the form of solar cell calculators and other small, low energy consuming devices. [3].

ADVANTAGES

- Renewable source of energy
- Pollution free
- After the capital cost, the cost of power generation is quite low
- Wide range of applications, powering street lights to satellites

DISADVANTAGES

- Capital cost is very high
- Large area of land is required
- Large number of solar panels are required
- Affected by seasons.

Wind energy:

Wind can be used to do work. The kinetic energy of the wind can be changed into other forms of energy, either mechanical energy or electrical energy.

When a boat lifts a sail, it is using wind energy to push it through the water. This is one form of work. Farmers have been using wind energy for many years to pump water from wells us-

ing windmills like the one on the right. Wind is also used to turn large grinding stones to grind wheat or corn, just like a water wheel is turned by water power.
Today, the wind is also used to make electricity. Blowing wind spins the blades on a wind turbine – just like a large toy pinwheel. This device is called a wind turbine and not a windmill. A windmill grinds or mills grain, or is used to pump water.
The blades of the turbine are attached to a hub that is mounted on a turning shaft. The shaft goes through a gear transmission box where the turning speed is increased. The transmission is attached to a high speed shaft which turns a generator that makes electricity.

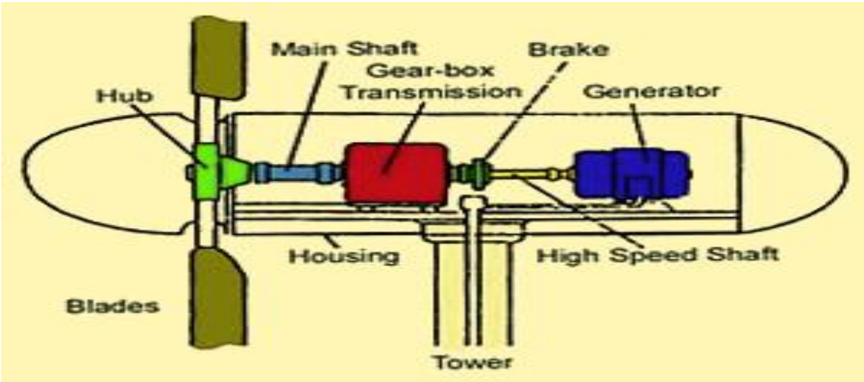

Fig:2,Wind turbine

ADVANTAGES

- Wind is Renewable and free of cost.
- Pollution free.
- Can be installed in remote villages, thus reducing costly transmission lines.

DISADVANTAGES

- Capital cost is very high.
- Large area of land is required.
  Maintenance cost is very high.

Biomass:

Biomass fuels come from living things: wood products, dried vegetation, crop residues, and aquatic plants. Wood is a biomass fuel. As long as we continue to plant new trees to replace those cut down, we will always have wood to burn. Just as with the fossil fuels, the energy stored in biomass fuels came originally from the Sun.
It is such a widely utilized source of energy, probably due to its low cost and indigenous nature, that it accounts for almost 15% of the world's total energy supply and as much as 35% in developing countries, mostly for cooking and heating. Electricity can also be generated from Biomass and stored to be used in homes. Let's see this simple illustration of how biomass is used to generate electricity.
1. Energy from the sun is transferred and stored in plants. When the plants are cut or die, wood chips, straw and other plant matter is delivered to the bunker
2. This is burned to heat water in a boiler to release heat energy (steam).
3. The energy/power from the steam is directed to turbines with pipes

4. The steam turns a number of blades in the turbine and generators, which are made of coils and magnets.
5. The charged magnetic fields produce electricity, which is sent to homes by cables.

Biomass Energy- is any organic materials that can be burned and used as a source of fuel
Biomass is a renewable energy source because the energy it contains comes from the sun. Through the process of photosynthesis, chlorophyll in plants captures the sun's energy by converting carbon dioxide from the air and water from the ground into carbohydrates, complex compounds composed of carbon, hydrogen, and oxygen. When these carbohydrates are burned, they turn back into carbon dioxide and water and release the sun's energy they contain. In this way, biomass functions as a sort of natural battery for storing solar energy. As long as biomass is produced sustainable—with only as much used as is grown—the battery will last indefinitely.
The most common way to capture the energy from biomass was to burn it, to make heat, steam, and electricity. But advances in recent years have shown that there are more efficient and cleaner ways to use biomass. It can be converted into liquid fuels, for example, or cooked in a process called "gasification" to produce combustible gases. And certain crops such as switch grass and willow trees are especially suited as "energy crops," plants grown specifically for energy generation.

Bio-gas:

Biogas is a mixture of mainly methane and carbon dioxide with very small amounts of hydrogen sulphide and other impurities. The methane content can range from 50% to 80% (on a volumetric basis).
Biogas is commonly produced by anaerobic digestion of wet organic waste. This occurs in municipals wastewater and sewage treatment plants, industrial operations that have liquid wastes containing organic material, and on farms where animals are kept or held in a small area, such as pig or poultry farms. Anaerobic digestion is essentially a continuous process so it requires a reliable continuous feed of material. The digestion can occur in purpose built sealed containers or in covered ponds.

Hydropower:

Hydropower is a clean, renewable and reliable energy source which converts kinetic energy from falling water into electricity, without consuming more water than is produced by nature.

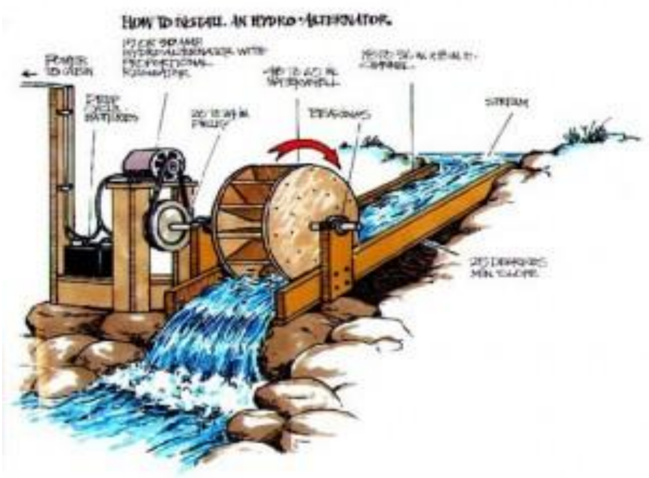

Fig:3Hydropower

The first water wheels were used well over 2000 years ago, and the technology has since been refined to become very efficient in the production of electricity.
The potential energy stored in a body of water held at a given height is converted to kinetic energy (movement energy) which is used to turn a turbine and create electricity[4].

ADVANTAGES

- It is inexhaustible source of energy
- No problem of pollution
- The cost of power generation is quite low
- High output can be obtained compared to solar or wind energy

DISADVANTAGES

- Capital cost is very high
- As the head is not constant, variable output is obtained
- As the head is low, large amount of water is necessary for the turbine
- It will not operate when the available head is less than 0.5m

Geothermal energy:

Geothermal In some places the rocks underground are hot. Deep wells can be drilled and cold water pumped down. The water runs through fractures in the rocks and is heated up. It returns to the surface as hot water and steam, where its' energy can be used to drive turbines and electricity generators. Geothermal energy is called a renewable energy source because the water is replenished by rainfall, and the heat is continuously produced by the earth.

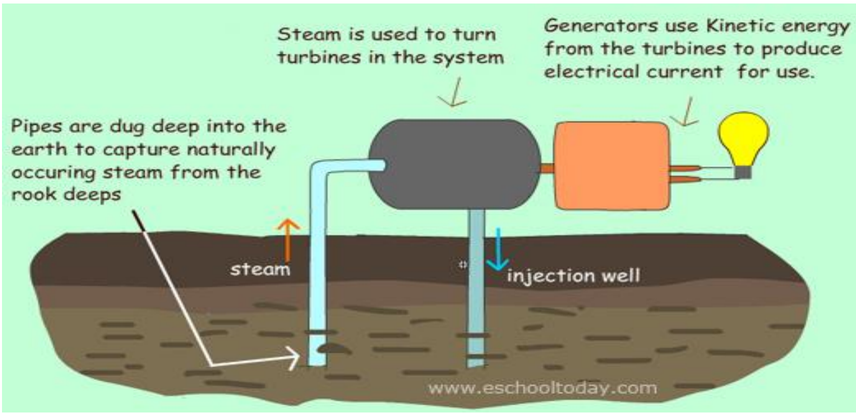

Fig: 4Geothermal power system

ADVANTAGES

- Geothermal energy is cheaper
- Used as space heating for buildings
- Used as industrial process heat
- Geothermal energy is inexhaustible

DISADVANTAGES

- Low overall power production efficiency (about 15%)
- Large areas are needed foe exploitation of geothermal energy.

Table 1.1 Comparisons of Renewable Energy Resources.

Renewable Energy	Waste Re-quired	Power	Renew abil-ity Creden-tials	Environ-mental Effect	Consistency
Biomass	Yes	Constant, reliable and controllable	Fine	Most Friendly	Good
Wind	None	Intermittent	Fine	Less friendly	Poor
Solar	None	Intermittent	Fine	Less friendly	Poor
Hydropower	None	Intermittent	Good	Most friendly	Poor
Biogas	Yes	Less con-stant, con-trollable	Fine	Most Friendly	Good
Geothermal	None	Intermittent	Fine	Friendly	Poor

1.2 Basic Concept of Biogas

Technologies used to convert organic materials to biogas, such as anaerobic digestion, are not new. Their application is also not widespread. Biogas production involves the biological fer-mentation of organic materials—agricultural wastes, manures and industrial effluents, munic-ipal solid waste—in an oxygen-deficient environment to produce methane, carbon dioxide, and hydrogen sulfide. The gas can be used directly for combustion in cooking or lighting or indirectly in fuel combustion engines delivering electrical or motor power. The slow diffu-sion of this technology is a result of initial construction costs, lack of organizational and community involvement, insufficient training opportunities in construction and maintenance, and difficulties in maintaining sufficient and consistent raw material inputs.

According to recent trends, an increase in the production of bio energy crops is occurring. This practice can produce beneficial and adverse environmental impacts. Bio energy crops can re-vegetate barren land, reclaim waterlogged or salinated soils, and stabilize erosion-prone land. They can provide habitats and increase biodiversity if managed properly. However, they may also displace agricultural production, contribute to deforestation, and even introduce invasive, potentially harmful, non-native species.

The operation of a biogas digester presents several potential environmental problems, but these problems can be minimized with proper planning and operation. Special precautions are required, for example, if human or hog wastes are used in digesters. Humans and some animals share similar feces-borne parasites and pathogens. For this reason, some authorities warn about the dangers of raw fecal waste and do not recommend applying sludge to soil where root and vegetable crops are cultivated. To minimize health risks, the digester should be built close to a lavatory or livestock shed so that the excrement may be deposited directly without unnecessary handling.

The disposal of liquid overflow (supernatant) from the digester may occasionally have adverse effects. Normally this liquid is clear and odorless and has some value as a dissolved fertilizer. If water is scarce, the supernatant may be recycled into the digester with new organic feedstock. Otherwise, it can be used to water plants or moisten compost materials. But in an improperly working digester, the supernatant may be dark and offensive. If it is not recycled, this liquid should be buried or mixed with soil in an isolated spot.

As with natural gas, biogas composition should be tested, and precautions taken to prevent leaks and losses. Surveillance is also important, since biogas is usually odorless and difficult to detect. In closed rooms, leaking gas can lead to asphyxiation or explosion.

In areas where manure or dung is a free community resource, the installation of biogas digesters may cause unanticipated social impacts. If manure becomes a valuable commodity, lower income families may no longer be able to afford it. In the initial planning stages, the question of who stands to lose or gain from an energy project deserves careful attention. Community input is important.

Strict air emissions and ash disposal regulations should be followed to avoid the emission of hazardous ash and compounds resulting from the burning of plastics, heavy metals chemicals and other substances encountered when incinerating municipal solid waste.

1.3 Use of Biogas

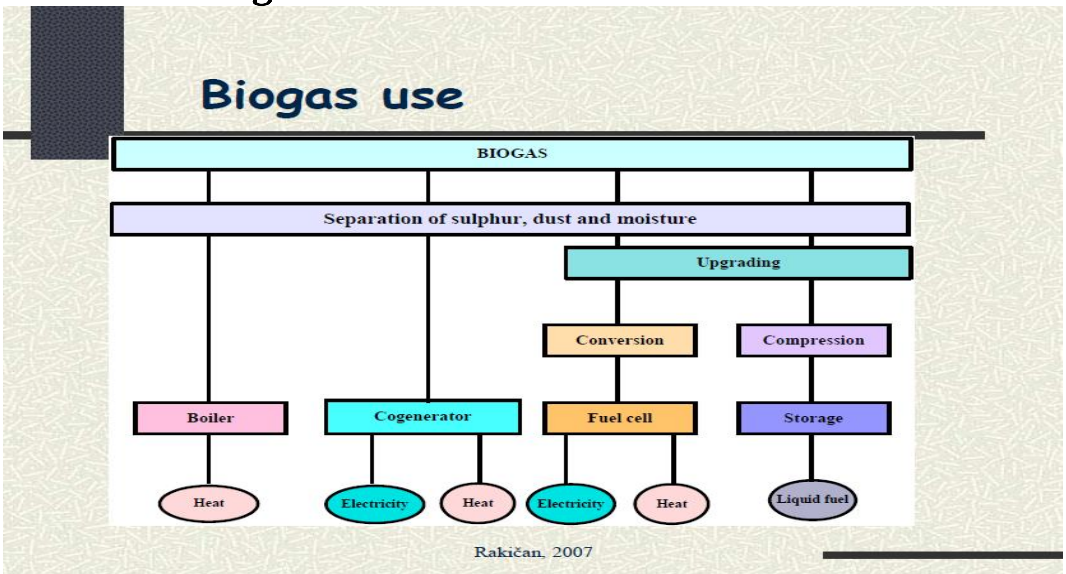

Fig: 5 use of biogas

1.4 Characteristic and Composition of Biogas

Bio-gas is a mixture of :

Methane (CH_4)	**: 50 to 70 %**
Carbon-dioxide (CO_2)	**:30 to 40 %**
Hydrogen (H_2)	**:5 to 10 %**
Nitrogen (N_2)	**: 1 to 2 %**
Hydrogen Sulphide (H_2S)	**Small quantity**

Bio-gas is generated when bacteria degrade biological material in absence of oxygen process known as anaerobic digestion. This process produces less temperature hence valuable in terms of energy conservation.

1.5 Biogas energy sources

Biogas a clean and renewable form of energy could augment conventional energy sources. Produced through anaerobic degradation in a very complex process and requires certain environmental conditions as well as different bacteria populations

Animal manure

The largest underutilized resources for biogas production are found in agriculture. Approx. 4-5% of the animal manure produced is currently used for biogas production, corresponding to just over 1.2 million m3/year. It is naturally not realistic to expect to achieve a 100% utilization, but a much higher usage would bring definite benefits to the environment.

Industrial waste

Existing biogas plants also take in considerable amounts of organic industrial waste from the food industry including slaughterhouse waste. The amount is estimated at around 350,000 t/year and the arrangement can be seen as an example of an effective and sustainable recycling of resources. In this case, the organic matter is used for energy production and the nutrients are recycled to agricultural land to replace commercial fertilizer. This resource also contributes significantly to making the biogas plants viable, partly because the waste often has a high gas potential (high DM and fat content) and partly because the plant often charges a gate fee for handling it. The amount of industrial waste available in this country is, however, nearly fully utilized, which means we are now importing some of the waste for biogas production.

Sewage sludge

Much of the sewage sludge currently produced is already being digested at sewage treatment plants around the country. In certain instances, it may be possible to redirect the sludge to biogas plants and thus ensure a better digestion of the sludge and, not least, a recycling of the nutrients to farmland. But this is a bit of a problematic issue. Some food producers, for example, do not allow digested, sludge-containing biomasses to be applied to land used for food production, even if the biomass complies with all environmental regulations. The reason is not logical or based on environmental considerations. Food producers simply fear the reaction of consumers, because consumers do not always react rationally. The word ‘sludge’ has, in the public ear, a negative ring to it and then it is immaterial that the practice is well regulated and sustainable – companies dare not run the risk for fear of a consumer boycott. In any future expansion of sewage treatment facilities, it is advisable to opt for the anaerobic process that produces energy rather than the aerobic process that uses energy.

