What Can Biogas Do For You?

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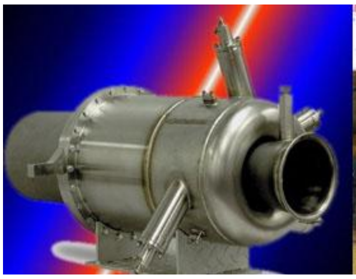

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Biogas

There is some evidence showing biogas was used for heating bath water in Assyria during the 10th century BC and in Persia during the 16th century AD. In Marco Polo's accounts there is reference to covered sewage ponds, and the use of biogas goes back 2,000-3,000 years in ancient Chinese literature. Biogas is not a new invention, although new technology is making it easier to deploy it at various scales. The first digestion plant was built at a leper colony in Bombay, India in 1859 AD and the idea reached England in 1895 when biogas was recovered from a sewage treatment facility and used to fuel street lamps in Exeter.

Today, using biogas as a fuel for cooking and lighting is a well-established practice in a number of countries. Biogas is a combustible gas mixture comprising around 60% methane and 40% carbon dioxide that is formed when organic materials, such as animal (and human) dung or vegetable matter are broken down by microbiological activity at warm temperatures (30 - 40°C or 50 - 60°C) in an anaerobic environment. This same process occurs naturally at the bottom of ponds and marshes and gives rise to marsh gas or methane.

In China and at the end of 2006, there were 22.6 million households (15% of all households) with biogas digesters and a network of rural 'biogas service centres' to provide the necessary infrastructure support, such as financing and maintenance (ABPC). China was not the only one on the biogas wagon, and by the end of 2004, India had installed 3.67 million digesters (SNV). Other countries with active programs include Nepal, Sri Lanka, Kenya, and several countries in Latin America. As rising global atmospheric carbon dioxide emission levels become of greater concern and as people realise the benefits of developing integrated energy supply options, then biogas becomes an increasingly attractive option.

Biogas is an environmentally friendly energy source that can be easily produced, almost anywhere. The capacity to produce biogas is directly proportional to the agricultural level of a country. For countries which are generally not self-sufficient in energy production, the relative ease of production makes it a particularly important energy resource.

How is biogas used?

Biogas is a clean cooking and lighting fuel that can be produced at varying scales; from small household systems to large-scale commercial plants producing several thousand cubic metres a day. Biogas can be used for electricity generation, heating, cooking, process steam and powering farm equipment. In terms of electricity generation there are two main types of installation:

- Turbines that burn methane, mixed with compressed air. As they burn, the hot pressurized gases are forced out of the combustion chamber and through a turbine wheel, causing it to spin and turn the generator, thus making the electricity. Biogas can be fed directly into a gas-fired combustion turbine. Microturbines most often used in this application.

- Reciprocating gas engines that have been modified from natural gas engines but which can handle the larger quantities of carbon dioxide and contaminants that are found in biogas. These can be small household scale units generating a few kWs to much larger scale engines delivering electrical power in the MW range.

For cooking, biogas burns with a clean flame and comparable to that of liquefied petroleum gas. Biogas can be used directly in a simple low-pressure gas burner, and makes for both clean energy, and a clean household. Once the initial investment in the system is made there is no need to spend money on fuel. Importantly there are no more smoky fires from burning wood or charcoal. This is a huge benefit as the wood smoke from cooking fires causes respiratory illness and kills many young children each year. It also means an end to the time consuming searches for wood fuel. Cooking on biogas is far quicker and easier than cooking with firewood and a biogas system is cleaner and safer. In addition, biogas systems produce excellent fertilizers for use in the garden or on the farm.

In many villages around the world lighting is a basic need as well as a status symbol. Unfortunately the lighting efficiency of biogas lamps is generally quite low, averaging between 3% and 5%. Nonetheless, a good biogas lamp can illuminate a room far better than a wick kerosene lamp, and produces a light intensity comparable to a pressure kerosene lamp or an electric light bulb in the power range of 25-75 Watts.

