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Introduction To Biogas & Applications

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Abstract
Biomass is a scientific term for living matter, more specifically any organic matter that has been derived from plants as a result of the photosynthetic conversion process. The word biomass is also used to denote the products derived from living organisms – wood from trees, harvested grasses, plant parts, and residues such as stems and leaves, as well as aquatic plants. The solid biomass processing facility may also generate process heat and electric power. As more efficient bioenergy technologies are developed, fossil fuel inputs will be reduced; biomass and its by-products can also be used as sources for fuelling many energy needs. The energy value of biomass from plant matter originally comes from solar energy through the process known as photosynthesis. In nature, all biomass ultimately decomposes to its elementary molecules with the release of heat. During conversion processes such as combustion, biomass releases its energy, often in the form of heat, and the carbon is re-oxidised to carbon dioxide to replace that which was absorbed while the plant was growing. Essentially the use of biomass for energy is the reversal of photosynthesis.

Keywords
Biogas, Biomass, Slurry, Anaerobic Digestion Digester.

Introduction
Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source and in many cases exerts a very small carbon footprint.
Biogas can be produced by anaerobic digestion with anaerobic organisms, which digest material inside a closed system, or fermentation of biodegradable materials.[1]
Biogas is primarily methane and carbon dioxide and may have small amounts of hydrogen sulphide moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat.[2]
Biogas can be compressed, the same way natural gas is compressed to CNG, and used to power motor vehicles. In the UK, for example, biogas is estimated to have the potential to replace around 17% of vehicle fuel. It qualifies for renewable energy subsidies in some parts of the world. Biogas can be cleaned and upgraded to natural gas standards, when it becomes bio-methane. Biogas is considered to be a renewable resource because its production-and-use cycle is continuous, and it generates no net carbon dioxide. Organic material grows, is converted and used and then regrows in a continually repeating cycle. From a carbon perspective, as much carbon dioxide is absorbed from the atmosphere in the growth of the primary bio-resource as is released when the material is ultimately converted to energy.

BIOMASS : Biomass is **organic matter** derived from living, or recently living organisms.
Biomass can be used as a source of energy and it most often refers to plants or plant-based materials which are not used for food or feed, and are specifically called **lignocellulosic biomass (Plant Dry Matter).**
As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: thermal, chemical, and biochemical methods.

Biomass Sources
Historically, humans have harnessed biomass-derived energy since the time when people began burning wood to make fire.
Even today, biomass is the only source of fuel for domestic use in many developing countries. Biomass is all biologically-produced matter based in carbon, hydrogen and oxygen. The estimated biomass production in the world is 104.9 pentagrams (104.9 * 10^{15} g - about 105 billion metric tons) of carbon per year, about half in the ocean and half on land.
<u>**Examples**</u>: forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste.

- . Wood energy is derived by using lignocellulosic biomass (second-generation biofuel) as fuel. Harvested wood may be used directly as a fuel or collected from wood waste streams to be processed intopellet (or other forms of fuels say pellet guns). The largest source of energy from wood is **pulping liquor or "black liquor,"** a waste product from processes of the pulp, paper and paperboard industry.
- In the second sense, biomass includes plant or animal matter that can be converted into fibres or other industrial chemicals, including bio fuels. Industrial biomass can be grown from numerous types of plants.

<u>**Examples:**</u> Miscanthus, switchgrass, hemp, corn, poplar, willow, sorghum, sugarcane, bamboo, and a variety of tree species, ranging from eucalyptus to oil palm (palm oil).

Typical composition of biogas	
Compound	%
Methane	50–75
Carbon dioxide	25–50
Nitrogen	0–10
Hydrogen	0–1
Hydrogen sulphide	0–3
Oxygen	0–0.5
Source: *www.kolumbus.fi, 2007*	