Household waste

Household waste can also be used in biogas production and has previously been used in several plants. In some plants this is still the case, but most have stopped the use, either due to problems with the sorting resulting in too many impurities (knives and forks, plastic bags, etc.) that upset the digestion process, or due to problems with smell. This disposal route must, however, still be regarded as the most sustainable, again due to the scope for energy extraction and recycling of nutrients.

Energy crops

In recent years the use of energy crops has become increasingly interesting partly because of the limited supply of organic industrial waste. Virtually all arable crops can be used, as can crop residues such as turnip and potato tops. The only requirement is that the crop must be relatively easily digestible. In other words, the material must not contain too much lignin. The potential is huge – it is simply a question of how much land you wish to put down to energy crops. One exciting aspect of growing energy crops is that their cultivation can be more environmentally friendly than that of traditional crops. This is true particularly for perennial crops such as permanent grass, and they could therefore be used to reduce problems with the leaching of nitrogen in sensitive areas. The biomass can be either freshly cut or in the form of silage. This means that some can be stored for use during the winter months.

The growing of legumes such as grass-clover, Lucerne, or broad beans can provide an additional source of nitrogen to the crop rotation via the ability of these plants to fix nitrogen in their roots. In this way, less mineral fertilizer again needs to be used, which can improve the energy balance of their cultivation even further as the production of mineral-N is very energy demanding. With the right crop, careful planning and control, energy crops therefore offer a potentially high bio energy output and also an effective protection of the environment against the leaching of nitrogen. Some people, nevertheless, see an ethical dilemma in growing energy crops on farmland when there are so many starving people in the world. But if you are thinking along these lines, you should perhaps also consider whether it is ethical to produce and eat such large quantities of animal products as we do. This also requires the use of vast areas of agricultural land that could alternatively have been used for the production of food crops. And, finally, it will not be the first time in history that a large proportion of farmland is put aside for non-food crops. Only 60-70 years ago up to 20% of farmland was used to produce feed for the country's well-developed transport system: horses.

1.6 Emerging End Uses of Biogas

The new approaches and technologies in anaerobic digestion and biomass gasification described in the previous section create a large resource base for the production of biogas in the Midwest. Fortunately, the same innovation expands the potential ways that biogas energy can be used (Figure ll). These developments are highly complementary: One of the best ways to tap new resources for the production of biogas is to provide diverse end-uses for biogas that can overcome site-specific infrastructure or economic constraints. The most common use for biogas is electrical production and heating, but new technologies can create renewable natural gas and compressed renewable natural gas vehicle fuels. In addition, the versatility of biogas allows facilities to provide multiple end-uses at the same location, further increasing the ability of biogas to play an increasingly large role in the energy landscape [5].

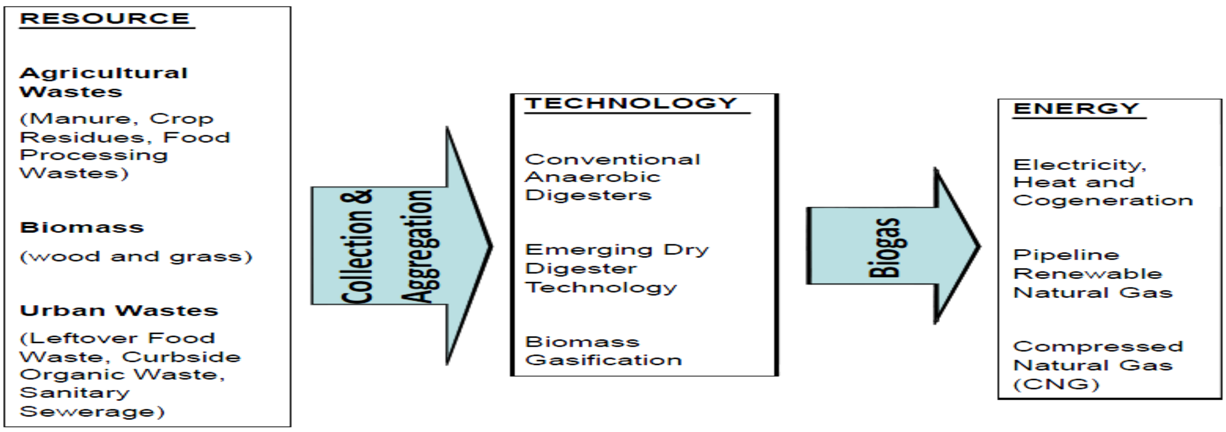

fig: 6 Diverse End Uses of Biogas

1.7 Benefits of Biogas Technology

Well-functioning biogas systems can yield a range of benefits for users, the society and the environment in general:

- Production of energy (heat, light, electricity);
- Transformation of organic wastes into high-quality fertilizer;
- Improvement of hygienic conditions through reduction of pathogens, worm eggs and flies;
- Reduction of workload, mainly for women, in firewood collection and cooking;
- Positive environmental externalities through protection of soil, water, air and woody Vegetation;
- Economic benefits through energy and fertilizer substitution, additional income sources and increasing yields of animal husbandry and agriculture;
- Other economic and eco-benefit through decentralized energy generation, import Substitution and environmental protection.

Biogas technology can substantially contribute to conservation and development, if the concrete conditions are favorable. However, the required high level of investment in capital and other limitations of biogas technology should also be thoroughly considered.

1.8 Summery

Biogas is one of the most promising renewable energy resources. It is organic materials such as animal dung, human manure, house hold waste and municipals wastewater can be converted in to electricity or clean-burning fuels. The main importance's of biogas energy are as following:

- Biogas fuels are available almost everywhere on earth.
- It is relatively cheap, virtually inexhaustible, and, properly managed.
- Biogas energy reducing many kinds of air pollution and net carbon emissions.

Chapter02

2. Electrical Energy Production from Biogas

This clearly indicates the relation between methane content of biogas and power generation possibility. Based on methane content and biogas engine efficiency, power generation from biogas can be calculated for any biogas resources.

The electrical energy produced using renewable fuel created from agriculture and municipal waste products is termed biogas electricity. Biogas is produced in anaerobic digesters using microbes to convert organic wastes into methane gas. This gas is then used to generate electricity in power plants, both large and small, rather than using non-renewable fuels. An alternate method of production of biogas occurs in landfills. The organic matter in the landfill undergoes anaerobic decomposition deep within the landfill mass, and in specially designed landfills the resulting methane gas is trapped for later use as fuel.
Small-scale production of biogas electricity occurs primarily on farms where manure is converted to methane gas using an anaerobic digester. The chemical energy in the methane is converted to mechanical energy when the methane is burned to power a turbine. This, in turn, converts the mechanical energy to electrical energy that can be used as a power source for the farm. In small-scale energy production, a micro turbine or engine is generally used to produce electricity. Excess heat may also be trapped and used to heat water or a small building.

2.1 Energy conversion technologies of Biogas

A renewable energy extension program has to focus on areas with the potential and the need for this form of energy. In Bangladesh there is a wide electricity grid to towns and Upazilla (peri-urban) areas. There is also a network of natural gas pipes, which also reaches many households. Both energy forms are in relation to the high demand in shortage. This shortage will further rise. It is difficult for Bangladesh to assure its energy provision. Biogas in small and medium scale should be extended particularly in areas without electricity and natural gas grid. Larger-scale digesters with electricity conversion can be built in areas with or without electricity link. They would contribute to reduce the consumption of the respective primary energy forms. The existing biogas operated generators are all asynchrony generators. They need an own independent electric grid, which consumes the electricity in the range of their output potential. In larger scale operations of 100 kW electricity production (at least 4500 m3 biogas per day) or more, synchronized generators could be utilized and supply the electricity into the grid. This requires a higher technical standard and can be looked into in the future. There would also be an option to produce biogas from municipal organic waste in a biogas plant near an electric power plant and utilize the gas in the power plant complementary to the natural gas.

2.2 Conversion technologies

- **Anaerobic Digestion**
- **Gasification**
- **Pyrolysis**
- **Combustion**

Anaerobic Digestion

Anaerobic digestion is one of the most common chemical processes in nature. Anaerobic means the decay or breakdown in the absence of air or more specifically oxygen. The process is similar to fermentation as the transformation is brought about by micro-organisms (bacteria) called anaerobes. Like with the production of alcohol (ethanol) digestion takes place in two stages. First, in the medium of digestion certain micro-organisms break-down the materials into simple sugars, alcohol, glycerol and peptides. When these components are present in the correct amounts and the conditions are correct, a second group of micro-organisms converts these simpler molecules into methane gas. The micro-organisms are particularly sensitive to environmental conditions including temperature and acidity.
Anaerobic digestion occurs between 32o F and 150o F. However the optimum temperature which promotes activity of the micro-organisms and consequently produce more methane gas is between 85o and 95o F. In colder climates this is difficult to maintain but worthwhile trying to achieve. Below 60o F little gas is produced.
Acidity is also important with a desired pH of between 7 and 8. With a low acid content the - high pH - the fermenting slows down until the bacteria produce enough acid (acidic carbon dioxide) to restore the balance. Acidity can be measured using litmus paper.
Carbon and nitrogen are the other two components for a digester and are both required for the micro-organisms to live. However, the bacteria consume the carbon at about 30 times faster than the nitrogen. This 30:1 ratio produces the maximum amount of gas. If the ratio is not correct the bacteria will usually compensate creating the right balance within the digester.
As mentioned earlier the gas produced in a digester is not pure methane and is usually 75% methane and carbon dioxide (CO_2) with trace amounts of hydrogen, nitrogen and other gases characteristic of the original materials used in the digester.
The slurry that is left after the digestion process is complete is mainly composed of organic humus, with small amounts of nitrogen and phosphates. This final product of gas production makes an excellent fertilizer and soil conditioner.
It should be noted that the time in starting the digester and producing gas can be as long as four weeks – but sometimes as short as two weeks. This is because the bacteria will first need time to breakdown the slurry into alcohols and sugars, before the second group of bacteria, the gas producing ones, can adjust the carbon/nitrogen mix and the acidity level for reasonable amounts of gas to be produced [6].

Gasification

This paper focuses on bio gasification as a means of producing fuel from material that might otherwise be wasted or that has only a single end use, for example, as fertilizer. The alternative biomass conversion technologies are burning raw waste to get rid of it, composting, distillation, burning raw waste to provide process or other beat, gasification, and pyrolysis. To compare all of these technologies, you must examine each technology separately, weighing its advantages and disadvantages and taking into account such factors as the availability and cost of capital, energy costs, the relative value of a particular raw waste and the end products it produces, the availability of human and material resources, and the impact of the technology on the environment. The discussion below presents some examples of the kinds of factors you need to consider in balancing one technology against another.

If the sole objective is to reduce waste, burning raw waste may be a good choice, provided it is sufficiently dry, air pollution is controlled, and there is a means to dispose of the ash. One disadvantage of burning raw waste for disposal is that it is a very inefficient use of energy. The energy produced by burning is wasted. In some situations, simply making the waste material available to people who can use it for cooking fuel may be a more effective means of disposal. And it does help assure that the heat energy will be put to use.

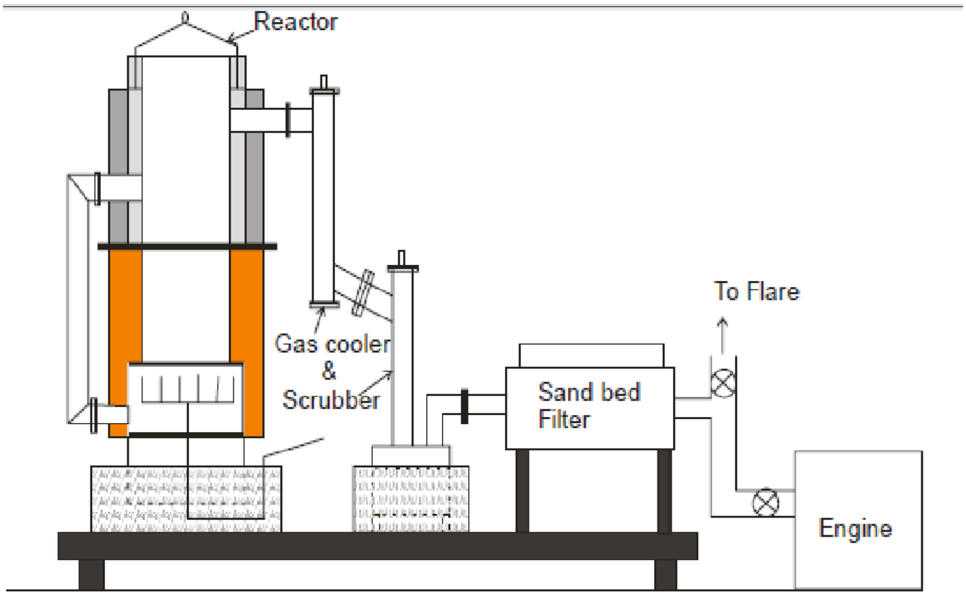

fig:7 Schematic representation of Gasifies

Composting is an excellent way to turn waste products into a commodity--fertilizer--simply and economically. One disadvantage of composting is that some of the nutrients in the raw waste--particularly nitrogen, phosphorus, and potassium--convert to a gas, evaporate, and are lost to the atmosphere, or they leach out through the soil. Moreover, composting is limited to producing only fertilizer.

If you want to do more with raw waste than composting or just getting rid of it--that is, if you want to harness the energy from the raw waste material to produce fuels or other products--you will need to make additional investments in capital, materials, and labor. As we have seen in this paper, a biogas digester yields both a fuel gas and a high quality fertilizer. Unlike composting, the digestion process retains and even improves the nutrient value of the original feedstock. With bio gasification, raw wastes can be digested, and returned to the environment in the form of fertilizer and fuel, without degrading the environment.

Keep in mind, however, that the equipment (e.g., a digester, systems, pumps) necessary for bio gasification will generally be more expensive than the equipment (e.g., a wagon equipped with a loader, a manure spreader) necessary for composting.
The remaining four biomass conversion technologies--distillation, controlled burning to provide process or other heat, gasification, and pyrolysis--collectively produce an even wider

range of products than bio gasification. Distillation of raw wastes produces sugar and alcohol, for example; controlled burning produces heat to, say, a boiler. Pyrolysis produces biofuels such as charcoal and crude oil; and gasification produces still other bio fuels such as low- and medium-energy gas (often called producer gas). These four technologies differ chiefly in their equipment requirements (i.e., depending on the technology, the hardware can be as simple as a cook stove or retort or as intricate as a distillation plant), in their techniques (i.e., some techniques are more complex than others, resulting in higher product yields), and in costs.

In sum, comparing one biomass conversion technology with another must be based on what end products you want from the technology, end product user how much you are willing to spend, relative economies of scale, skill levels, availability of raw waste materials, environmental impact, and many other factors.

Pyrolysis

After combustion, chemical reactions belong to the same category, so that a molecular dissociation plant could be compared to an ordinary incinerator. Pyrolysis process, based on induced reactions with no oxygen, is often confused with better known gasifies using important quantities of oxygen (air or steam added depending on the stoichiometric needs of the reactions) to accelerate the reaction of matter dissociation. Gasification needs controls and calibrations depending on the type of input materials, which are very often heterogeneous.

Pyrolysis technology is not influenced by the heterogeneity of the input materials (although same organic derivation and low wet percentage must be granted). Processing in total absence of oxygen, pyrolysis technology enables to remove, from the ecosystem larger quantities of CO_2, when compared to conventional technologies.

Combustion

The combustion of biogas produces a hot, clean flame that does not dirty pots or irritates the eyes, as does the smoke from other fuels. Biogas has a wide range of different uses – it can be burnt directly as a fuel for cooking, lighting, heating, water pumping, or grain milling, and it can be used to fuel combustion engines. In larger applications where scale and skills warrant, biogas can be pressurized and stored, cleaned for sale to commercial gas suppliers, or converted to electricity and sold to power grids, to meet peak energy needs.
Although biogas generation has been utilized since the 1950's, and the principles of digestion are well documented, little is known about the burning of such gases. This is due to the complex nature of methane, and difficulties associated in getting it to burn. In most cases, burners are developed using a 'trial-and-error' process, rather than consulting a text, or applying a formula.
There are many different designs of biogas burner available. Figure 1 illustrates the different aspects of a burner that have to be considered when it is being designed or when different burner designs are compared. A burner mixes gas and air in the correct proportion and feeds the mixture to a burner head, which supports the flame under the vessel to be heated. The flow of gas into the burner is controlled by the size of the main jet, as well as the gas pressure.