Many parts of rural Africa still don't have electric power. The lack of domestic lighting significantly reduces the opportunities to raise standards of living. In such areas, biogas makes it possible for households to improve their work areas and also enables work after dark. Children can do their home-work during the evening hours and the useable hours of the day are extended for the whole community.

Greenhouse gases

The UN, Food and Agriculture Organization estimates that current emissions of methane and nitrous oxide from manure of domesticated animals are responsible for about 6% of man-made greenhouse gas emissions. By collecting and controlling animal manure there is great potential for reduction of greenhouse gas emissions. If biogas is used to replace the use of fossil fuels greenhouse gas emissions will be greatly curtailed, reducing greenhouse gas emissions.

In some cases, anaerobic digestion is only used to produce fertilizer, and the biogas is merely a by-product which is then vented from the digester. This has serious negative environmental impacts as methane is a damaging greenhouse gas with 21 times the global warming potential than carbon dioxide. When the gas is burnt, it is one of the few energy processes that is 'carbon negative' in that it reduces the amount of greenhouse gases emitted by the raw material (dung emits methane). Biogas systems can help in the fight against global warming by allowing us to burn methane from organic waste, instead of letting it escape into the atmosphere where it adds to the greenhouse effect. It also helps by letting us leave more trees standing!

Biogas in context

Technical context

There are several technologies for obtaining biogas:

- The most common is the fermentation of human and/or animal waste, diluted to slurry, in specially designed digesters.
- Where water is scarce, an adapted technology uses a drier mix with high yields and more manageable residues.
- A recent approach using starches from waste foods and grain in much smaller quantities has created a small-scale technology appropriate for both urban and rural communities.
- Where there are no livestock, new technologies show that fuel crops can yield biogas.
- Larger-scale, more recently developed technologies capture methane from municipal waste landfill sites.

When building a biogas digester, certain criteria must be met if it is to be successful, for instance:

- Sufficient raw feedstuffs must be available on a long-term basis and over the whole year, or supplies of biogas will be inconsistent and people will lose confidence in the technology;
- The temperature has to be high enough to cause the digestion process to work or additional building work to create a warm environment may make it prohibitively expensive; and
- For fixed-dome type digesters, the quality of the building materials must be high as the biogas is held under pressure within the dome.

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Social context

Skills and know-how are needed both to build and to maintain biogas plants. Many units built in the past have been abandoned for lack of servicing skills, so there are some very real issues that need to be considered. For instance:

- A biogas project is more likely to succeed in a developing country if there is a market for the fertilizer end product;
- Considering supply chain should be part of the planning stage of biogas project;
- Even if the set-up costs are subsidised, those who will use the gas should have some financial stake in the construction or they may not have a sufficient sense of ownership to maintain the plant;
- Handling animal and human wastes might be a sensitive cultural issue and the use of the gas may be unacceptable in some societies;
- Collection of dung may be problematic if the livestock is not held in a fixed place but is allowed to wander freely;
- Promotion and dissemination of the benefits of biogas will be needed if it is to be accepted in the rural areas where feedstock is available;
- Using human waste appears to be more successful when it is associated with an institution such as a school or a hospital, rather than an individual home; and
- Non-Government Organisation involvement can ensure that technologies are appropriate and acceptable to the community at large.

Financial and Political Context

There is no doubt that government promotion and involvement can assist in dissemination of information on biogas. The uptake of biogas by a community can be a win-win solution as it provides clean energy and reduces problems associated with waste. One only has to look at the number of biogas installations in China to see how effective government policy can be.

Once the biogas plants are in operation the private sector investment can support the long-term sustainability. One drawback for the rollout of this technology is relatively high set-up costs, so it only becomes affordable to those on higher incomes. To offset this problem micro-credit can be used in conjunction with other credit schemes. Well targeted subsidies may also enable a larger number of people to access biogas technologies and thus stimulate the market. For example, USAID's Nepal Biogas Microfinance Capacity Building Program has established appropriate financial institutions to help continue and sustain the development of the biogas sector in Nepal.