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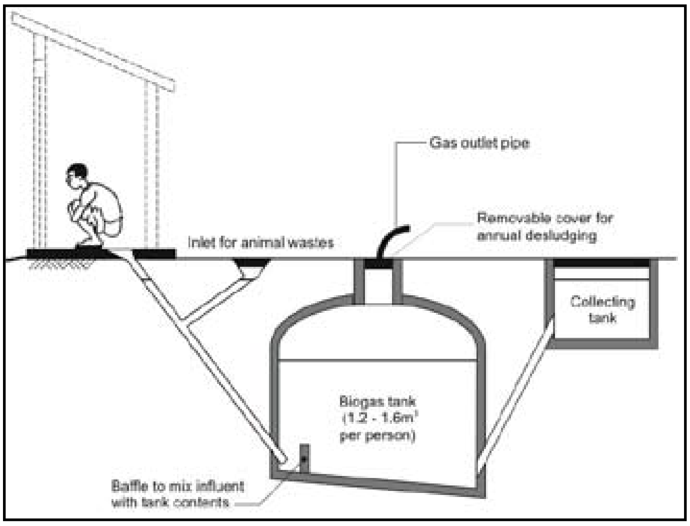
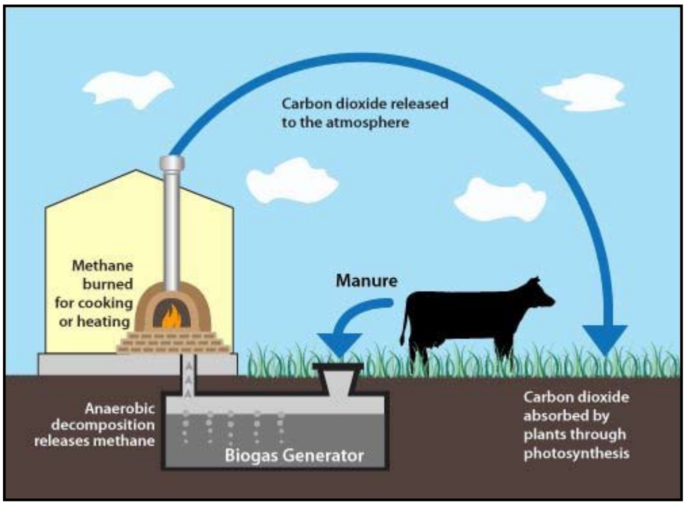
Biogas Generation:

Traditional Method

Today, there are several different techniques for producing biogas and several models and designs of biogas machines and plants now exist. Nevertheless, the concept remains simple and the same.
The heart of any biogas system or production arrangement is known as a biodigester (or simply a 'digester').
A digester is a sealed and airtight tank or container (usually made of concrete or plastic) that behaves like the stomach of a human being. It collects waste (raw materials) and 'digests' it with the help of billions of bacteria.
Like I mentioned above, for biogas to be produced, this digestion must happen in the absence of oxygen (scientifically known as 'anaerobic digestion'). The valuable by product of this digestion process is methane, the cooking gas that we so desperately need.
The methane gas that is produced usually rises and builds up at the top of the digester. A gas pipe is attached to the top of the digester to carry the produced gas back into the house (usually the kitchen) where it is used as fuel for cooking and heating.

The images below provide a visual representation of biogas production and how it works.





Other parts of a biogas system include a feeder pipe, through which the waste materials (from the toilet, kitchen and other sources) enter the digester. There is also an overflow pipe or tank that ensures that the pressure inside the digester remains within safe limits.
The final other interesting part of a biogas plant is an outlet or collection pipe for the solid and liquid residue that is left behind after the digestion process.
This residue (also known as 'slurry') is commonly referred to as a **'biofertilizer'** because it is very rich in nitrogen and phosphorus which makes it a good manure/fertilizer for your garden or small farm.
Biogas production has a long life span. A small scale biogas production plant in your backyard can last for up to 20 years and will require little maintenance during its life time.

Modern Technology

Biogas is the gas resulting from an anaerobic digestion process. A biogas plant can convert animal manure, green plants, waste from agro industry and slaughterhouses into combustible gas. Biogas can be used in similar ways as natural gas in gas stoves, lamps or as fuel for engines. It consists of 50-75% methane, 25-45% carbon dioxide, 2-8% water vapour and traces of O2 N2, NH3 H2 H2S. Compare this with natural gas, which contains 80 to 90% methane. The energy content of the gas depends mainly on its methane content. High methane content is therefore desirable. A certain carbon dioxide and water vapour content is unavoidable, but **sulphur content must be minimised** - particularly for use in engines.
The average calorific value of biogas is about 21-23.5 MJ/m³, so that 1 m³ of biogas corresponds to 0.5-0.6 l diesel fuel or about 6 kWh (FNR, 2009).
The biogas yield of a plant depends not only on the type of feedstock, but also on the plant design, fermentation temperature and retention time. Maize silage for example - a common feedstock in Germany - yields about 8 times more biogas per ton than cow manure. In Germany, cow manure and energy crops are the main forms of feedstock. About 2 live-stock units (corresponding to about 2 cows or 12 rearing pigs) plus 1 ha of maize and grass are expected to yield a constant output of about 2 kW.
In the South Asian context, ESMAP uses a typical specific input-output relation of about 14 kg of fresh cattle dung (the approximate production of one cow on one day) plus 0.06 l diesel fuel to produce 1kWh electricity.