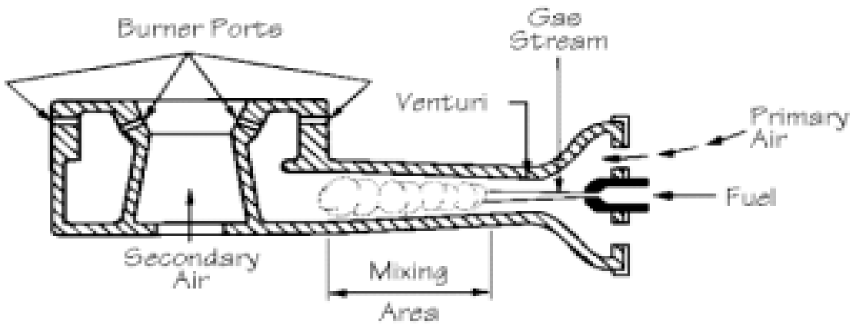

Fig:8 Example of a pre-mixed domestic cooker

Direct Combustion

Biogas conversion in direct combustion provides the simplest method of direct utilization on-site. Most combustion systems designed for either propane or natural gas may be easily modified for biogas. Care must be taken to consider the heat input rate, the fluid handling capability, the flame stability and the furnace atmosphere when such modifications are made. Due to the lower heating value of biogas equipment may operate at a lower rating and the size of gas inlet piping may need to be increased.

If cogeneration is employed in the biogas conversion system heat normally wasted may be recovered and used for hot water production. In the gas of gas turbines, the waste heat may be used to make steam and drive an additional steam turbine with the final waste heat going to hot water production and this is termed a combined cycle cogeneration system. Combining hot water recovery with electricity generation, biogas can provide an overall conversion efficiency of 65-85%. Modern gas turbine plants are small, extremely efficient, and visually unobtrusive.

An additional direct combustion conversion process which should be considered is the use of steam to run adsorption refrigeration systems. Such systems can be employed to provide heating and cooling and can utilize waste heat from a topping cycle. In typical adsorption systems, a fluid is contacted with a salt brine and the heat of solution is rejected. Input heat then boils the fluid from the brine, it is condensed and then used as a refrigerant fluid in a standard expansions valve arrangement. Multi-staged adsorption systems can be combined to improve the coefficient of performance of the overall system.

Internal Combustion Systems

For smaller biogas installations shaft horsepower and electrical generation is most effectively met by the use of a stationary internal combustion engine. Adequate removal of hydrogen sulfide to below 10 ppm is important to reduce engine maintain requirement. Often more frequent changing of engine oil and testing for oil sulfur content can increase engine component life. Some applications have used a dual-fuel carburetor so that propane or natural gas can be employed to start-up and shut down the engine system effectively removing trace sulfide from the internal parts.

When waste heat from engine cooling and exhaust gases is recovered and used the efficiency of the engine cogeneration system improves. Waste heat may be used for digester heating, space heating, hot water and or refrigeration.

2.3 Conversion of biogas to electricity

Reciprocating engines (ICE)

Turbine

Microturbine

Sterling engines

Organic Rankin Cycle (ORC)

Biogas to CHP (Combined heat and power) is an energy production method. The efficiency of installations using biogas in the CHP unit is higher, and their number is growing, whereas the thermal efficiency is always higher than electrical efficiency for all CHP units. The energy use of biogas plants in cogeneration can involve the application of reciprocating gas engines, gas turbines and microturbines. CHP plants using gas-powered reciprocating engines usually produce hot water or saturated steam. Heat is recovered from the heat exchanger on the engine casing, oil cooler and exhaust heat exchanger. CHP operation can also be used in gas turbines, involving a simple cycle gas turbine with a eat recovery heat exchanger which recovers the heat in the turbine exhaust and converts it to useful thermal energy, typically in the form of steam or hot water. Combined cycle operation occurs when high pressure steam is generated from recovered exhaust heat and then used to create additional power employing a steam turbine. Gas turbines are mostly used in combined heat and power systems of more than 1 MW (only a few types of gas turbines of less than 1 MW are available). At the same time, it should be realized that nits of the smallest size, feature low efficiency and relatively high unit investment costs.

Micro turbines can also be used in CHP systems. In these applications, the waste heat from micro turbine exhaust is used to produce hot water (up to 93oC). This option can replace a relatively expensive fuel, such as propane, needed to heat water in colder climates to meet space-heating requirements. The sale or use of micro turbine waste heat can significantly enhance project economy. Hot water can be used to heat building space, to drive absorption cooling, and to supply other thermal energy needs in a building or industrial process. The Sterling engines can also be operated in a CHP mode, but only with hot water. In this mode, the waste heat produced as a byproduct of the electricity generation process is recovered and utilized.

Reciprocating engines (ICE)

The reciprocating internal combustion engine represents the most widely used technology for electricity generation from biogas. The reason is mainly both the power and the economic feasibility of the system. These engines represent a prevalent and consolidated technology, and the related economic risks are very low compared to other technologies.
Gas-powered reciprocating engines, also called gas powered internal combustion engines, are the modified versions of medium- and high-speed engines powered by liquid fuels. The modifications applied in gas-fuelled engines typically include: changes in the shape of head and the top part of pistons, adding a gas and liquid fuel system, expansion of the engine cooling system and the exhaust heat removal system.

Turbines

Gas turbines represent the second most frequently used technology for biogas energy production, even though the number of installations is significantly lower than that of the ICEs. Compared with an internal combustion engine of the same size, a gas turbine features lower generation efficiency and a markedly lower power to heat ratio cogeneration ratio). On the other hand, a gas turbine is significantly lighter (e.g. a 1 MW turbine weighs approx. 1 tone, whereas an ICE of the same size – approx. 10 tones) and smaller. In a gas turbine, the only source of heat is the exhaust gas which can still be converted to useful energy. Gas turbines operate based on a thermodynamic Bray ton Cycle. The term "gas" refers to the atmospheric air that is taken into the engine and used as the working medium in the energy conversion process. This atmospheric air is first drawn into the engine where it is compressed, heated, and then expanded for power generation. The power produced by the expansion turbine and consumed by a compressor is proportional to the absolute temperature of the gas passing through the device. A gas turbine that uses biogas is very similar to a natural gas turbine, except that it requires twice the number of fuel-regulating valves and injectors, which is the effect of low eating value. The biogas-based turbine systems require more inspections, cleaning and general maintenance. It requires a higher level of biogas treatment for the removal of siloxanes, which finally increases the project costs. Gas turbines are available in sizes ranging from 500 kW to 250 MW, however at landfills most LFG energy projects are at minimum of 3 MW to more than 5 MW (where gas flows exceed a minimum of 2,300 Nm3/h). The most common gas turbine in operation at LFG recovery projects in USA is the Centaur, manufactured by Solar Turbines, a subsidiary of Caterpillar. A simple-cycle gas turbine for power-only generation has efficiencies approaching 40% and overall CHP efficiencies of up to 80%.

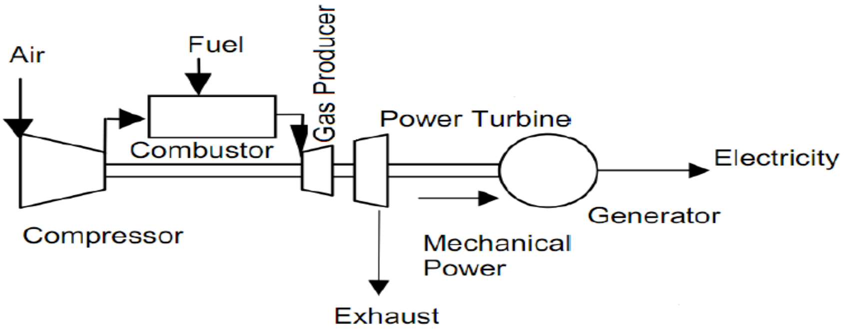

fig:9 Component of simple-cycle Gas Turbine.

Microturbines

Micro turbines are small combustion turbines that can be used in stationary power generation applications. The basic components of a micro turbine are the compressor, turbine generator, and recuperator. In a micro turbine, the combustion air (inlet air) is compressed using a compressor and then it is preheated in the recuperator using heat from the turbine exhaust in order to increase overall efficiency. The heated air and biogas are burned in the combustion chamber, and the release of heat causes the expansion of the gas. The expanding gas, sent through a gas turbine, turns the generator, which then produces electricity. The size range for micro turbines, available under development, is from 30 to 400 kW. The sizes of the micro turbines offered by producers are as follows:

• Capstone (Chatsworth, California, USA) 30 kW, 65 kW and 200 kW,
• Ingersoll-Rand (Portsmouth, New Hampshire, England)70 kW and 250 kW,
• Turban (Malmo, Sweden) 100 kW,
• Elliott Energy Systems (Jeannette, Pennsylvania, USA) 80 kW,
• Busman Power (Southampton, England) 80 kW.

Micro turbines have relatively low electric efficiencies, even with recuperates electric, efficiencies are typically 20÷32%, with overall CHP efficiencies of 0÷80%.Microturbines can be successfully fired on biogas provided a careful consideration is given to the way that the gas is handled and treated. For example, a micro turbine can run on landfill gas with methane content as low as 30%.

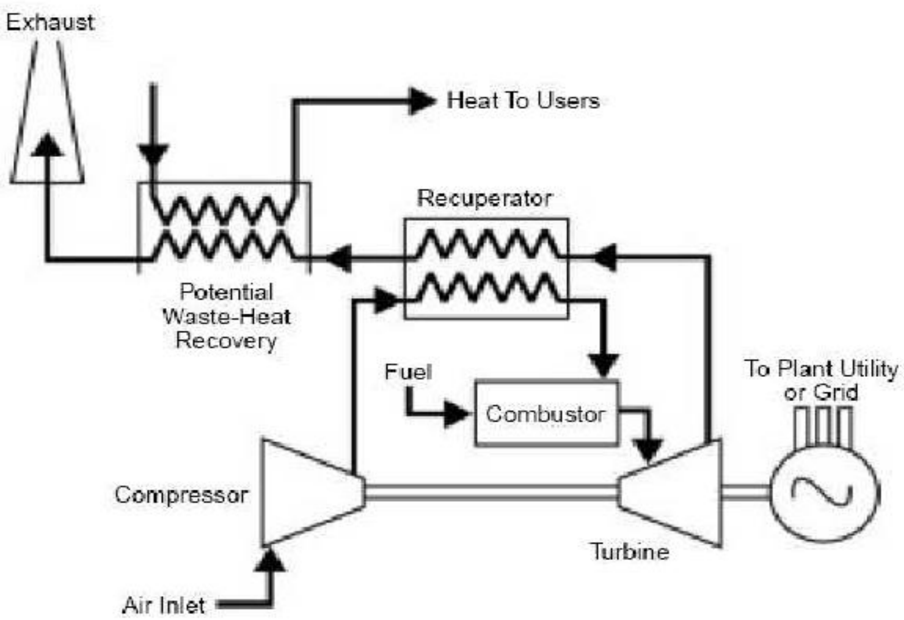

fig:10 Micro turbine CHP system.

Sterling engines

Traditional gas or diesel internal-combustion engines mix fuel and air inside the cylinder. The mixture is ignited causing combustion that pushes against the piston. The Sterling engine works differently. It contains a working gas (which may be air or an inert gas such as helium or hydrogen) that is sealed inside the engine and used over and over. Rather than burning the fuel inside the cylinder, the Sterling engine uses external heat to expand the gas contained inside the cylinder. As it expands, the gas pushes against the piston. The Sterling engine then recycles the captive working gas by cooling and compressing it, then reheating it again to expand and drive the pistons which, in turn, drive a generator and produce electricity. To date, few organizations have produced trial Sterling engines using exhaust from fossil fuel combustors. Those that have been produced are designed to generate less than 200 kW of power, and none of these are commercially available.
All the recent research related to Sterling engines has been focused on small-sized engines, from less than 2,5 kW (Sun power, Inc.) to about 100 kW (MTI's ASE engine,
Sterling Thermal Motors – now STM Power) and more technology-focused companies, including Tam in Enterprises, Sterling Technology Co., Whispertech, United Sterling and Sterling Energy Systems. Mechanical Technology Incorporated (MTI) is currently developing a Sterling engine called the Mod III, which could be adapted to use LFG.

The electrical efficiency of the power units is 30% with 80% efficiency in the total CHP system. The recovered heat in the form of hot water can be used for space heating either in commercial, or industrial processes.

Organic Rankin Cycle (ORC)

An alternative way of complementing the above list of technologies can be the application of a technology to convert heat energy into electricity using a system built on the basis of the ORC process. The Organic Rankin Cycle (ORC) process is not significantly different from the traditional Rankin cycle (used for steam turbine power plants) with water circulation. The only difference is the working fluid. The ORC process utilizes an organic fluid of high molecular mass, rather than water. The above application is recommended for biogas plants with an output exceeding 300 kW, and for cases where there is no demand for heat. About 20% of the thermal energy from the associated CHP generation was available for the ORC process[7].

2.4 Types of Biogas Plants

The three main types of simple biogas plants are shown in Figure 2:

- **Balloon plants**
- **Fixed-dome plants**
- **Floating-drum plants**

Balloon Plants

The balloon plant consists of a digester bag (e.g., PVC) in the upper part in which the gas is stored. The inlet and outlet are attached directly to the plastic skin of the balloon. The gas pressure is achieved through the elasticity of the balloon and by added weights placed on the balloon.

The advantages of this system are its low cost, ease of transportation, low construction sophistication, high digester temperatures, and its rather simple cleaning, emptying and maintenance.

The disadvantages can be the relatively short life span, high susceptibility to damage, little creation of local employment and, therefore, limited self-help potential.

A variation of the balloon plant is the channel-type digester, which is usually covered with plastic sheeting and a sunshade (see Figure 2E). Balloon plants can be recommended wherever the balloon skin is not likely to be damaged and where temperatures are not too high.

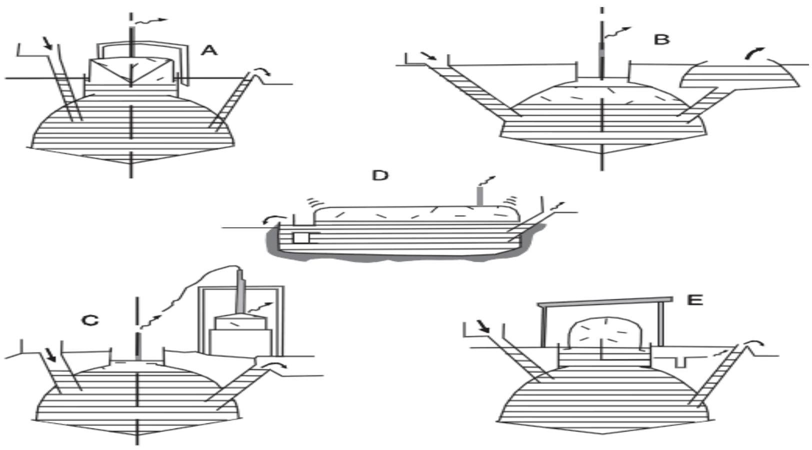

fig:11Note:Floating-drum plant (A), fixed-dome plant (B), fixed-dome plant with separate gas holder (C),balloon plant (D), channel-type digester with plastic sheeting and sunshade (E).Source: Biogas Plants.

Benefits of Balloon plant generators include:

- Simple
- Quick to construct
- Transportable
- Low cost/standardized construction
- Shallow – suitable for high water table

Disadvantages of Balloon plant generators include:

- Variable gas pressure
- Easily damaged/not weather resistant
- Not structurally stable/fixed
- Short working life
- Difficult to clean

Fixed-Dome Plants

The fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester. When the production of gas starts, the slurry is displaced into the compensation tank. The gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank.

The advantages of this system are the relatively low construction costs and the absence of moving parts and rusting steel parts. If well-constructed, fixed-dome plants have a long life span. The underground construction saves space and protects the digester from temperature changes. The construction provides opportunities for skilled local employment.