Product Spotlight

Home Sized Indian Biogas System

The current practice of using low calorie inputs like cattle dung, distillery effluent, municipal solid waste or sewerage, makes small scale methane generation highly inefficient. By using high calorific feedstock which provides better nutritive value to microbes, the efficiency of methane generation can be increased by several orders of magnitude.

For instance, the Agrotech system pictured below claims just 2kg of feedstock produces about 500g of methane, and the reaction is completed within 24 hours. This system is much faster than a conventional biogas system which uses about 40 Kg of low calorie input to produce the same quality of methane, and requires about 40 days to complete the reaction.

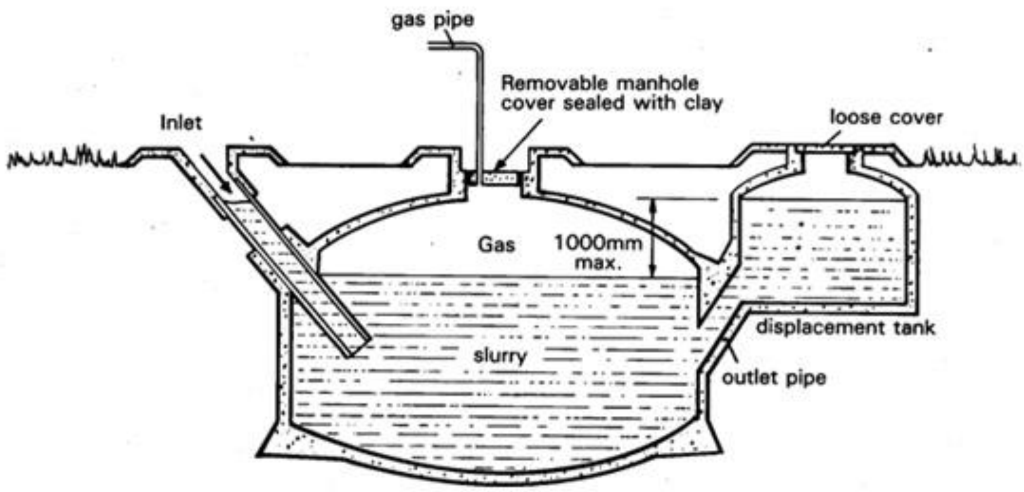
Made by: Vivam Agrotech Ltd, India.

Note: There are no benefits derived from promoting this product.