Gas Production Figures : If the daily amount of available dung (fresh weight) is known, gas production per day in warm tropical countries will approximately correspond to the following values:

- 1 kg cattle dung 40 litres biogas
- 1 kg buffalo dung 30 litres biogas
- 1 kg pig dung 60 litres biogas
- 1 kg chicken droppings 70 litres biogas

If the live weight of all animals whose dung is put into the biogas plant is known, the daily gas production will correspond approximately to the following values:

- cattle, buffalo and chicken: 1,5 litres biogas per day per 1 kg live weight
- pigs, humans: 30 litres biogas per day per 1 kg weight

Some Additional Facts :

- Each kilogram of biodegradable material yields 0.4 m³(400 litres) of gas.
- Gas lights consume around 0.1m³(100 litres) of gas in one

hour.

Conversion to Electricity

Theoretically, biogas can be converted directly into electricity by using a fuel cell. However, this process requires very clean gas and expensive fuel cells. Therefore, this option is still a matter for research and is not currently a practical option. The conversion of biogas to electric power by a generator set is much more practical. In contrast to natural gas, biogas is characterized by a high knock resistance and hence can be used in combustion motors with high compression rates.

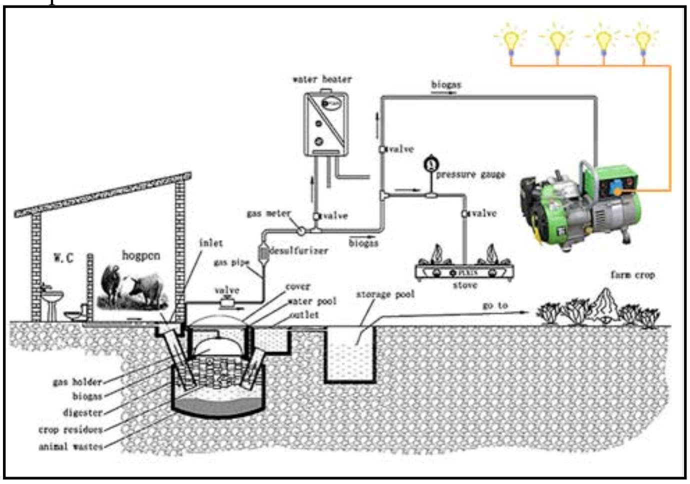


Fig: Schematic of a biogas plant used for power generation

- In most cases, biogas is used as fuel for combustion engines, which convert it to mechanical energy, powering an electric generator to produce electricity.
- The design of an electric generator is similar to the design of an electric motor. Most generators produce alternating AC electricity; they are therefore also called alternators or dynamos.
- Appropriate electric generators are available in virtually all countries and in all sizes. The technology is well known and maintenance is simple. In most cases, even universally available 3-phase electric motors can be converted into generators.
- Technologically far more challenging is the first stage of the generator set: the combustion engine using the biogas as fuel. In theory, biogas can be used as fuel in nearly all types of combustion engines, such as gas engines (Otto motor), diesel engines, gas turbines and Stirling motors etc.

Appropriate combustion Engine

External Combustion Engines (EC Engines)

- **Stirling Motors:** In such motors, biogas is combusted externally, which in turn heats the Stirling motor through a heat exchanger. The gas in the Stirling motor hence expands and thereby moves the mechanism of the engine. The resulting work is used to generate electricity. Stirling motors have the advantage of being tolerant of fuel composition and quality. They are, however, relatively expensive and characterised by low efficiency. Their use is therefore limited to a number of very specific applications.