The disadvantages are mainly the frequent problems with the gas-tightness of the brickwork gas holder, where even a small crack in the upper brickwork can cause a heavy loss of biogas. Therefore, fixed-dome plants are recommended only where construction can be supervised by experienced biogas technicians. The gas pressure fluctuates substantially depending on the volume of the stored gas. Even though the underground construction buffers temperature extremes, digester temperatures are low.

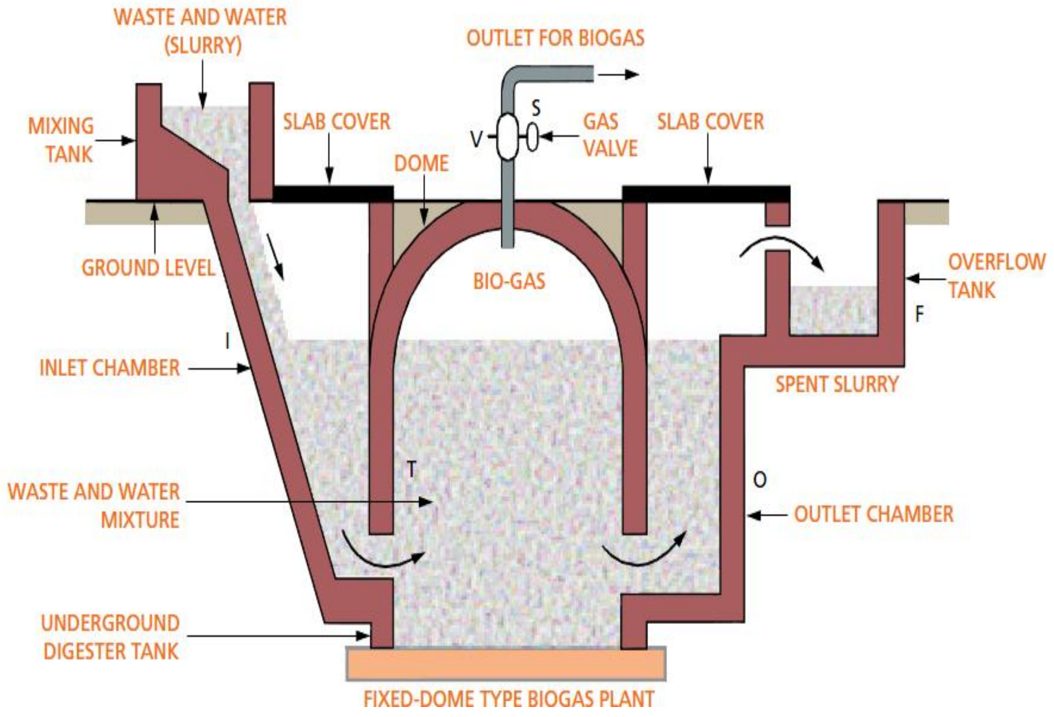

Fig. 12Fixed Dome Type Bio-Gas Plant

Benefits of fixed-dome generators include:

- simple design
- simple maintenance (no moving parts, no potential of rusting, long life (20 years+))
- lower set-up costs

Disadvantages of fixed-dome generators include:

- fluctuating gas pressure
- potential for leaks in mortar if not well constructed

Floating-Drum Plants

Floating-drum plants consist of an underground digester and a moving gasholder. The gasholder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. The gas drum is prevented from tilting by a guiding frame. If the drum floats in a water jacket, it cannot get stuck, even in substrate with a high solid content.
The main advantage of this system is its simple, easy operation, as the volume of stored gas is directly visible to the user. The gas pressure is constant and determined by the weight of the gas holder. The construction is relatively easy and mistakes do not lead to major problems in operation or gas yield.
The disadvantages are high material costs of the steel drum and the susceptibility of steel parts due to corrosion. Because of this, floating-drum plants have a shorter life span than fixed-dome plants and regular maintenance costs for the painting of the drum.to contrast these simple biogas plants, Figure 3 gives an impression about dimensions of industrial plants that have been built in Europe.

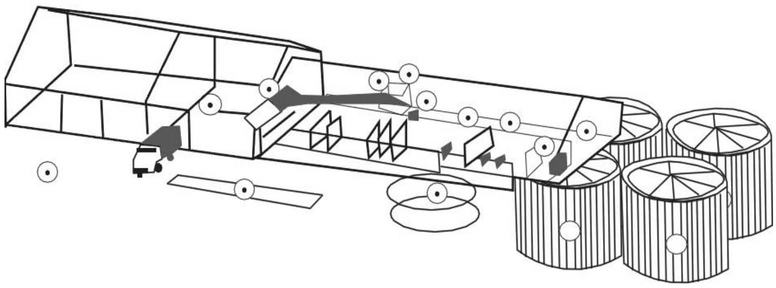

Figure: 13Industrial biogas plant with utilization of domestic organic waste

Benefits of floating-drum generators include:

- Constant gas pressure
- Can see how much gas had collected clearly (by height of drum)

Disadvantages of floating drum generators include:

- Corrosion problems with steel
- Expense of steel drum
- Complex construction due to moving parts
- Water jacket MUST be kept topped up to provide the gas seal

2.5 Digester Types

The digester is the component of the manure management system that optimizes naturally occurring anaerobic bacteria to decompose and treat the manure while producing biogas. Digesters are covered with an air-tight impermeable cover to trap the biogas for on-farm energy use. The choice of which digester to use is driven by the existing (or planned) manure handling system at the facility. The digester must be designed to operate as part of the facility’s operations. One of three basic options will generally be suitable for most conditions. Contains several NRCS Conservation Practice Standards for digesters. Table summarizes the main characteristics of these digester technologies:

Table 1.2: Summary Characteristics of Digester Technologies

Characteristics	Covered Lagoon	Complete Mix Digester	Plug Flow Digester	Fixed Film
Digestion Vessel	Deep Lagoon	Round/Square In/Above-Ground Tank	Rectangular In-Ground Tank	Above Ground Tank
Level of Technology	Low	Medium	Low	Medium
Supplemental Heat	No	Yes	Yes	No
Total Solids	0.5 - 3%	3 - 10%	11 - 13%	3%
Solids Characteristics	Fine	Coarse	Coarse	Very Fine
HRT* (days)	40 - 60	15+	15+	2-3
Farm Type	Dairy, Hog	Dairy, Hog	Dairy Only	Dairy, Hog
Optimum Location	Temperate and Warm Climates	All Climates	All Climates	Temperate and Warm

* Hydraulic Retention Time (HRT) is the average number of days a volume of manure remains in the digester.

Covered Lagoon Digester.

Complete Mix Digester.

Plug Flow Digester

Fixed Film Digester.

Covered Lagoon Digester.

Covered lagoons are used to treat and produce biogas from liquid manure with less than 3 percent solids. Generally, large lagoon volumes are required, preferably with depths greater than 12 feet. The typical volume of the required lagoon can be roughly estimated by multiplying the daily manure flush volume by 40 to 60 days. Covered lagoons for energy recovery are compatible with flush manure systems in warm climates. Covered lagoons may be used in cold climates for seasonal biogas recovery and odor control (gas flaring). There are two types of covers, bank-to-bank and modular. A bank-to-bank cover is used in moderate to heavy rainfall regions. A modular cover is used for arid regions. Table 1.3 illustrates a modular floating cover for lagoon applications. Typically, multiple modules cover the lagoon surface and can be fabricated from various materials.

Complete Mix Digester.

Complete mix digesters are engineered tanks, above or below ground, that treat slurry manure with a solids concentration in the range of 3 to 10 percent. These structures require less land than lagoons and are heated. Complete mix digesters are compatible with combinations of scraped and flushed manure.

Plug Flow Digester:

Plug flow digesters are engineered, heated, rectangular tanks that treat scraped dairy manure with a range of 11 to 13 percent total solids. Swine manure cannot be treated with a plug flow digester due to its lack of fiber.

Fixed Film Digester.

Fixed-film digesters consist of a tank filled with plastic media. The media supports a thin layer of anaerobic bacteria called biofilm (hence the term “fixed-film”). As the waste manure passes through the media, biogas is produced. Like covered lagoon digesters fixed-film digesters are best suited for dilute waste streams typically associated with flush manure handling or pit recharge manure collection. Fixed-film digesters can be used for both dairy and swine wastes. However, separation of dairy manure is required to remove slowly degradable solids.

2.6 Biogas mechanics

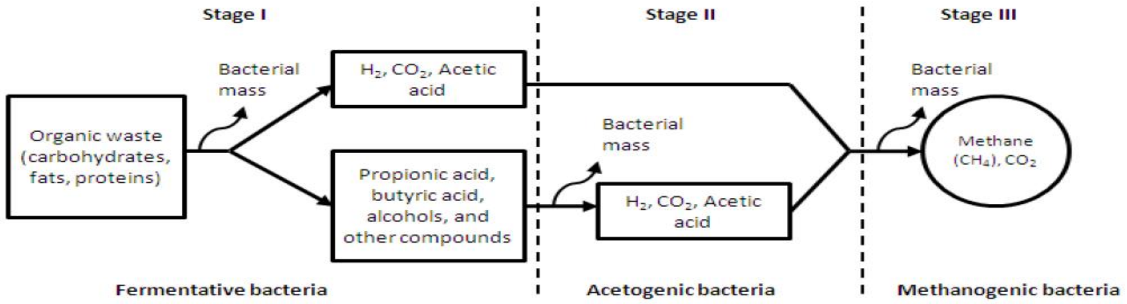

fig:14 Schematic of biogas reaction

Stage 1 – Hydrolysis

Bacteria decompose long chains of complex carbohydrates and proteins in the biomass into smaller molecules.

Stage 2 – Acidification

Acid-producing bacteria convert the smaller molecules produced in the first step into acetic acid (CH3COOH), hydrogen (H2) and carbon dioxide (CO2).

Stage 3 – Methane formation (Anaerobic)

Methane-producing bacteria convert the acetic acid (CH3COOH), hydrogen (H2) and carbon dioxide (CO2) into methane (CH4) and carbon dioxide (CO2). This mixture of gas is known as biogas.

2.7 The Bio-Gas Process

The following figure illustrated the process of transforming waste to energy.

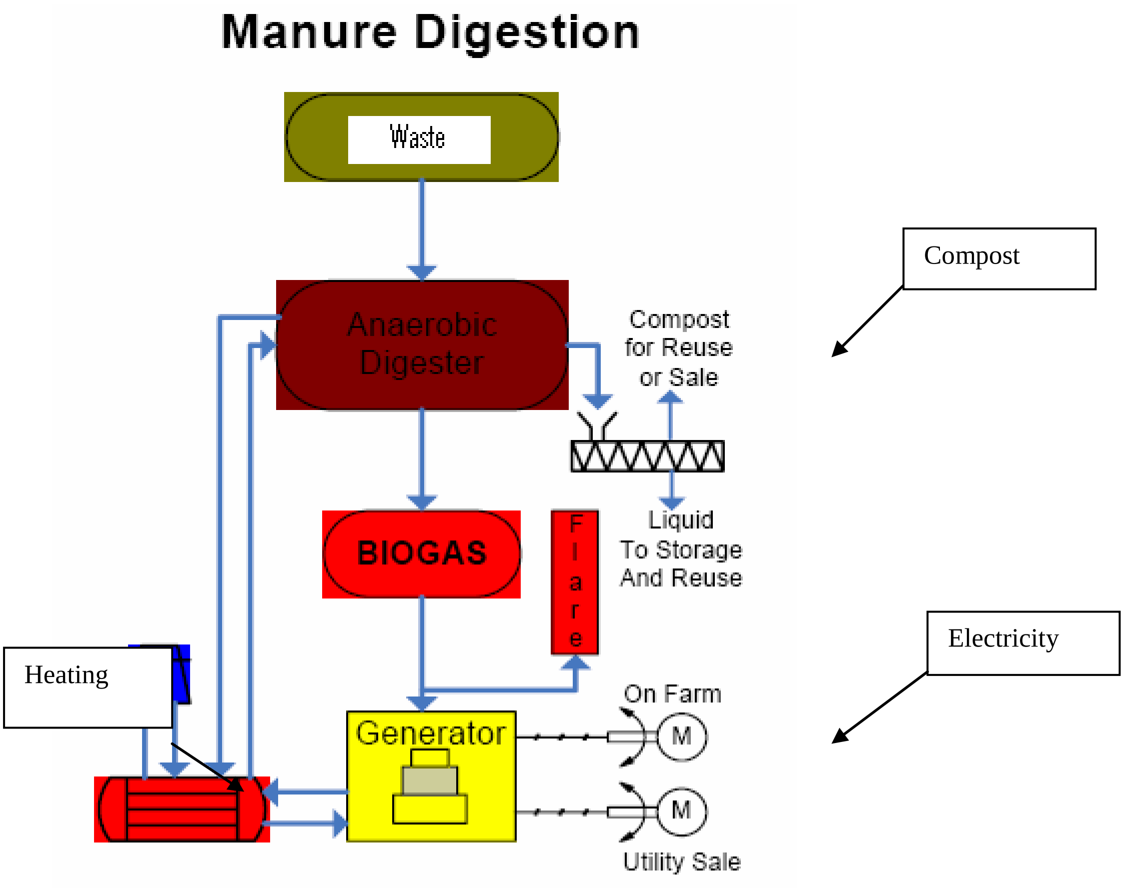

Fig:15 the basic function of a bio-gas plant

2.8 Bio-electricity from Biogas:

The poultry industry of Bangladesh produces about 20,000 ton poultry waste per day. About 50 MW electricity can be produced from the poultry wastes. It will serve the dual purpose of generating electricity from renewable sources and addressing environmental hazard.
The Infrastructure Development Company Ltd (IDCOL) a government owned non-bank financial institutes, is going to finance more bio-electricity projects in Bangladesh. About 34,000 biogas plants have been installed under IDCOL renewable energy program. IDCOL has so far financed 5 biogas based power plants, the largest one having a capacity of 400kW from rice husk. IDCOL has a vision to finance 450 bio-electricity plants and biomass gasification based power plant with an average capacity of 50 kW by 2017 [1].
Under IDCOL project, a biogas plant is built at Bahuria chala in Bhawal Mirzapur, Gazipur-1703. The owner of this plant Shohorab Dewyan has a poultry farm with a total of 6,000 birds. About 10 KW of electricity produced from the poultry litter generated in the farm.

Fig:16 Picture of 10 kw biogas power plant in Bahuria chala, Bhawal Mirzapur, Gazipur-1703

Under the project about 28.8 cubic meter of biogas is generated per day which is fed in a 15.2 KW biogas generator to produce electricity. He installed a ZS1110 model dual fuel (gas & diesel) generator. The gas enter into generator through a biogas filter. The Installation cost of the generator is 125,000 TK. About 3 KW is used to meet the captive demand of the farm and owner house. And rest of the electricity about 7 KW is sold to nearest shop and houses. He uses one television, one refrigerator, two fans, five bulbs for this own house and 45 bulbs (23 watt) for his poultry farm. He also use biogas for cooking purpose. He sells electricity to the nearest shop for 100 taka/month for one 23 watt bulb. He supply electricity about 25 shops and 2 houses. Byproduct of this plant is used as organic fertilizer for his land and rest of the fertilizer is sold to other farmers.

2.9 Biogas from Kitchen Waste:

Kitchen waste dumped everyday do garbage. We can easily run the gas burner in the same kitchen. It is possible by producing biogas from the drupe waste.
Kitchen waste can easily produces biogas for cooking. Bangladeshi Engineer has setup a bio-gas plant at his building rooftop in the capital's mirpur area. He informs about six kilogram kitchen waste can produce enough gas a family needsfor cooking thrice a day.
Engineer Mr.Zubair looking on renewable energy has set up a biogas plant at his build's roof-top in Mirpur Dhaka. Now it produces biogas fermenting the daily supply of waste from the kitchen. The city corporation can easily relieved from kitchen waste if we can setup biogas plant at the rooftop of every high-rise apartments and buildings. We can easily get organic fertilizer as a byproduct and we can also get biogas from the plant.