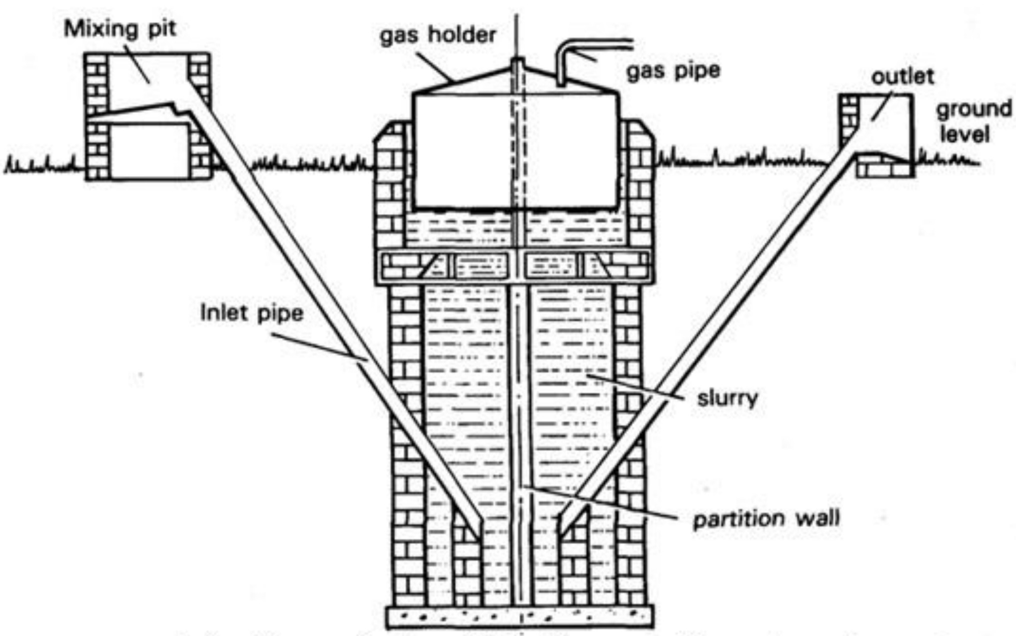
Household biogas

Chinese and Indian Designs

The most widespread designs of digester are the Chinese fixed dome digester and the Indian floating cover biogas digester shown below. The digestion process is the same in each digester but the gas collection method is different. With the Indian design, gas collects under the steel gas holder, which rises as it fills with gas. The height of the gas holder out of the pit indicates how much gas is available, and the pressure is constant. The floating cover type acts as a storage chamber, whereas the fixed dome type has a lower gas storage capacity and requires good sealing if gas leakage is to be prevented. Both these systems have been designed for use with animal waste or dung.



China - Fixed Dome Biogas Digester



India - Biogas digester with floating gas holder and no water seal

To begin the process waste is fed into the digester via the inlet pipe (mixing pit in Indian design) and undergoes digestion in the digestion chamber. The temperature of the process is quite critical - methane producing bacteria operate most efficiently at temperatures between 30 - 40°C or 50 - 60°C - and in colder climates heat may have to be added to the chamber to encourage the bacteria to carry out their function. The gas product is a combination of methane and carbon dioxide, typically in the ratio of 6:4. Digestion time ranges from a couple of weeks to a couple of months depending on the feedstock and the digestion temperature. The residual slurry is removed at the outlet and can be used as a fertiliser.

If biogas is going to be useful to a household the gas needs to be constantly available. Both the Chinese and Indian type digesters allow continuous addition of feedstock (organic material) which displaces the spent feedstock and are more likely to be the most appropriate and useful household systems. There are other designs like "batch systems" but these require the physical removal of the slurry and residue every few days. This means adding new feedstock after each clean-out, and this is both labour intensive and disruptive to household gas supply.

The Indian type of digester is generally more expensive to construct because it has a steel gas holder, although the Chinese design is prone to gas leakages. Getting a good seal on the Chinese version depends on the quality of the internal plastering which is rendered over the porous concrete.

The biogas process requires an input material provided as liquid slurry with around 5 to 10% solids. Only materials which breakdown readily can be used in the digester, as highly fibrous materials like wood and straw are not easily digested by bacteria. Some feedstock are more productive than others, and softer feedstock like dung and leaves react well in the digester. Materials like leaves or grass mixed with nitrogen-rich substances such as urine or poultry droppings work well.

The benefits a family can derive from having a biogas digester cannot be over emphasised. Not only will a plant provide the efficient treatment of manure and other organic waste it will also provide valuable gas for cooking, lighting, and water heating. In addition there is the by-product of highly quality organic fertiliser.

In the Download section of **Build-A-Biogas-Plant** there are designs for both the Chinese and Indian digesters. You will also find a simple manometer design, to measure the biogas pressure and a method for measuring C02 content. From our information base you can study and learn all that is necessary to build your own biogas digester. The material available is generally written in easy to understand language and by reading through the various publications you will soon develop and understanding of what is required to build your plant.


Biogas Generator

Many people ask about generating electricity from biogas. There are two engine types considered to be appropriate for conversion to biogas which are:

- Otto (gasoline) engines, 4-stroke;
- diesel engines, 4-stroke.

The Member Area also holds a very informative paper on engine conversions and another on purifying biogas (removing corrosive hydrogen sulphide). Small generators or large ones as seen on page 12 are now being manufactured to run specifically on biogas.

Household biogas

Compact ARTI digester using waste foodstuffs

There are many people of course who don't have livestock or who live in an urban environment where the two conventional systems discussed above are not appropriate and cannot be utilised. If you live in a built up area, the ARTI system is for you!