In most commercially run biogas power plants today, internal combustion motors have become the standard technology either as gas or diesel motors.

Internal Combustion Engines

- **Diesel Engines** operate on biogas only in dual fuel mode. To facilitate the ignition of the biogas, a small amount of ignition gas is injected together with the biogas. Modern pilot injection gas engines need about 2% additional ignition oil. Almost every diesel engine can be converted into a pilot injection gas engine. These motors running in dual fuel mode have the advantage that they can also use gas with low heating value. But in that case, they consume a considerable amount of diesel. Up to engine sizes of about 200kW the pilot injection engines seem to have advantages against gas motors due to slightly higher efficiency (3-4% higher) and lower investment costs.
- **Gas Motors** with spark ignition (Otto system) can operate on biogas alone. In practice, a small amount of petrol (gasoline) is often used to start the engine.
- This technology is used for very small generator sets (~ 0.5-10 kW) as well as for large power plants. Especially in Germany, these engines have advantages as they do not need additional fossil fuels that would lead to lower feed-in tariffs according to the Renewable Energy Law (EEG).
- **Gas Turbines** are occasionally used as biogas engines especially in the US. They are very small and can meet the strict exhaust emissions requirements of the California Air Resources Board (CARB) for operation on landfill and digester gases. Small biogas turbines with power outputs of 30-75 kW are available in the market. However, they are rarely used for small-scale applications in developing countries. They are expensive and due to their spinning at very high speeds and the high operating temperatures, the design and manufacturing of gas turbines is a challenging issue from both the engineering and material point of view. Maintenance of such a turbine is very different from well-known maintenance of a truck engine and therefore requires specific skills.

Today, experience of the use of combustion motors to produce electricity from biogas is extensive; this can be regarded as a proven standard technology. Over 4,000 biogas plants with internal combustion motors are in operation in Germany.

However, it has taken lengthy and determined effort to make this technology as durable and reliable as it is today. Internal combustion motors have high requirements in terms of fuel quality. Harmful components - especially hydrogen sulphide in the gas can shorten the lifetime of a motor considerably and cause serious damage.

<u>This must be addressed in two ways :</u>

- Production of clean biogas; and
- Use of appropriate and robust motors and components.

In theory, most engines originally intended for cars, trucks, ships or stationary use can run on biogas as fuel and are available almost everywhere within a power range between 10 and 500 kW. This holds true especially in the case of dual fuel use. Robust engines with a certain sulphur resistance are mostly free of non-ferrous metal as these materials are highly prone to damage through sulphur-rich biogas.

Appropriate Gas Quality

For use in gas or diesel engines, the gas must fulfil certain requirements :

- The methane content should be as high as possible as this is

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the main combustible part of the gas;

- The water vapour and CO2 content should be as low as possible, mainly because they lead to a low calorific value of the gas;
- The sulphur content in particular, mainly in form of H2S, must be low, as it is converted to corrosion-causing acids by condensation and combustion.

The **water vapour** content can be reduced by condensation in the gas storage or on the way to the engine.

The reduction of the **hydrogen sulphide (H2S)** content in the biogas can be addressed via a range of technical methods. These can be classified as chemical, biological, or physical and divided into internal and external methods. Much experimentation has been carried out in the last two decades.

However, as complete elimination is unnecessary for use in robust engines, the following simple methods have generally established themselves as standard :

- An **optimised steady fermentation process** with continuous availability of appropriate feedstock is important to produce a gas of homogenous quality.
- The **injection of a small amount of oxygen** (air) into the headspace of the storage fermenter leads to oxidation of H2S by microorganisms and hence the elimination of a considerable part of the sulphur from the gaseous phase. This is the most frequently used method for desulphurisation. It is cheap and can eliminate up to 95% of the sulphur content in the biogas. However, the right proportioning of air still seems to be a challenge.
- Another option is **external chemical treatment in a filter**. The active material may be:
  - 1. Iron-hydroxide: Fe (OH)2 + H2S -> FeS + 2 H2O. This process is reversible and the filter can be regenerated by adding oxygen. Adsorption material may be iron-rich soils, waste material from steel or aluminium production ;
  - 2. Activated carbon: Certain companies provide activated carbon filters as a standard component in their gensets.

Standard quality sulphur filters and filter material can be purchased on the market.