Fig:17 Biogas generation for Kitchen Waste in Mirpur Dhaka

Engineer Zubair's plant operates on waste collected from kitchen of each of the flat of the building he leaves in. The biogas produced by the plant is being used for cooking. He informs, amount of gas prepared from 6 kg of waste daily can easily serves a small family for cooking three times in a day. In this case kitchen waste required such as vegetable waste, rice water, rice starch, lentil ranch water. If we provide a waste in to each to each of our neighbors, they can fill and give it back to us. These plants can easily be setup on the rooftop of any house. It costs only three to four thousand taka. He collected reject from market at a very cheap rate to build a biogas plant. Mr.Zubair collects kitchen waste from each apartment and feed it into the plant and he gets biogas for the next days. After the gas is extracted the residue left is not to be dumped, rather it comes as a high quality organic fertilizer. He informs, he is applying the fertilizer to his vegetable garden and seasonal orchard on the same rooftop. Need for gas rises everyday in this country but the reality sees it accessibility plummeting against the place of its rising demand. Right at this moment the biogas plant than ran on the kitchen waste can surely be in alternate way of quenching thirst for domestic gas supply. In addition the fertilizer comes as a bonus.[25]

2.10 Biogas from poultry Litter and Cow Dung:

In Bangladesh only 3% of the people enjoy the facility of natural gas coming to their homes through pipe lines. The lucky few mostly live in the cities. Most of the Bangladesh's rural people depend on biomass, crop residues, plant debris, animal dung and wood for fuel creating deforestation, flood, soil erosion etc. Women and children, on whom the burden of collecting fuel falls, suffer the most. They are the worst victims of indoor air pollution such as smokes in the kitchens.
Grameen Shakti (GS) one of the largest and fastest-growing renewable energy companies in Bangladesh. GS is the leading company on renewable energy to promote, develop and popularize renewable energy technologies in remote, rural areas of Bangladesh. GS constructed about 27,313 biogas plant as of December 2013 [26].

GS has been promoting and constructing both domestic and larger sizes biogas plants to rural villagers. Impact on biogas plant owners has been positive and demand is increasing day by day.

Abdul Basten Sharker, an owner of biogas plant who live at Mawna in Sreepur,Gazipur is using 2.4 m^3 biogas pant under GS program. He is producing biogas for cooking purpose form poultry litter. He has a poultry farm with 500 layer poultry breeds which produce enough gas for cooking three times in a day for 5 member's family. Byproduct from the plant is used as fish feed.

Fig:18 Picture of 2.4 m^3 biogas power plant in Mawna , Sreepur, Gazipur

Another biogas plant owner Md. Shariful Islam Sarkar using 2.4 m^3 biogas pant form 1 year. He is producing biogas for cooking purpose form 500 poultry birds litter. He also uses cow dung from three cows when the birds are sold. Everyday 65 kg cow dung is needed for running 2.4 m^3 biogas pant. He uses organic fertilizer for his land and fish feed

Md. Motahar hossain, who has 4.8 m^3 large size biogas pant. He produces biogas from 1000 layer poultry breeds. He uses this gas for cooking purpose and providing heat for the poultry chickens. He uses organic fertilizer for his land and rest fertilizer sells to other farmers. A large amount of gas remain unused for such kind of large plant. There are lack of entrepreneurs who will produce biogas for commercial purpose.

Fig:19 Picture of 4.8 m^3 biogas power plant in Mawna , Sreepur, Gazipur

Grameen Shakti (GS) construct five size of biogas plant. Cost and Operational hours depends on different sizes. Biogas plant size and constructional cost are given below. [26]

Table 1.3 Biogas Plant size & construction cost [27]**:**

Size (m^3)	Operational hours per day	Daily cow dung required (kg)	Daily poultry droppings required (kg)	Approx. construction cost (BDT)	Approx. construction cost (BDT) Down payment 15% (BDT))	Loan amount after down payment (BDT)	Subsidy amount (BDT)	Loan amount after subsidy (BDT)	Service charge for 2 years at 6% flat rate (BDT)	Loan amount with service charge (BDT)	Monthly Installment (BDT)
1.6	3-4	43	23	26,000	3,900	22,100	5,000	17,100	2,052	19,152	798
2.0	4-5	54	28	32,000	4,800	27,200	5,000	22,200	2,664	24,864	1,036
2.4	5-6	65	34	36,000	5,400	30,600	5,000	25,600	3,072	28,672	1,195
3.2	7-8	87	45	43,000	6,450	36,550	5,000	31,550	3,786	35,336	1,473
4.8	10-12	130	68	52,000	7,800	44,200	5,000	39,200	4,704	43,904	1,830

2.11 Summary

Biogas conversion and electrical energy production process technically and economically feasible system. Biogas to energy conversion and electrical energy generation is importance in following reasons:

- Selection of a proper conversion technology for biogas depends upon the form in which the energy is required.
- Methane -based gas fuels produced by fermentation are considered low costly for use in stationary.
- Only biogas from anaerobic digestion is currently a cost-effective fuel for use in static.
- Biogas planet and digester type are more effectively use for energy produced. Electricity produced to methane gas from biogas process.
- At present, the primary approach for generating electricity from biogas is direct combustion system and internal combustion system generating efficiencies.

Chapter 03

3. Proposal for biogas energy plant from waste & human manure in banshee housing society.

Its known to all that Dhaka city is now a densely populated country. Its said that more or less 20 million peoples live in Dhaka now. So housing for that great number of people is a vital problem for Dhaka now. This problem started from early nineties and therefore housing society or project theme became more well-liked. Bonosree housing society is the result of that crisis situated in behind the Bangladesh Television Vhobon, Rampur a, one of the prominent zone of Dhaka city. This is a well planned housing society, approved by RAJUK. There are 7 blocks in Bonosree with having 8 roads like 1-8. About to 46 house in each road which are mainly 6 storied. From the above data its pretty clear that like Dhaka its also a largely populated area but the basic difference in planning where overall Dhaka city facing great trouble.

Now-a-days we have to think our problem in smart way. As like our population, electricity is also a great problem for us. The smarter way is to combine our problem with our resources. That's the only solution to survive. We consider our large population is our great asset. From this asset we are proposing to produce Bio gas which can easily reduce our electricity problem in economical way.

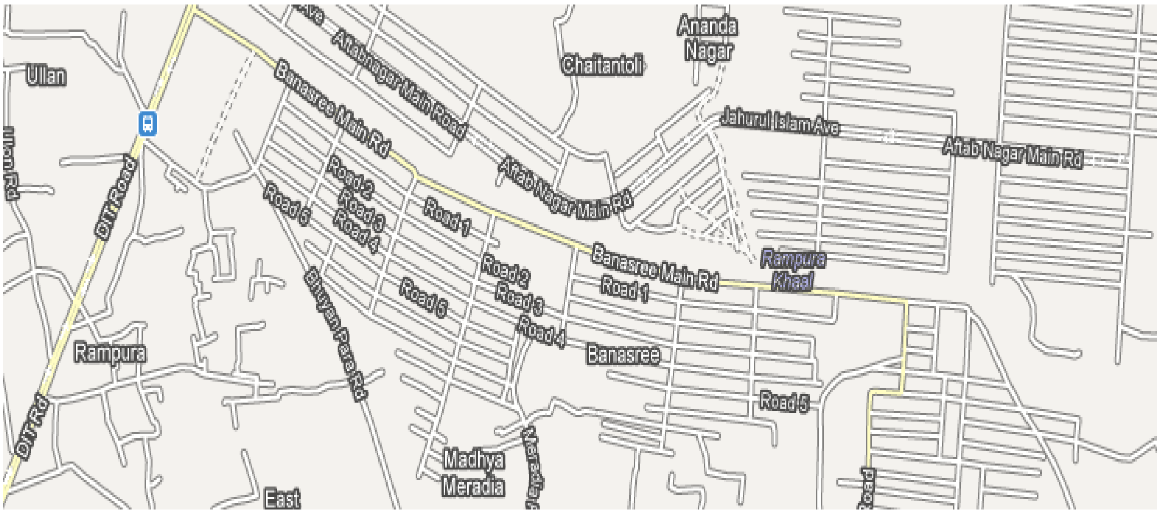

Fig:20 Map of Banasree Housing Society.(From Google Map)

3.1 Electricity requirement In Banasree Housing Society.

Load calculation a house:

Table :1.4 Load calculation a house

Instrument	Quantities	Watt	Total watt/KW
Energy Saving Lamp	8	23	184
Fan	4	75	300
TV	1	100	100
PC	1	80	80
Air Condition (1.5 ton)	1	1200	1200
Refrigerator	1	600	600
Total			2.464 kw

Total Load Calculation in Banasree Housing Society

Table :1.5 Total Load Calculation in Banasree Housing Society

Total house	= 16200
Total Power	= 39,916.8 KW

3.2 Waste & Manure Collection in Banasree Housing Society

Table :1.6 Waste & Manure Collection in Banasree Housing Society

Every day waste pre house	= 0.5 kg	
Total waste collection	=(16,200*0.5)	=8,100 kg or 8.1 ton (1)

Every day manure collection	=(16,200 house*4person)	=64,800 person
Per day per person manure produce	= 0.3 kg	
Total manure collection	=(64,800*0.3)	=19,440 kg

In Total	=8.1 (1) +19.44 (2)	=27.54 ton

3.3 Electricity Produced In Banasree Housing Society from Biogas

$E = \mu \times H \times f \times \upsilon$
Where, E = Energy output
μ = Efficiency
Cogeneration and Distributed Generation Journal
H = Heat of combustion for methane, 28 MJ/m3
f = Fraction of methane in biogas
υ = Biogas volume
And
$\upsilon = C \times m$
Where, C = Biogas yield per kg of solid excrement
m = Total mass of the solid excrement input
[8].

The power output in the generator case with 64800 person human manure is as follows:
$E = \mu \times H \times f \times \upsilon$ E = (30%) × (28 MJ/m3) × (50%) × (0.03 m3/kg) × (64800 person) × (0.3kg/person/day)
=0.3*28*0.5*0.03*64800*0.3=2449.44
Converting to electrical power (EP),
EP = E/(3.6 MJ/kWh) = (2449.44/3.6) kWh = 680.4kwh(continuous)

The power output in the generator case with 16200 houses waste is as follows:

$E = \mu \times H \times f \times \upsilon$ E
= (30%) × (28 MJ/m^3) × (60%) × (0.03 m^3/kg) × (16200houses) × (0.5kg/house/day)
=0.3*28*0.6*0.03*16200*0.5=1224.72
EP=E/3.6MJ/kwh=(1224.72/3.6)kwh=340.2kwh (continuous)

So, total power output is
680.4+340.2=1020.6 kwh

Here we use tow generator, each 600kw Biogas Generator
Engine model: 12V190ZLZ.

Fig:21 Biogas Generator

3.4 Sizing the digester:

The ratio of waste, manure and water is 1: 1

Manure = 19,440kg manure + 19,440kg water = 38,880 kg

Waste = 8,100 kg waste + 8,100 kg water = 16,200 kg

Total input per day = 55,080 kg

V_{total} of digester's feed= 55.08 m^3/day

V_{feed}= 1/40 $V_{digester}$

$V_{digester}$ = 40 x 55.08m^3= 2,203.2 m^3

V_{holder} = 1/5 X 2,203.2 m^3 = 440.64 m^3

Total digester volume = $V_{holder} + V_{digester}$ = 440.64 + 2,203.2 = 2,643.84 m^3
[9]

3.5 Basic layout of a biogas plant

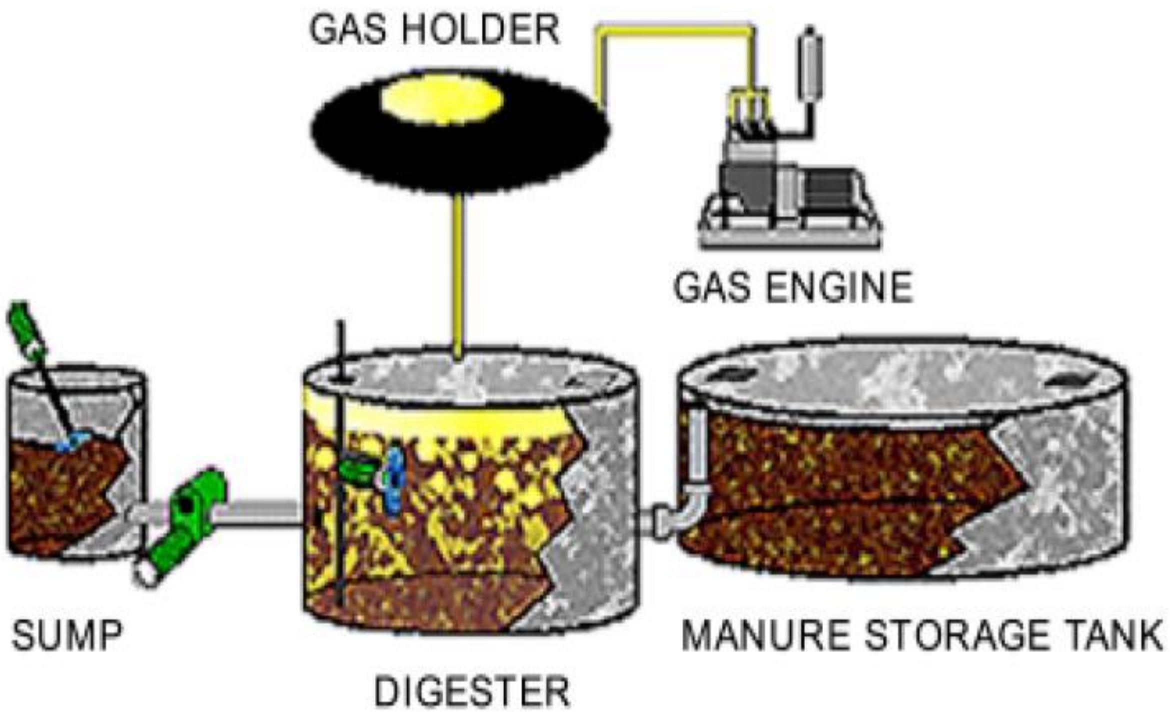

Fig: 22 Basic Lay Out of a Biogas Plant

3.6 Block Diagram of Biogas plant at Banasree Housing Society

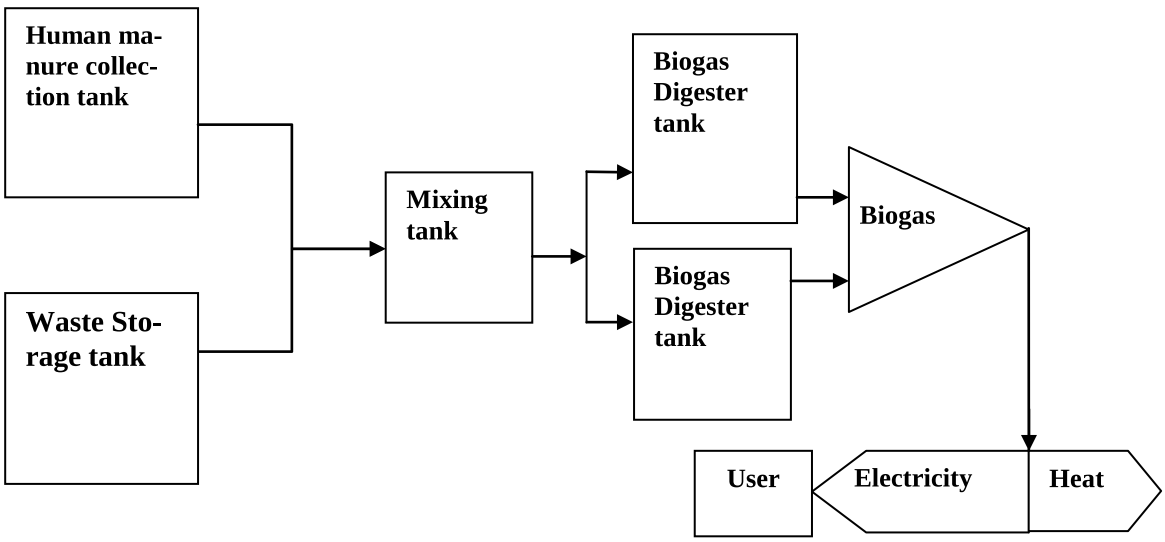

Fig:19 Block diagram of Biogas plant

-Operation product

3.7 Design of the plant:

The design of the plant is based upon many factors. Some of the major factors imposing specific design constraints have been discussed below.

1. Sizing:

The size of the plant was primarily decided by the number of beneficiaries that signed up for the project. Plant has a design capacity of 27,540 kg per day.