The Indian Appropriate Rural Technology Institute (ARTI) has developed a small biogas digester that uses starchy or sugary wastes as feedstock, including waste flour, vegetable residues, waste food, fruit peelings, rotten fruit, oil cake, rhizomes of banana, canna (a plant similar to a lily but rich in starch), and non-edible seeds.

These household digesters have a small footprint and are made from cut-down high-density polythene (HDPE) water tanks. A heat gun can be used to make them and standard HDPE fittings can be used. The standard plant uses two tanks, with volumes of typically around 0.75 m3. The smaller tank on top is the gas holder and is inverted over the larger fermenter so it telescopes inside. It is the fermenter which holds the mixture of decomposing feedstock and water.

ARTI Biogas Design

For best results the feedstock (stuff you put in the fermenter) should be blended so that it is smooth. The feeding of the plant is built up over a few weeks until it provides a steady supply of gas, typically 250-500 g of gas per day from 1-2 kg (dry matter) of feed. An inlet is provided for adding feedstock, and an overflow for removing the digested residue. The digester is set up in a sunny place close to the kitchen, and a pipe takes the biogas to the kitchen. The download area of **Build-A-Biogas-Plant** has more information on design, construction and operation of an ARTI style biogas digester

Household biogas

Tube Digesters

The cost of the tube style plastic biodigester is relatively low, varying according to size and location. For instance, in Colombia the cost per m3 of liquid volume is around $US30, taking into account that this includes the container and its connection, cement boxes for the inlets and outlets, plastic gas reservoir, stove, labour to prepare the trench and installation of the biodigester. In Viet Nam the average cost per m3 is only $US7 (materials only), giving a total cost for one biodigester of 5.4 m3 of US$37.80, including two burners. In Western countries the cost polythene tubes are also quite cheap.

Long tubular polyethylene that is used in agriculture is produced in most countries. The choice of fittings and related materials will be limited to what is available locally on farms or in rural markets.

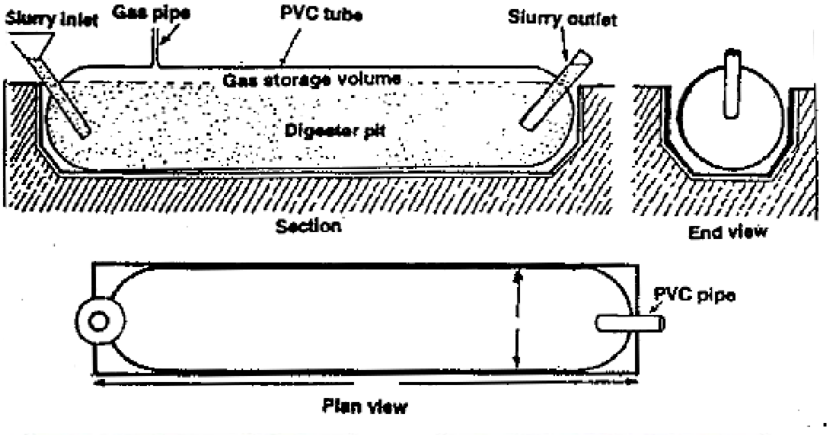


Photo 27. Holding the plastic

Photo 28. Pumping air

Photo 29. Pumping air until the tube is full

Photo 30. Tying the tube but leaving enough plastic to insert the outlet pipe

From designing, construction, cooking, or understanding how to build tube digesters, it is all here at **Build-A-Biogas-Plant**.

Community biogas

The large quantities of cow-dung and other organic waste in rural areas can be used to produce significant amounts of biogas in an organised way. Generation of biogas in this way or “biogas farming” has the potential to counter the rising prices of crude oil and could emerge to be an alternative to fossil fuels whose stocks will soon be depleted.

Salasar Agrotech Pvt. Ltd. developed the Balaji biogas plant which is a good example of hydraulic biogas system. This plant is made with the help of a steel mould, and by concreting the complete plant in sections. This modular construction approach means a series of identical biogas plant can be produced in a relatively short time frame.