Energy Requirement For Heating The Slurry

Energy required for heating the slurry in digester can be calculated by using the formulae below.

$Q_T = m \times c \times (T_2 - T_1)$ - equation 1

Where

Q_T is the total heat (Energy required for heating the slurry) and is expressed in Kilo-joule (Kj).

m is the mass of the slurry and is expressed in Kilo-gram(Kg).

c is the specific heat of slurry and is expressed in Kj/Kg°C.

T_2 is the desired temperature of slurry and is expressed in °C.

T_1 is the current temperature of slurry and is expressed in °C.

mass of slurry = volume of digester (V) × density of slurry(ρ) and is expressed in Kg. - equation 2

Where V is the volume of digester, expressed in m^3 and ρ is the density of slurry, expressed in Kg/m^3 .

Density of slurry (ρ) = density of water + density of cow dung - equation 3

Density of water is 1000 Kg/m^3

Density of cow dung is 0.13 Kg/m^3

Putting these values in equation 2

Density of slurry (ρ) = (1000+0.13) $Kgm^{-3}/2 \approx 500\ Kg/m^3$

From equation 1 we can get the mass of slurry by multiplying volume of digester with density of slurry calculated above.

Specific heat of slurry = {specific heat of water (4.2Kj/Kg°c) + specific heat of cow dung (2.8Kj/Kg°c)}/2

= 3.5Kg/Kg°c

Putting these values in equation one we can know the energy required for heating the slurry. The unit of energy is Kj(Kilo joule)

Favourable Temperature For Methane Generation

The time period for which material can be kept in digester depends on the temperature of the digester. 50°c is needed for holding the material (slurry/organic waste) for 2 weeks while at 15°c temperature it can be prolonged for 2 months. Average is around 1 month. Gauge the Amount of material kept in the digester per day and then multiply by 30 to calculate the size of digester.

Anaerobic digestion occurs in the temperature range of 0°c to 65°c. The optimum temperature for methane production is 29°c to 35°c as in this range microbial activity takes place. Little gas production occurs below 16°c.

Technical Aspects

There is mature, reliable high quality technology available on the global market. The techno-logical difficulties with which small biogas plants were confronted two decades ago have been resolved.

Different methods of desulphurisation have been successfully established and combustion motors tolerant to biogas that have proven their durability are available in the market. Sufficient know-how for planning and constructing reliable biogas power plants is also available.

Germany is one of the leading countries in terms of high quality components and know-how required for electricity-generating biogas plants. Know-how and technical components are also available in China, Thailand and other Asian countries as well as in Brazil. Electricity generation from biogas in Africa is still limited to a few pilot plants, with Kenya apparently being one of the centres of development and experience. For the construction of efficient and reliable biogas power plants, at least some technical core components must be imported from industrialised countries.

The electricity generation component of a biogas power plant does not require much more know-how and effort for maintenance than a normal generator set for fossil fuels with a well-functioning biogas fermentation process as an indispensable prerequisite.

Case Study

Case Study of Kakadpana Test Maharashtra

The trial run of Gasifier in Kakadpana test project in Nasik District of Maharashtra was started on 13th April, 2011. One Gasifier of 10 kW capacity has been installed and commissioned fully in the project on 16th April, 2011. Kakadpana hamlet consists of 85 households and has Warli ST Population, which is known for warli painting. The hamlet is situated at a distance of about 110 Kms from District Headquarter and 40 Kms. from Block Headquarter Trimbakeshwar. The village is surrounded by thin Forest. This project has been implemented by Gomukh, Environmental Trust for Sustainable Development, Pune and Maharashtra Energy Development Agency (MEDA) has been the monitoring & coordinating agency for this project. The biomass gasifier meets the daily requirement of domestic lighting in 85 households, street lighting and other entertainment activities. Each household has been provided with two light points and one power point for domestic lighting and entertainment. With the introduction of electricity, the lifestyle of the villagers has been changed. The smile on the faces of the villagers can be seen clearly and indicates that their distant dream of light is fulfilled so easily and become true, which they never expected in this life. They now started working late in the evening, especially women folk and also go to bed very late at night, which resulted increase in their income. The students are also started studying during night. The electricity is being provided in the village for 6-7 hrs. everyday i.e. from 7.00 PM to 2.00 AM at night. The GOMUKH, NGO is now planning to dig a bore well in the village to solve their drinking water, as well as partial irrigational problem, which is at present acute in the village. On the demand of villagers, GOMUKH is also planning to construct a Community Hall in the village and place a Colour Television, so that the maximum no. of villagers may be benefited and watch the useful programmes of their interest, including National News. The fear of wild animals has reduced, as 10 street lights have been installed in the village, which provide adequate illumination during night. This has brought a sea change in their outlook towards development of their village. The villagers have decided to use the power generated for many other applications, such as, flour mill, chafe/fodder cutter machines and water pumps. 2 Nos. of biogas plants are also being installed in the village for meeting out their cooking requirements. The VEC has undertaken plantation of Karanj & fuel wood in 5 hectare land, which would provide biomass for running the gasifier.