1. Mixing tank

Human manure and house hold waste is mixed in the mixing tank. This process of mixing requires electricity supply.

2. Digester

There are 2 digesters each of size 1321.92 m3 and floating dome type. The digestion time is 40 days.

3. Electricity Generation

There are 2 generator each 600kw Biogas Generator, Engine modal: 12V190ZLZ

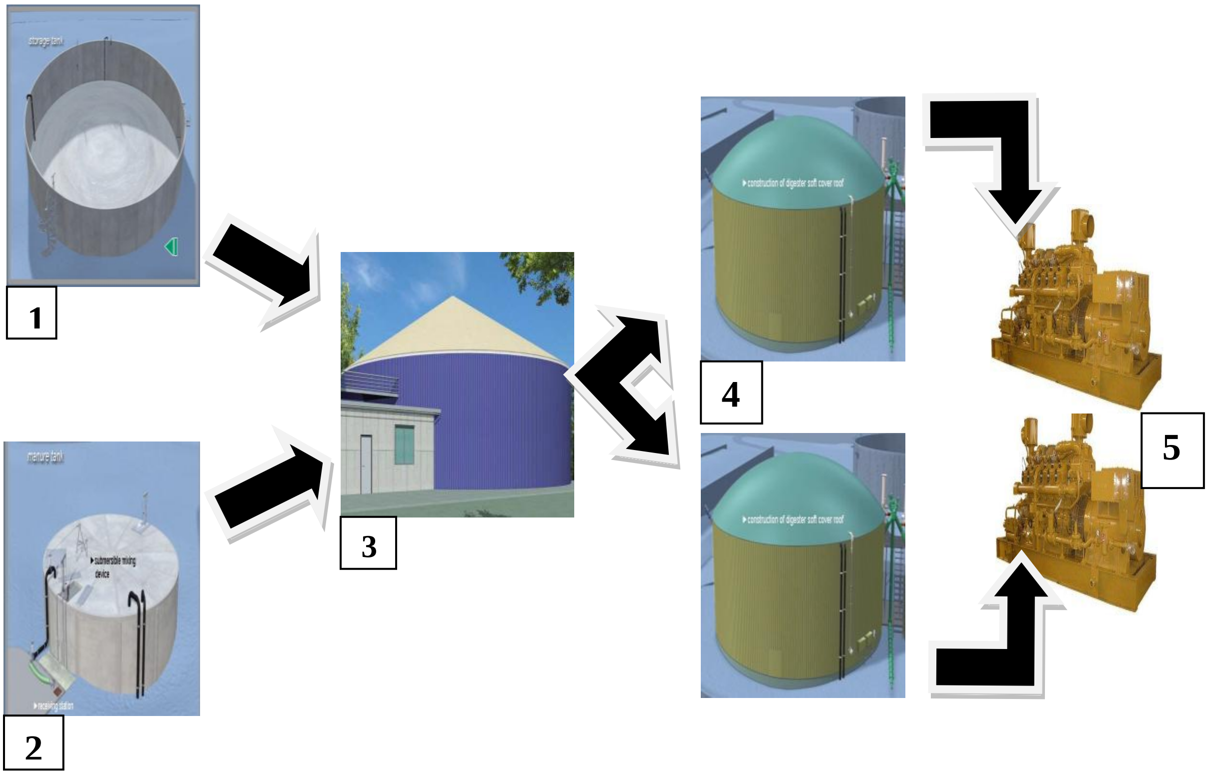

Fig:23 Layout of Banasree housing society Biogas power plant.

Table:1.7 Basic apparatus

1	Manure collocation tank
2	Waste collation storage tank
3	Mixing tank
4	Digester tank
5	Generator

3.8 Banasree housing society Biogas Energy Plant

We proposal Floating-drum plant digester at Banasree housing society is

Floating-drum plants

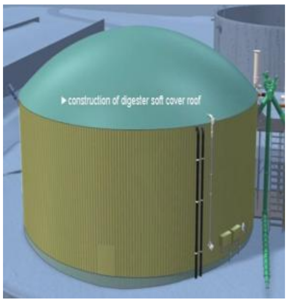

Fig:24 Floating-drum plan

Manure collation tank

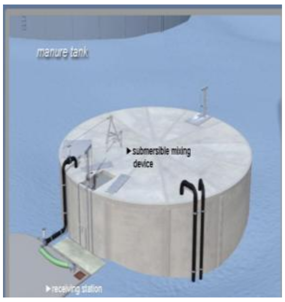

Fig:25 Manure collation tank

Waste collation storage tank

Fig:26 Waste storage tank

Biogas energy plant

Fig:27Biogas energy plant

Cost Analysis of a Biogas Power Plant:

The total installed costs of biomass power generation technologies varies significantly by technology and country.

Installation Cost (Fixed Cost):		**Price:**
I.	Land	100,00,000 TK
II.	Manure collocation tank	1,00,000 TK
III.	Waste collection storage tank	1,00,000 TK
IV.	Mixing tank	1,50,000 TK
V.	Digester tank	2,35,000 TK
VI.	Generator	165,00,000 TK
VII.	Labor	12,00,000 TK
	Total Installation Cost =	282,85,000 TK

Running Cost (Variable Cost) per day:		**Price:**
I.	Collection and transportation cost	30,000 TK
II.	Water supply for cleaning the stable and mixing the substrate	3,000 TK
III.	Feeding and operating of the plant	10,000 TK
IV.	Supervision, maintenance and repair of the plant	2,000 TK
V.	Storage and disposal of the slurry	1,000 TK
VI.	Administration.	10,000 TK
	Running Cost =	56,000 TK

Considering 10 years Life Time of the plant,

The Fixed Cost per hour = 282,85,000 ÷ (365 × 10 × 24)

= 282,85,000 ÷ 87600

= 322.88 TK

And,

The Variable Cost per hour = (56,000 ÷ 24)

= 322.88 TK

Cost Per unit = (Variable cost + Fixed Cost) ÷ Power Output

= (2333.33 + 322.88) ÷ 340.2

= 2656 ÷ 340.2

= 7.807 TK

3.9 Summery

The aim of this project to continue on the feasibility of biogas electricity generation in Banasree housing society, with a specific focus on key objectives:

- To design a model for a scale up biogas electrical plant in Banasree housing society.
- To find 600kw Biogas Generator, Engine modal: 12V190ZLZ to run on biogas power plan, using bio digester, gas storage, and clean-up processes.
- Requirement of electricity in Banasree housing society and how much we produced electrical power using biogas technology.

For the biogas technology of the project, proper use in waste management to produced electrical power.

4. Existing Experience in Different Countries

Germany

The technologies of anaerobic fermentation and electricity generation from the resulting biogas have been well known for a long time. Such plants have been in operation for many years particularly for sanitation purposes. However, power generation from biogas using agricultural feedstock became more common shortly after the introduction of a feed-in tariff. Around 0.11 € per kWh (plus specific bonuses) was the guaranteed base price for plants up to 150 kW (EEG 2009).

In 2009, more than 4,500 biogas power plants were in operation in Germany with more than 1,500 MW installed power capacity. Specific know-how and technological solutions are thus available to a very high standard. However, despite the guaranteed feed-in tariff, the profitability of the plants has not always been guaranteed. With fluctuating prices for feedstock, often especially for plants and grains produced specifically for power generation, the profitability of the plants has varied from year to year.

The size of power plants has grown rapidly over the years. While the average size of a biogas power plant was 60 kW in 1999, it was 300 kW only 10 years later (2009). The reason for this lies in the decreasing specific cost of bigger plants - about 50% lower for a 300kW plant than for a 60kW plant.

Today, the profitability of biogas plants in Germany depends greatly on the potential to sell heat as well as producing electricity. The heat output of combined heat and power (CHP) generators is used to provide hot water for community heating systems for households, schools, public swimming pools etc. Furthermore, special bonuses, such as bonuses paid for the use of renewable raw material (NaWaRo), are also important for the profitable operation of the plants.

Model Number:

Generator Model name is Cummins, Perkins, Googol, CSR [21]

Figure :28 Biogas Generator

4.1 Developing and Newly Industrialized Countries

Millions of biogas plants have been installed all over the world within the last two decades, financed or supported by national and international programmes. It is not possible to give a comprehensive overview of these activities within the context of this paper. However, the following chapter will focus on activities carried out in co-operation or at least in close contact with GTZ as well as selected promising activities that might prove relevant for future approaches.

Since the late seventies, GTZ has launched several projects for the dissemination of biogas technology:

- Bilateral projects with Ethiopia, Cameroon and Lesotho
- The Biogas Dissemination Programme active in Belize, Bolivia, Jamaica, Nicaragua, Burkina Faso, Tanzania, Kenya, Burundi and Thailand
- Special Energy Programmes with Biogas activity in Tanzania, Burundi, Kenya, Ivory Coast, Burkina Faso and Mali.

Most of the plants installed by these programmes were designed for households, hospitals and farmers, mainly using the gas directly as fuel for cooking and lighting. The principal focus of bigger plants constructed for slaughterhouses or similar applications is sanitation.

However, the generation of electricity has also played a role and several pilot plants were installed in the 1980s and 1990s, mostly in the power range 10 kW to 100 kW. Nevertheless, it appears that very few of these plants are still in operation or have worked successfully over the years. Such plants doubtless faced many technical problems as a standard technology for electricity generation from biogas could not be established at the time.

Activity continued, however, and the final conclusions of this paper are based on the following examples of more recent approaches, although it is still very difficult to obtain substantial operational data.

China

China is the world’s leading country in the application of anaerobic biomass digestion technology in quantitative terms. Besides millions of small biogas plants in farms, there are over one thousand bigger plants, many of which use industrial waste from paper, sugar and the pharmaceutical industry as feedstock. The main purpose of these plants is to reduce waste and slurry problems. The gas is used directly for cooking, lighting or heating purposes and only few of the plants installed in China are destined for electricity production - in general big plants - as only those with capacities higher than 0.5 MW are allowed to connect to the grid. However, power generation from biogas has become the focus of support programmes in recent years. A tenfold increase in electricity generation from biogas is planned between 2005 and 2013.

The GTZ Sino-German Project on Optimization of Efficient Biomass Utilization (2009-2013) aims to improve the technical standard and performance of medium and large-scale biogas plants producing energy from biomass. The program me recommends shifting financial support from an investment-oriented to an output-oriented scheme, supported by demonstration projects, policy support and capacity.

Model Number:

Brand Name: SR Model Brand Name: SR Model Number: SR-20/SR100

Figure:29 Biogas generator in china Biogas power plant

Specifications

china biogas power plant to generate electricity

low cost, environment-friendly

use the waste to produce biogas

Figure : 30 Dram size of the Biogas power plant

Table : 1.8 Measurement of the Dram size

Size of the biogas plant :	**6/8/10/12/20/40/50/100 cubic meter**
Thickness of steel plate :	**1.5 mm / 2 mm**
Angle bar :	**5 x5mm and 3 x3mm**

The steel mould is applied to construct the concrete digester of the Chinese hydraulic biogas plant. The assembly is very convenient, and the structure of the mould is firm. It is only one day to build the Chinese hydraulic biogas plant with the steel mould.

Figure: 31 Construction of Biogas dram

The Chinese-type model digester is comprised of a cylindrical body, two spherical domes, inlet pit, out let pit and an inspection opening. the digester is made using cement and bricks and it is a permanent structure. Just as in the Indian digester this has two drains to feed waste and to collect the composted waste.

The biogas is collected in the upper chamber and the waste decomposed in the lower chamber.If the gas pressure exceeds the atmospheric pressure(1bar) and there is no gas extracted from the dome. Then the rot substrate squeezed from the reactor into the filled pipe, but often in the pool of the counterpoise. If the produced gas is more than the up used gas, then the slime level will increase. If the up used gas is more than the produced gas during the gas extraction, then teh slime level will sink and the rot slime will flow back. The volume of the counterpoise pool must be huge so that the represses rot substare can be digested at the hight gas volume, the gas pressure is not constant in the practice. It increases with the quantity of the stored gas. The gas must be regularly produced; Therefore the gas pressure organizer or the swimming gas repository room is important.

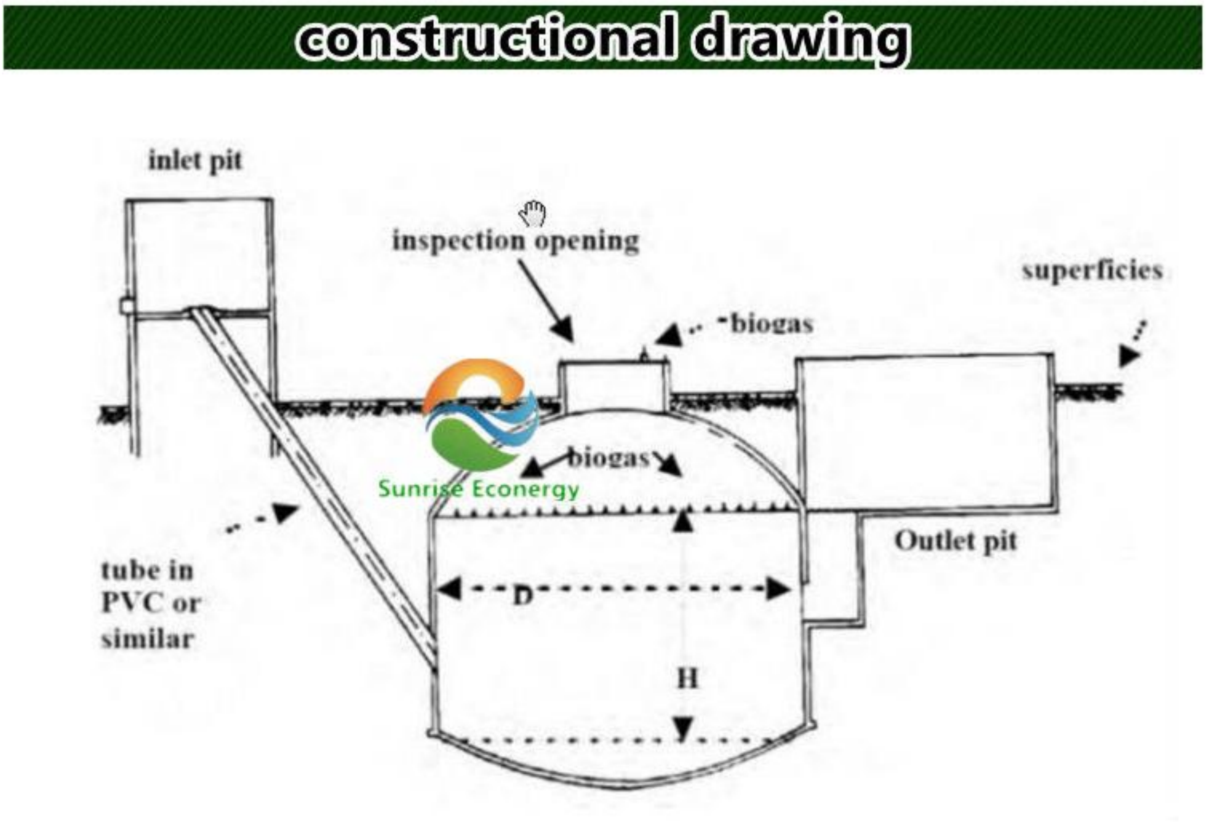

Figure:32 Basic Constructional Drowing

The Chinese-type model digester is comprised of a cylindrical body, two spherical domes, inlet pit, out let pit and an inspection opening. the digester is made using cement and bricks

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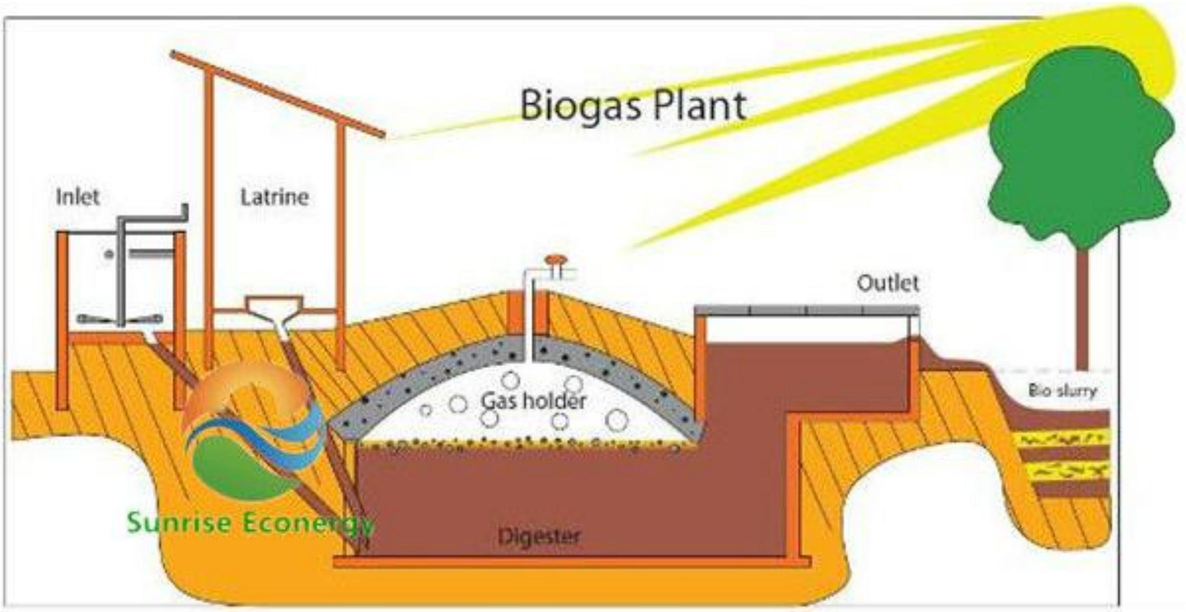

Figure:33 Biogas power plant Design

India

India has extensive experience of biogas plants. Over 1.8 million cattle dung digesters had been installed in India by the mid 1990s. However, around one third of these were inoperative by early 2000 (ESMAP, 2005) and there is little experience of commercial electricity generation at small and medium level.