The viability of a particular community biogas plant design depends on the particular environment in which it operates and the Chinese and other Indian systems mentioned earlier can be scaled up to cater for a small community needs.

There is also benefit when considering systems of this size to consider alternative routes, which may in the future be more appropriate. For instance, gasification using biomass (wood, waste from crops, vegetable, etc.) is heated in an air-lean environment to produce a gas which can then be used to run engines. Apart from running engines to generate electricity, **Gasifiers** can also power vehicles like cars and trucks.

In designing a community system the reliability of the system depends on providing adequate supplies of feedstock to keep the plant operative. If the physical resources are not constantly available, a backup source of fuel (for cooking stoves etc) should be included as additional costs to the overall biogas system.

Although there are a number of large biogas plants in various countries few can be said to be a truly community plant. One Indian ‘mini’ community system was operated between 1969 and 1970 in Khiroda Panchayat, near Bhusaval, Maharashtra.

The idea of community plants provides the potential to bring the benefits of biogas systems within reach of the poorer sections of the rural population. Unfortunately, most cooperative ventures seem to only succeed when there is positive leadership (individual or institutional) and once cooperation is absent, a system will soon fail.

Farming

Dairy farms and other confined animal feedlots, especially larger ones, are under increasing public and regulatory pressure to manage their animal manure to control environmental problems. A major concern is odour, which has been a prime force behind local ordinances to control feedlot expansion. There are also potential problems with storing and spreading the manure, along with the potential for spills. Anaerobic digesters have come into their own over the last several years for their potential to address some of the environmental impacts of manure management while providing farmers with economic benefits (Nelson and Lamb).

In a large scale system raw manure is processed using an oxygen free container (heated if in colder climates), allowing digestion that began in the cow's stomach to continue and be enhanced. Products of anaerobic digestion of livestock manure include a combustible gas (i.e. biogas), liquid effluent, and digested solids. The liquid effluent is a low-odour fertilizer with characteristics closer to commercial fertilizers that provide more flexibility to farmers in land application. This can often be substituted for the increasingly expensive commercial fertilizers. The phosphorus (P) rich digested solids are commonly used as bedding for cows, but also have value as soil supplements either on agricultural lands or for landscapers and greenhouses (Kramer).

The development of anaerobic digesters for livestock manure treatment and energy production has accelerated at a very face pace over the past few years. Factors influencing this market demand include: increased technical reliability of anaerobic digesters through the deployment of successful operating systems over the past decade; growing concern of farm owners about environmental quality; an increasing number of states and federal programs designed to cost share in the development of these

systems; and the emergence of new state energy policies designed to expand growth in reliable renewable energy and green power markets (AgSTAR Program).

A vast array of anaerobic digesters have been developed and placed in operation over the past fifty years, and a variety of schemes could be used to classify the digestion processes. When considering waste from a dairy, the most important classification is whether or not it can be used to convert dairy waste solids to gas while meeting the goals of anaerobic digestion. The goals of dairy waste anaerobic digestion are as follows:

- Reduce the mass of solids
- Reduce the odours associated with the waste products
- Produce clean effluent for recycle and irrigation
- Concentrate the nutrients in a solid product for storage or export
- Generate energy
- Reduce pathogens associated with the waste

The processes that have been used for digesting dairy waste can be subdivided into high rate and low rate processes. Low rate processes consist of covered anaerobic lagoons, plug flow digesters, and mesophilic completely mixed digesters. High rate reactors include the thermophilic completely mixed digesters, anaerobic contact digesters, and hybrid contact/fixed film reactors.

Western nations have until recently, been much less enthusiastic about biogas technology than most third world countries. The basic older style digester is labour intensive, and until systems became mechanised and automated there was little uptake in the West. These automated large scale farm biogas plants are on the scale of town sewage plants and capital costs can run into millions of dollars.

Most of this section has been about large farm digesters, but medium biogas systems with volumes ranging from 50 m3 upward for cattle, pigs and/or poultry can still be built using the Chinese and Indian designs seen on page 7. Of course this size digester is not just the domain of farmers, and restaurant owners or collectors of food waste could construct a digester as their waste products a perfect feedstock.