Cost Estimation

Exact estimations for the construction and operation of biogas plants serve the following purposes[1]:

- to compare the costs of alternative models (optimal project selection)
- for the information of the users as far as future financial burdens are concerned
- the calculation of financing needs including public subsidies (budget planning)

As far as costs are concerned there are three major categories:

- Production costs
- Running costs
- Capital costs

Production Costs

The production costs include all expenses and lost income which are necessary for the construction of the plant e.g.: the land, excavation-work, construction of the digester and gas-holder, the piping system, the gas utilization system, the dung storage system and other buildings. The construction costs comprise wages and material.

The production costs of biogas plants are determined by the following factors

- purchasing costs or opportunity costs for land which is needed for the biogas plant and slurry storage;
- model of the biogas plant;
- size and dimensioning of the biogas unit
- amount and prices of material
- labour input and wages
- The degree of participation of the future biogas user and his opportunity costs for labour.

Calculating total production cost

To gain a rough idea of the typical costs of a simple, unheated biogas plant, the following figures can be used: total cost for a biogas plant, including all essential installations but not including land, is between 50-75 US Dollar per m^3 capacity. 35 - 40% of the total costs are for the digester.

The specific cost of gas production in community plants or large plants is generally lower compared with small family plants. The cost for the gas distribution (mainly piping) usually increases with the size of the plant. For communal plants with several end-users of biogas, the piping costs are high and compensate the digression by 'economics of size' partly or wholly. In regions where plant heating is necessary, large-scale plants would be more economical.

To keep the construction costs low, labour provided by the future biogas users is desirable. Often, the whole excavation work is done without hired labour. On the whole, a reduction of up to 15% of the wages can be effected by user-labour. If periods of low farm activities are chosen for the construction of the biogas plant, opportunity costs for labour can be kept low.

Running Costs

The operation and maintenance costs consist of wage and material cost for

- acquisition (purchase, collection and transportation) of the substrate;
- water supply for cleaning the stable and mixing the substrate;
- feeding and operating of the plant;
- supervision, maintenance and repair of the plant;
- storage and disposal of the slurry;
- gas distribution and utilization;
- Administration.

The running costs of a biogas plant with a professional management are just as important as the construction costs, for example for operation, maintenance, expenses for painting, service and repair.

Large-scale biogas plants have high water consumption. Investigations are necessary, if the water quantity required causes additional costs in the long run. These could be construction costs for water piping or fees for public water supply. The question of water rights has to be clarified. Steps to be taken to cover the demand for water during dry periods require thorough planning.

Lifetime of Plants

In calculating the depreciation, the economic life-span of plants can be taken as 15 years, provided maintenance and repair are carried out regularly. Certain parts of the plant have to be replaced after 8 - 10 years, e.g. a steel gas holder. The steel parts need to be repainted every year or every second year. As a rule, real prices and interest rates should be used in the calculations. For cost calculation inflation rates are irrelevant as long as construction costs refer to one point of time. However, in calculating the cash reserves put aside for servicing and repair the inflation rate must be considered.

Average Cost of a Biogas Plant

The cost per cubic meter of digester volume decreases as volume rises. Therefore, the appropriate size of the biogas plant should be estimated.

For simple, unheated plants in tropical countries, the digester

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size is roughly

- 12 to 20-fold the quantity of substrate put in daily at average expected digester temperatures over 25°C and
- 18 to 25-fold the quantity of daily feeding for temperature between 20 and 25°C.