The GTZ Project Indo-German Energy Program me (IGEN) recently started a rural electrification program me with biogas plants of around 60 k Watt output.

Context

India's annual per capita energy consumption of 0.7 tons of oil-equivalent and its electricity consumption of roughly 835 KWh are less than one seventh of that of developed countries. This creates challenges in all areas of society and in all regions, rural as well as urban. Restricted access to energy, be it for private households, industrial consumers or businesses, limits opportunities for economic development and poverty reduction.

The quality of the energy supply is also an important factor, especially in India. In an energy system characterized by a mismatch between supply and demand, two approaches are seen as vital for future development: 1) exploiting the potential to enhance energy efficiency and reduce losses along the supply chain, thereby optimizing resource use (and reducing costs), and 2) introducing renewable energies, both to supply remote areas, and to help improve the overall supply situation and diversify the energy mix.

The use of energy efficiency measures and renewable energy sources is leading increasingly to the more sustainable management of energy, and contributing to climate protection.

Approach

The Indo-German Energy Program is implemented jointly by GIZ and KfW development bank, in cooperation with their Indian partners. It addresses the challenges described above by supporting energy efficiency improvements and renewable energy generation in rural and urban areas. With regards to energy efficiency, the main focus of the program is on support for implementation of the Energy Conservation Act. The Act involves interventions in many different areas, such as energy-intensive industries, manufacturers of household appliances and industrial equipment, residential households, consulting firms and power stations.

The program was expanded in 2010 to include the renewable energy component, in which GIZ is collaborating with the Indian Ministry of New and Renewable Energy (MNRE) to promote renewable in rural areas. Here, the focus is on developing business models and supporting energy schemes and programs.

The program involves local and international experts in the following specific activities:

Labeling of household appliances and energy-intensive industrial equipment with respect to energy efficiency

Certification of energy managers and energy auditors

Setting norms and standards for energy intensive industries

Transferring and promoting cutting-edge technology to reduce energy consumption

Promoting public-private partnerships to raise awareness of the need to save energy

Developing and piloting innovative business models for rural energy enterprises

Supporting rural energy schemes and programs in Uttarakhand, Bihar, West Bengal, and Uttar Pradesh

Developing the capacities of, and providing support to public and private sector institutions for implementing internationally accepted measures under the Clean Development Mechanism (CDM)

Maintaining one of India's largest websites on this subject

Results achieved so far

Regulations on energy efficiency labeling for various household appliances and energy-intensive equipment are at an advanced stage of implementation.

Approximately 8,000 professionals have completed the necessary examinations for certification as energy managers and auditors.

The private sector now invests over EUR 400 million annually to implement energy efficiency measures; to date, annual energy savings worth about EUR 300 million have been reported as a result of these investments.

28 state designated agencies have been set up, and another seven at the union territory level, which now receive support for the implementation of the Energy Conservation Act. The world's first baseline for calculating the CO2 emission-factor has been prepared and institutionalized for the Indian power grid.

Mapping and performance verification has been carried out for 85 thermal power plants in the public sector, producing an estimate of potential coal savings of 6.92 million tones per year.

A CDM Program me of Activities to introduce improved biomass cooking stoves was registered successfully in 2013. This will provide financial support to future projects promoting clean cooking technologies.

The SELCO Incubation Centre was launched in 2012 to support start-up companies in the rural energy sector. By November 2013, nine solar lighting enterprises had started expanding into rural areas with support from the incubation program me.[23]

Model Number: BF-M1125HV 100kW [24]

Fig:34 Biogas Generator in IGEN

Bangladesh

More than 25,000 biogas plants have been set up in Bangladesh. However, most of them are family-sized and used only for cooking burners. Over 2,000 of these biogas plants have been constructed on poultry farms. In such cases, the main purpose of the plants is not only the generation of gas; the plants are also necessary owing to the bad odor caused by poultry droppings and for other environmental reasons.

Feasibility studies A feasibility study (GTZ-PURE, 2005) with financial analyses of plants with 100–50,000 birds came to the following conclusions:

- Larger farms may opt for electricity production, but selling gas is more profitable
- Selling electricity is economically viable only with the additional sales of at least one of the other two products: gas or fertilizer (assumption: only 50% of the gas is used for electricity generation).

These feasibility findings from 2005 correspond quite well with actual development as evi-denced by the first examples of electricity generation from biogas in poultry farms.

A AS poultry farm The Advance Animal Science Co. Ltd. (AAS), a dairy and poultry farm in Kashimpur of Ga-zipur district, supported by GTZ, has an electricity grid connection but also generates power from biogas using cow dung and chicken droppings as feedstock. In order to generate power, the biogas is passed through a traditional gas generator set with minor mod-ifications.

Only one-third of the plant's capacity is used for electricity generation. According to press this electricity co-generating unit is rendered profitable by the savings involved in reducing the electricity bill. The financial contribution of the by-products, such as bio-fertilizer and the gas provided to some cooking burners in the neighborhood, is obviously consider-able.

From a financial perspective, certain additional effects are not easily measurable: • Enhance-ment of environmental security in the farm area and the removal of bad smells. • Indepen-dence of the erratic power supply from the national grid.

This Advance Animal Co. biogas power plant is the second of its kind, following one from a similar pilot project in Faridpur started two years earlier.

In the wake of these first pilot projects, expectations in Bangladesh are high. AAS estimates that a poultry farm of 5,000 birds could generate 5 kW of electricity. Selling electricity in the neighboring areas seems to be economically viable from an output of 10 kW.

East Africa, Tanzania and Kenya

In Kenya, Tanzania and neighboring countries, biogas is traditionally used in small and very small installations for providing household energy and for supplying social institutions with gas as fuel for cooking, heating and lighting. With GTZ support, over 1,000 small and medium-size plants and one bigger digester of over $100m^3$ have been installed by CARMATEC in Tanzania from 1983 on. However, potentials for industrial biogas and electricity generation in East Africa remain largely untapped.

Hale Sisal Farm, Tanzania In Tanzania a pilot project managed and partly financed by the United Nations Industrial Development Organization (UNIDO) entitled 'Cleaner Integral Utilization of Sisal Waste for Bio-gas and Bio fertilizers' involved a biogas pilot plant with a capacity of 150 k Watt at the Hale Sisal Estate in the Korowai District of Tango region.

According to UNIDO statements, the project showed that sisal residues constitute an efficient substrate for anaerobic digestion, generating gas, electricity, and bio-fertilizer. In 2007, UNIDO announced that the results will be transferred to other interested sisal growing nations for replication.

However, the originally planned second and third phases of plant development were never realized (Practical Action, 2009). This can be seen as an indicator of the plant's potential lack of profitability and confirms the views of experts based in the region that the plant's design seemed ill-adapted to the required sisal operations, and that its substantial operating problems were due to low quality technical components.

Sisal-cum-cattle farm in Kilifi, Kenya The biogas plant with electricity generation on a sisal-cum-cattle farm in Kilifi, Kenya is usually referred to as a positive example. It converts agricultural waste such as cow manure and sisal into biogas and produces electricity and heat as end products. The technology is practically the same as that used in Germany. The plant design seems to be well-adapted to farm operations and has been operational since September 2007. The biogas plant in Kilifi, operated by the Biogas Power Company (EA) Ltd., a joint venture of Kilifi Plantations (KE) and the German companies agriKomp GmbH and Schnell Zündstrahlmotoren AG & Co. KG, was established through a tripartite Public Private Partnership (PPP) with GTZ. According to the publications of the operating organization, the biogas plant in Kilifi is the biggest in Kenya.

The basic technical data of the plant are as follows: • 750 cbm digester; • Inst. capacity: 150 kWat; actual production max. 90 kW, not connected to the grid; • 4 t substrate / day: dung from 200 cattle (40%), sisal waste (60%); • Feedstock available for extension up to 1 MWel if excess electricity could be sold to the grid at a fair tariff; • El. Production cost: 0,16 EUR / kWh (for comparison: grid electricity 0,15-0,18 EUR / kWh).

Framework conditions:

- Frequent power cuts due to technical faults and low capacity
- Companies have to install emergency backup power systems, mostly diesel (costs: 0,25-0,42 €/kWh)
- Kenya: High and fluctuating power costs owing to pass-through of fossil fuel costs (e.g. Kilifi: 0,1575 – 0,185 €/kWh)
- Improvement is likely owing to strong government and private sector efforts, but in the medium term, there remains the persistent risk of power cuts due to the vulnerability of hydro power to drought
- There is currently no biogas-specific regulation in East Africa
- Power production of biogas falls under 'Standardized PPA' (TZ) or 'Feed-in Law' (KE)
- In Kenya, biogas is covered by 'biomass' tariffs, which are too low.

The lessons learnt in Kilifi (Franz, 2009):

- Equipment import: professional agent and close liaison with authorities for clearance of plant equipment required
- Tariffs/grid connection: the need to liaise at a very early stage with the Energy Regulatory Authorities to allow for structured and smooth process
- Local capacities: the need to bring qualified staff and train local staff
- Local manufacture: local manufacturing of pipes, wiring, and civil works should be possible and reduce costs.

PSDA project, Kenya With support of the GTZ Project PSDA, two small biogas power plants were also installed. However electricity generation could be realized only partly:

The original purpose of the plant in Keekonyokie was to deliver electricity for a refrigerating storage house. The storage house was built and the cooling compressor was purchased but the thermal insulation has not yet been installed. In the meantime, the gas generated from slaughterhouse waste is fed into a mini gas grid and supplied to 6 restaurants. The designated generator set consists of an adapted diesel engine for dual fuel use and a generator with 20kWel output. The estimated cost is €0.14/kWh compared to a grid price of €0.16/kWh.

At the Abdul Sidis farm, vegetable residues are used as feedstock and the (off-grid) electricity generated by a 20 kWel genset is mainly used for a water pump. Estimated costs are again around €0.14/kWh compared to diesel-generated electricity at a price of €0.36/kWh. Daily savings are estimated to reach €10.

Both plants seem to work well in technical terms.

‘Rattler Model’ Independent of GTZ activities, the company BME GmbH in Bavaria offers a ‘High Performance, Temperature Controlled (HPTC)’ biogas plant system known as the ‘Rattler Model’. According to company communications, at least 3 of these plants have been installed in Eastern Africa, 3 are under construction and 2 are in concrete planning: • In Kenya in Mombasa (2007), Morang’s, Bombay, Bungoma (8/2009); • Further plants are planned in Dagoretti (KE), in Kigoma, Tanzania, in Zanzibar, Uganda, Ruanda and Madagascar.

Most of these installations were carried out in cooperation with UNIDO. • The plants of this system have a two-stage digestion system, with separate Hydrolysis and acidification mechanization; • It has a controlled temperature of 37°C with insulation and solar heating system. • Due to the design, even high fibrous material can be digested and a high biogas output per m^3 digester volume and day is possible. • The digester and a separate storage are made from plastic bags of a three layer material. • Desulphurization is achieved exclusively through the addition of a little air into the gas storage tank. Owing to the steady fermentation temperature and constant gas production and composition, this method seems to work very well.

A typical HTC plant has a 25 m^3 digester bag, a 20 m^3 biogas storage bag and two 4 m^3 hydrolysis units, a bio filtering system for filtering the hydrolysis gas generated in the hydrolysis unit, a desulphurization pump and a condensation trap.

The first HPTC plants in Africa apparently used diesel engines, replacing up to 80% of the diesel with biogas. In 2009, a 10kWel generator set running only on biogas was developed by modifying a commercially available petrol generator set used on construction sites in Europe.

Most of these plants were set up near slaughterhouses to use the waste and to provide them and neighboring buildings with electricity.

The company calculates the cost of installing the plant at around €30,000, but emphasizes that profitable operation is possible even without special feed-in tariffs in remote areas where electricity generation with small diesel generators is extraordinary expensive. It calculates a payback period of 2.5 years.

However, during discussions with different biogas experts, concerns were raised regarding this expensive model. It remains to be seen whether the higher price for these sophisticated high temperature plants can be compensated for by higher and more stable production.

Feasibility studies in Kenya The planning and construction agency AKUT U mweltschutz in Berlin carried out some feasibility and concept studies for specific biogas plant projects in the agricultural sector of Kenya. All plants were designed to use as much locally available technology and expertise for construction as possible.

<u>The studies carried out between 2006 and 2009 came to the following general conclusions (Burked, 2009):</u>

- Many substrates from typical agricultural production in Kenya can be used for biogas production
- However, the feed-in tariff for electricity that cannot be used in-house is crucial for the economical operation of biogas power plants. Most of the projects are on hold until there are appropriate feed-in tariffs available for the national grid
- In case of exclusive in-house use of electricity, the feasibility studies show that plants can only be operated economically if there is also a profitable use for the thermal energy output of the CHPS. However, in most cases thermal energy demand is insufficient
- Use of slurry is recommended
- Capacity building should be provided for operators.

Key support to the development of the Kenyan biogas sector was earlier provided through GTZ's bilateral Program for **Private Sector Development in Agriculture (PSDA)**. GTZ has recently been commissioned to implement the 'Project Development Program– East Africa' (PDP) on behalf of the German Ministry of Economics and Technology under the 'Renewable Made in Germany' initiative. The program aims to build partnerships between German and East African companies in the field of renewable energy. Biogas has been identified as one of the priority areas. The PPP lessons have now been integrated into the various follow-up activities of this program, and the information presented below has been com-piled in the context of the PDP.

After the positive experience with the pilot plant in Kilifi, investors and government have expressed increasing interest and asked GTZ to make recommendations.

Study on agro-industrial biogas potential, Kenya GTZ commissioned the DBFZ (Detaches Biomasse Forschungs Zentrum) to undertake a study on 'Agro industrial Biogas in Kenya' (GTZ, 2010) examining the theoretical potential of 13 types of biomass from agro-industrial businesses in Kenya to municipal waste in Nairobi. The report concludes that the potential electric capacity of generated biogas is high. Biogas from all examined subsectors could cover up to 16% of the total Kenyan electricity production as of 2007/08.

Municipal solid waste, sisal and coffee production are the most promising sectors with the greatest potential. However, specific electricity production costs for small plants (50kWel) range between 0.11 and 0.29 US$/kWh. A basic feed-in tariff for small plants of about 0.20 US$/kWh was therefore proposed, but the implementation of such a prohibitively high tariff seems unrealistic. It seems probable that only bigger plants with profitability at a lower tariff of around 0.15 US$ will be able to take advantage of this.