In the **Build-A-Biogas-Plant** Download Area documents provide guidance on screening for project opportunities, selecting a gas use option and conducting site-assessments to identify technically appropriate and cost-effective biogas recovery processes for your farm.

Large scale installations

Industrialised countries commonly use biogas digesters where animal dung, and increasingly fuel crops are used as feedstock for large-scale biogas digesters. Brazil and the Philippines lead the world in crop-based digesters using sugar-cane residues as feedstock.

Interest and public support in biogas has been growing in most of the European countries. After a period of stagnation, caused by technical and economical difficulties, the environmental benefits and increasing price of fossil fuel have improved the competitiveness of biogas as an energy fuel. This has been seen in both small and large scale plants in Denmark, Germany (with over 3000 plants producing 500MW electricity and 1000MW of heat) and Switzerland, and as a transport fuel in Sweden (where vehicles using biomass were voted environmental cars of the year in 2005).

There have been interesting biogas projects in the UK, Ireland, and the Netherlands. Despite this, the use of biogas in Europe is modest in relation to the raw-material potential, and biogas produces only a very small share of the total energy supply. Several countries are experimenting with dedicated biogas energy crops, such as newly bred grass varieties (Sudan grass and tropical grass hybrids) or biogas 'super maize' developed in France. The crops are developed in such a way that they ferment easily and yield enough gas when used as a single substrate. Biogas crops can be used whole, which allows for the use of far more biomass per hectare.

When produced on a large scale, biogas can be fed into the electricity grid and enter the energy mix without consumers being aware of the change. A select number of European firms have already begun doing so, while farmers who generate excess biogas on their farms make use of incentives to sell the electricity they generate from it to the main power grid. In Germany, electricity from biogas is an integral part of the energy market. In 2005, biogas units produced 2.9 billion kilowatt-hours of electricity.

Despite recent economic instability, the construction of larger plants producing gas continues to be highly lucrative for both farmers and financial investors in Germany, with over 30 new plants planned for 2010 (Frost and Sullivan). The German bioenergy company Nawaro Bioenergie AG is completing the world's largest integrated biogas power station in Klarsee, Penkun, in the German state of Mecklenburg-Western Pomerania.

The complex will generate 20 megawatts (MW) of electricity by fermenting energy maize by liquid manure. After fermentation the biomethane is converted by combustion into electricity and heat. The complex utilises 40 Jenbacher Gas Engines that will cogenerate 20 megawatts of electricity and 22 megawatts in thermal output. The first module began operations in November 2006 and now 15 modules are operating. The 20MW output is enough to meet the energy needs of a town of 50,000 people (Biopact).

Dragon Power Company, China's biggest biogas - biomass energy company (50 power plants) plans to build about 30 biogas power plants by 2010, with an estimated total investment of 1.5 billion euro (Helmut Kaiser Consultancy).

India is planning to deal with one of its major problems – air pollution from transport, through the use of compressed biogas (CBG). Since over 70% of the world's long-term (2030) growth in demand for automotive fuels will come from rapidly developing countries like India, China and Pakistan biogas is highly relevant.