Since the final method of construction is only determined during the first years of a biogas project, it is impossible to exactly calculate the building costs ahead of the actual implementation. The **GTZ** computer program called "**BioCalc**" (produced by Bio System), can only provide an idea as it is based on only one type of plant.

Consequently, the following system is sufficient for a rough calculation:

- the cost of 6.5 sacks of cement x m^3 digester volume plus
- the cost of 5 days work for a mason x m^3 digester volume plus
- the costs of 100 m gas pipes (1/2"), plus
- the costs of two ball valves (1/2"), plus
- the cost of gas appliances which are feasible for this size.

The individual prices are to be determined for the project location. The sum then includes material and wages. The distance from the biogas plant to the point of gas consumption was assumed as being 25 m (the 100 m used in the calculation include costs for connectors and wages). Where greater distances are involved, the cost for gas pipes will have to be increased in proportion.

Benefits of Biogas Technology

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

- production of energy (heat, light, electricity);
- transformation of organic waste into high quality fertilizer;
- reduction of volume of disposed waste products;
- improvement of hygienic conditions through reduction of pathogens, worm eggs and flies;
- encouragement of better sanitation;
- reduction of workload, mainly for women, in firewood collection and cooking.
- environmental advantages through protection of soil, water, air and woody vegetation;
- micro-economical benefits through energy and fertilizer substitution, additional income sources and increasing yields of animal husbandry and agriculture;
- macro-economical benefits through decentralized energy generation, import substitution and environmental protection

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

Usage Of Waste

In developing countries, there is a direct link between the problem of fertilization and progressive deforestation due to high demand for firewood. In many rural areas, most of the inhabitants are dependant on dung and organic residue as fuel for cooking and heating. Such is the case, for example, in the treeless regions of India (Ganges plains, central highlands), Nepal and other countries of Asia, as well as in the Andes Mountains of South America and wide expanses of the African Continent. According to data published by the FAO, some 78 million tons of cow dung and 39 million tons of photogenic waste were burned in India alone in 1970. That amounts to approximately 35% of India's total non-commercial/nonconventional energy consumption.

The burning of dung and plant residue is a considerable waste of plant nutrients. Farmers in developing countries are in dire need of fertilizer for maintaining cropland productivity. Nonetheless, many small farmers continue to burn potentially valuable fertilizers, even though they cannot afford to buy chemical fertilizers. At the same time, the amount of technically available nitrogen, potassium and phosphorous in the form of organic materials is around eight times as high as the quantity of chemical fertilizers actually consumed in developing countries. Especially for small farmers, biogas technology is a suitable tool for making maximum use of scarce resources: After extraction of the energy content of dung and other organic waste material, the resulting sludge is still a good fertilizer, supporting general soil quality as well as higher crop yields.

Conclusion

Bioenergy is one of the primary sources of fuel in India. The energy utilization in Karnataka considering all types of energy sources and sector wise consumption revealed that traditional fuels such as firewood (7.440 million tonnes of oil equivalent -43.6%), agro residue (1.510 million tonnes of oil equivalent -8.85%), biogas, cow dung (0.250 million tonnes of oil equivalent -1.47%) accounts for 53.20% of the total energy consumption in Karnataka. In rural areas the dependency on the bioenergy to meet the domestic energy requirements are as high as 80-85%. The production and use of biogas for domestic purposes can drastically reduce the depletion of natural resources like forests, which are otherwise the prominent and traditional source of energy for cooking and lighting. It removes dependence on forest and enhances greeneries leading to improved environment.

Non-commercial energy constitutes 84%, met mainly by sources like firewood, agricultural residues and cow dung, while commercial energy share is 16%, met mainly by electricity, oil, etc. Availability of animal residues for biogas generation gives a viable alternative for cooking, lighting fuel and a useful fertiliser. Biogas technology is gaining additional upwind through new subsidy programmes for market incentive and development of renewable energies. Biogas potential is good (>60%). Analyses reveals that the domestic energy requirement can be met by biogas

However to support the present livestock population fodder from agricultural residues is insufficient, which could be augmented by growing fodder crops during non-agriculture seasons. Various alternatives for improved utilisation of bio resources and to enhance bio resource stock in a region are fuel-efficient stoves, biogas, energy plantations, etc.

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