Based on the 'hard facts' of this study's recommendations, follow-up is currently taking place under the PDP, focusing on targeted advice and cooperation with policymakers and investors on the tariff framework.

Brazil

Brazil is one of the countries whose biomass energy market is the most advanced. Biofuels are produced from sugar cane and hundreds of power plants use the remaining sugar cane bagasse as fuel. Most of these plants use direct combustion and have capacities for over 1 MW.

However, a number of small and medium sized biogas power plants also exist, mostly installed in agro-industrial settings. The main purpose of these plants (using the waste of a slaughterhouse or animal production facility) is sanitation and environmental protection. The second important benefit is gas and electricity production for in-house use in the companies.

There are probably large numbers of biogas plants in farms or small industries using the gas for individual power generation, as suggested by the provision of a specific biogas motor program by the Brazilian company Branco. It provides small motors, motor pumps and a generator set of 3.6 kW, especially for Biogas use (www.branco.com).

However, hardly any electricity provision from biogas for basic public energy needs has so far been realized. A program for the support of alternative energy resources (PROINFA), designed to feed-in more biomass energy into the national grid, was already approved in Brazil back in 2002. However, implementation met with delays, and only big power plants with direct combustion of the biomass were able to benefit from the program.

Feed-in Agreement in Parana Since 2009, in the southern state of Parana (PR), 5 biogas power plants have become the very first small plants to feed their power into the public grid (Grope, 2009).

These plants, with capacities of 20 – 160 kWel, won a tender to sell their electricity to the public energy provider Copel Distrubuicao SA in the southern Brazilian state of Parana. The feed-in tariff corresponds roughly to 0.05 EUR / kWh (Copel, 2009).

This price is not high enough to guarantee the profitable operation of biogas power plants in Brazil. It is nevertheless an important step forward, as it can help make the plants more profitable. Only the excess electricity is sold at the fixed feed-in tariff.

The GTZ Energy Program (‘Programa Energia’), on behalf of German Federal Ministry of Economic Cooperation and Development, supports the use of renewable energy and energy efficiency in Brazil and hence also the appropriate production and use of biogas. The program aims to improve framework conditions for the sustainable use of biogas, the analysis of experience and know-how transfer between German and Brazilian partners. In October 2009, the GTZ Energy Program entered into a partnership with the public energy utility Eletrosul, subsidiary of Eletrobras, the national electricity provider, focusing on know-how transfer in the field of biogas. Elytrous aims to construct biogas power plants for electricity generation in the South of Brazil.

4.2 Environmental Issues of Biogas Resources

Technologies used to convert organic materials to biogas, such as anaerobic digestion, are not new. Their application is also not widespread. Biogas production involves the biological fermentation of organic materials--agricultural wastes, manures and industrial effluents, municipal solid waste--in an oxygen-deficient environment to produce methane, carbon dioxide, and hydrogen sulfide. The gas can be used directly for combustion in cooking or lighting or indirectly in fuel combustion engines delivering electrical or motor power. The slow diffusion of this technology is a result of initial construction costs, lack of organizational and community involvement, insufficient training opportunities in construction and maintenance, and difficulties in maintaining sufficient and consistent raw material inputs.

According to recent trends, an increase in the production of bio energy crops is occurring. This practice can produce beneficial and adverse environmental impacts. Bio energy crops can re-vegetate barren land, reclaim waterlogged or sainted soils, and stabilize erosion-prone land. They can provide habitats and increase biodiversity if managed properly. However, they may also displace agricultural production, contribute to deforestation, and even introduce invasive, potentially harmful, non-native species.

The operation of a biogas digester presents several potential environmental problems, but these problems can be minimized with proper planning and operation. Special precautions are required, for example, if human or hog wastes are used in digesters. Humans and some animals share similar feces-borne parasites and pathogens. For this reason, some authorities warn about the dangers of raw fecal waste and do not recommend applying sludge to soil where root and vegetable crops are cultivated. To minimize health risks, the digester should be built close to a lavatory or livestock shed so that the excrement may be deposited directly without unnecessary handling.

The disposal of liquid overflow (supernatant) from the digester may occasionally have adverse effects. Normally this liquid is clear and odorless and has some value as a dissolved fertilizer. If water is scarce, the supernatant may be recycled into the digester with new organic feedstock. Otherwise, it can be used to water plants or moisten compost materials. But in an improperly working digester, the supernatant may be dark and offensive. If it is not recycled, this liquid should be buried or mixed with soil in an isolated spot.

As with natural gas, biogas composition should be tested, and precautions taken to prevent leaks and losses. Surveillance is also important, since biogas is usually odorless and difficult to detect. In closed rooms, leaking gas can lead to asphyxiation or explosion.

In areas where manure or dung is a free community resource, the installation of biogas digesters may cause unanticipated social impacts. If manure becomes a valuable commodity, lower income families may no longer be able to afford it. In the initial planning stages, the question of who stands to lose or gain from an energy project deserves careful attention. Community input is important.

Strict air emissions and ash disposal regulations should be followed to avoid the emission of hazardous ash and compounds resulting form the burning of plastics, heavy metals, chemicals and other substances encountered when incinerating municipal solid waste [10].

4.3 Environment Impacts of Bio-Resources

- Increasing the uses of bio-resources for energy would lead to reduce greenhouse gas emission.
- The production of electricity and heat from biogas decrease the CO_2 emission but is not completely free from environment hazards.
- Combustion of bio-resources air pollution, reduce soil erosion and improve soil quality.
- Production of biogas from waste and human manure can be help to waste management.

4.4 Environmental friendly solution

In contrast to fossil fuels, burning biogas only releases the amount of atmospheric CO_2 that was stored in the plant during its growth. Thus, the carbon cycle of biogas is closed. For that reason, utilization of biogas reduces CO_2 emissions and helps to avoid an increase of the CO_2 concentration in the atmosphere, which helps fighting global warming. Furthermore other GHG emissions, such as methane and nitrous oxide from untreated manure, are reduced. In general GHG saving due to biogas utilization can be arisen by:

Manure management:
Potential emissions saved due to CH_4 utilization of animal manure and slurry.

Substitution effect:
Emission saved due to electricity and heat (cogeneration) produced from biogas

Replacement of fossil fertilizers:
Emission saved due to replacement of mineral fertilizers with digestive Livestock production can result in methane (CH_4) emissions from enteric fermentation and both CH_4 and nitrous oxide (N_2O) emissions from livestock manure management. In many countries large livestock populations play an important source of GHG emissions.

Biogas production by AD results with forming of digestive, which replaces utilization of raw manure as fertilizer. Due to the fact that digestive has better fertilizer efficiency than raw animal manure, additional substitution of mineral fertilizers occurs. This results in GHG savings due to reduced production of mineral fertilizers.

4.5 ENVIRONMENTAL BENEFITS

Since the influent to the holding pond will have undergone complete digestion. Another environmental benefit from using biogas as an energy resource is that there is no net production of greenhouse gases. The carbon dioxide released during biogas combustion originally was organic plant material and so is just completing a cycle from atmosphere to plan to animal and back to the atmosphere. Methane is a more severe greenhouse gas than carbon dioxide and capture of biogas as a fuel prevents the release of methane into the atmosphere. Land application of solids and anaerobic lagoon treatment of liquid wastes releases a substantial amount of methane to the atmosphere. Capture of the methane for use as a fuel would significantly reduce the net greenhouse gas production from CAFOs[11].

4.6 Advantages and disadvantages of biogas

Anaerobic digestion process for biogas production has several advantages which make it a widely applicable technology:

- The produced Biogas can be used for several applications, such as heating, lighting, and for generating electricity
- Biogas plant is technically reliable and the technology has been considerably improved
- A method to treat organic waste from industry and household in an environmentally friendly way, where the residuals are reused in the farmlands as good quality fertilizers.
- A high degree of reduction in organic matter is achieved with a small increase in the bacterial biomass[12].
- Helps mitigate climate change by preventing methane and others Green- House Gas GHG from being released to the air.
- Reduces water pollution by using feedstock that would end up in rivers and lakes. As well reduce N-eutrophication of ground water.
- Economically viable when there is a regular supply of cattle dung and organic waste.
- Requires a small area compared to the disposal of municipal solid waste (e.g. disposal of waste in Landfill).
- Improve hygienic conditions.
- Reduces the annoyance caused by odors from manure.
- The residual sludge applicable as animal fodder or as fertilizer

In the other hand, this technology is still suffering from technical and economical obstacles, which are limiting its use as an energy source. The main disadvantages of using biogas technology are:

- The constructions of digesters are costly because they should be built to high structural standards in order to avoid cracking, leaking, and corrosion.
- Transportation of biomass is also costly especially for large-scale biogas plants and it contributes significantly to the total cost of energy produced from biogas.
- Corrosive impurities and a lower heating value, compared to natural gas, make biogas unsuitable to be compressed or injected into a pipeline system.
- The effluent biogas contains a small percent of carbon dioxide, water vapor, and hydrogen supplied. This decrease its efficiency and thereby its economical benefit.
- Cost reduction potential of biogas is low [13].

The dung from animals is an important source for fertilization. This type of biomass can be used in digester in case the residuals (slurry) from the digester were returned to the field. Slurry is reach with minerals and can be used as fertilizers instead of animal's dung. Dung may contain some viruses; therefore direct use of dung as fertilizer will have a potential risk of transferring diseases through plants to human. Hence, anaerobic treatment of dung before using it as fertilizer in form of slurry (the residuals from anaerobic digester) has advantage of reducing the risk of potential viruses and pathogens.

4.7 Summery

The environmental impacts of biogas utilization for energy and municipal waste are quite significant, and are arguably greater in scale and scope than any other class of energy resources-renewable or non-renewable. However, bio-energy production systems also need to be adapted to local conditions to avoid generating environmental problems. The environmental impacts of biomass energy are as following:

- Biogas contains little sulfur and nitrogen, so it does not produce the pollutants that can cause acid rain.
- The production of electricity and heat from biogas helps decrease the CO_2 emissions producing energy from the release of methane into the atmosphere from decomposition of unused human manure and wastes.
- When the fuel burn then greenhouse gases made which pollute the environment.

Chapter 05

5. Economics of Biogas Energy

An ideal plant should be as low-cost as possible in terms of the production cost per unit volume of biogas both to the user as well as to the society. At present, with subsidy, the cost of a plant to the society is higher than to an individual user.
The objectives of this research are:

- To show that the amount of biogas produced is worth to be used as a renewable energy for houses in Banasree housing society
- Determination of the feasibility of utilization such digesters in Banasree housing society and investigating their dissemination possibilities.
- Support and encourage this technology to be used in Banasree housing society especially it belongs to agricultural sector and power.
- Reducing the release of pollutant emissions.
- Disposal of human manure and waste by using it in an appropriate way instead of human manure and waste accumulation which makes environmental and health hazardous.

5.1 Economic Analysis

Some of the benefits and cost of biogas plants are not limited to the users. For example, if a large number of biogas plants are installed in a community, the non-users will also be benefited due to a cleaner community and conservation of forest in the area. Such benefits and costs that accrue even outside of the user's household is a subject matter of economic analysis. A single biogas plant does not significantly affect the economy as a whole. Therefore, economic analysis may not be relevant for a single plant but is of an immense importance at the community program level where the impact of the program on the economy is assessed.
In analyzing the economic viability of biogas program some intangible benefits like environmental impacts such as protection of forest, land-productivity improvement, reduction in carbon emissions etc; reduction in smoke-borne diseases and improvement in general health; improvement in economic condition due to employment opportunities and proper use of saved time; increased yield of crop with the use of nutrient-rich bio-slurry; social prestige and satisfaction etc. should be valued. Difficulties involves in identifying all these items of benefits and adjusting their market prices to reflect social preferences have been the major limitation of the economic analysis. The situation requires some level of generalization, simplifications, and even some restrictive assumption.

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

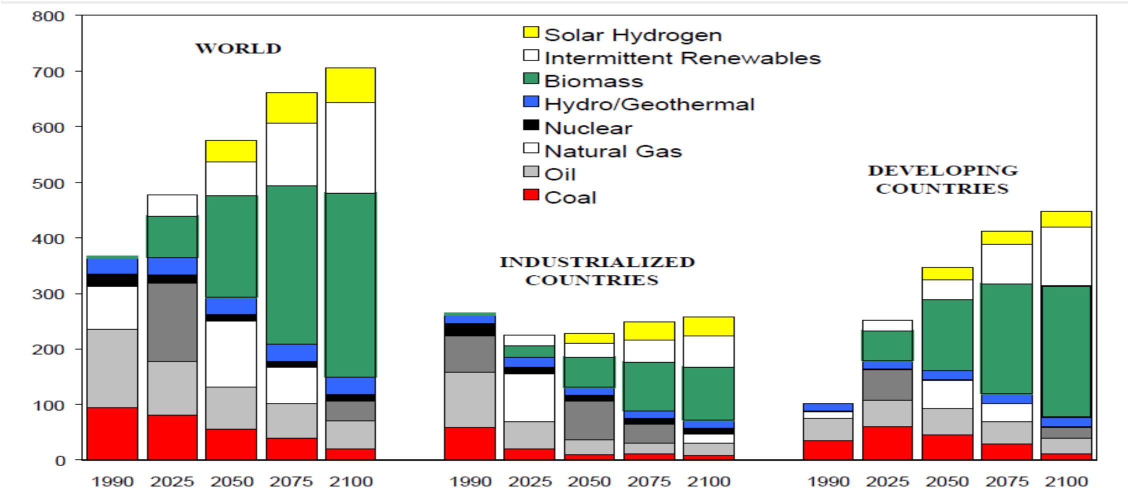

Figure: 35. Primary commercial energy use by source for the biomass-intensive variant of the shown for the world countries[18].

5.2 Socio economic issues

Biogas production has many social benefits and most of these are related to job creation and rural development. Especially in agricultural rural regions and small to medium size decentralized biogas systems, may have considerable advantages, such as:

- The development of a biogas sector stimulates the establishment of new enterprises, which will increase the income and give more job opportunities, but also will increase the economic growth of the area. Biogas can contribute to revitalize rural areas by making them attractive for facility manufacturers, investors and entrepreneurs.

- As biogas can generate electricity and heat and work as a substitute for vehicle fuel, its utilization contributes to reducing the dependency on fossil fuels, but also to energy diversification, security, competitiveness and sustainable supply.

- Biogas production and utilization influences the socio-economic structure in rural areas. Improves the social cohesion of the local population

5.3 Summary

There are economic benefits from the biogas based on housing society, medium industrial activities such as electricity generation, erosion control, and for the production of fuels, house hold waste, and green or renewable chemicals [16]. Generally, the overall economic impact of the biogas-based housing society was found to be significant. Economic benefits were favorable not only on the provincial or regional level but also to the national economy as a whole. The main economical impacts of biogas energy are as following [14, 15]:

- Waste, human manure and other types of biogas are widely used as fuels in the private and housing sectors, basically because they are cheaper than other fuels.
- The use of local biogas can save substantial amounts of foreign exchange.
- Overall, price increases in the long term will be moderate at worst

5.4 Finding

The findings of this study may have potential significance regarding scale up power generation in Banasree housing society, using biogas plants.

- Biogas technology is design of power generation with renewable energy resources.
- 1MW power can produced using unused material (human manure & house hold waste) and properly waste management.
- It is estimated that producing 1 MW of renewable energy is approximately equivalent to reducing 0.65 tones of CO_2 emissions.

Biogas technology is new in Bangladesh so many researches and practical studies have to be done to improve it, and then try to apply other uses of biogas as producing electricity energy.

Conclusion

Biogas technology has significant potential to mitigate several problems related to ecological imbalance, minimizing crucial fuel demand, improving hygiene and health, and thus, resulting in an overall improvement in the quality of life in rural, urban areas and semi-urban areas. From the study of this project it may conclude that biogas is one of the promising renewable energy resources because of following reasons:

- Biogas is a profitable alternative energy resource which is available throughout the world.
- The technologies required for biogas are affordable but their success depends largely on the availability of implementation.
- Biogas power generating cost comparatively low but installation cost is lower than the other renewable energy resources.
- The production of electricity and heat from biogas resources decrease the CO2 emissions but it is not completely free from environmental hazards.

Although it works as carbon dioxide absorber, on the other hand, solar power and wind power are very friendly to the environment but require considerable financing and involve fairly complex technologies.

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