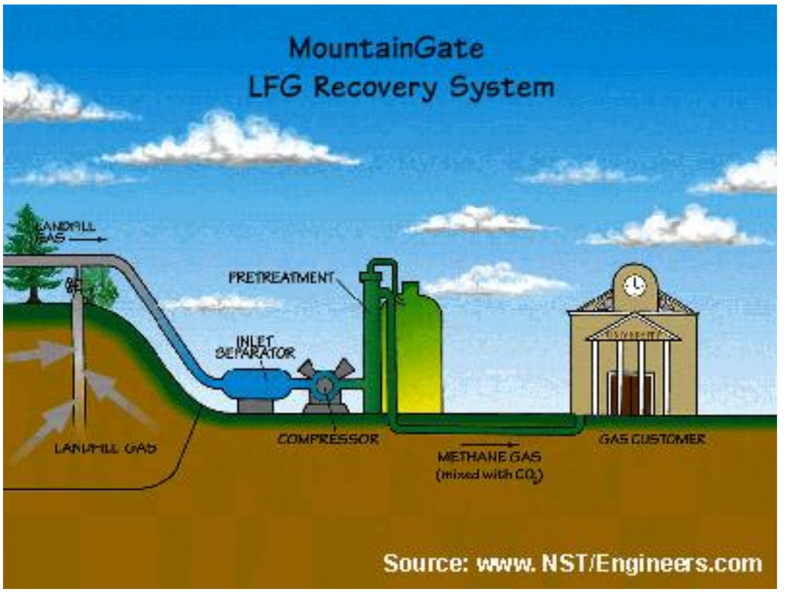
Landfill gas

Landfill gas (LFG) is produced by the anaerobic decomposition of buried organic waste. Municipal solid waste landfills produce significant quantities of LFG, and LFG will continue to be produced long after a landfill is closed. LFG typically has a methane content of about 40 to 55 percent. The balance is primarily carbon dioxide. If LFG is not beneficially used, it is incinerated in a flare. However, flared LFG represents a wasted energy resource.

LFG can be, and has been, productively utilised as a substitute for natural gas at an end user's gas burning equipment, for electric power generation, and to produce high quality gas for direct injection into natural gas pipelines. A variety of technologies have been used for electric power generation, including reciprocating engines, combustion turbines, steam cycle power plants and microturbines.

LFG production starts shortly after the waste is buried in a landfill site and LFG will continue to be produced as long as there is organic waste present. The decline in LFG production is gradual and in a dry climate, the rate of production will decline as little as 2 percent per year. In wetter climates, the rate of LFG production will decline at 6 to 10 percent per year.

The rate of LFG production is also affected by waste composition and landfill geometry, which in turn influence the bacterial populations within it, chemical make-up, and thermal characteristics.



In early 2008, Waste Management entered into a joint venture with Linde North America a leading global gases and engineering company. Their aim was to build a plant and convert landfill gas to liquefied natural gas (LFG to LNG) with a facility at the Altamont Landfill in Livermore, California. At this location, landfill gas is now being collected and processed to create clean, renewable fuels to "close the loop" on waste collection.

Since September 2009, when the commissioning process began, the plant has produced 200,000 gallons of LNG. To completely close the waste management loop, 500 of Waste Management's trucks throughout California are now running on the LNG created at the Altamont plant, instead of filling up with diesel (Treehugger).

Conclusion

A biogas plant can digest materials that are readily available on farms, such as animal dung and crop wastes. In an urban context a small biogas digester not only produces a clean, high-grade fuel gas, it also produces a residue that is a great fertilizer. The quality of this fertilizer is often higher than if the same materials were composted by more traditional methods. The compost from the plant does not smell or attract flies, and once it has been dried it is easy to apply to your vegetable garden or to crops in the fields.

Biogas is much more convenient to use than traditional fuels, such as firewood, dried dung and even liquid petroleum products. The smoke from other fuels makes pots dirty and irritates the eyes, where biogas gives a very hot clean flame. Biogas can be used in engines to drive machinery, water pumps or generate electricity. Groups of farmers can cooperate to buy and run a biogas plant with an engine and they will all benefit from the income earned from a cottage industry, such as a grain mill, or perhaps from the increased crop production resulting from pumped irrigation.

Biogas is a form of renewable energy and we are hopeful that it becomes much more integrated in our daily lives. Look around you and consider how you can best utilise the waste organic material that surrounds you… it is likely that a biogas plant could be developed to capitalise on this waste.

Our library at http://www.build-a-biogas-plant.com is full of information to get you started and operate your own biogas plant. By now we hope you have been able to satisfactorily answer the question, "What can biogas do for you?" The question is now, what will you do?

Still unsure what to do?

Here is a 3 Step Plan to Get You Going

1. **Do your homework – read background information on biogas**
2. **Talk to others who have a system similar to that which you want.**
3. **Plan and seek out local legal requirements before buying anything!**

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