PRACTICAL ACTION
Technology challenging poverty

BIOGAS

Introduction

Biogas is a well-established fuel for cooking and lighting in a number of countries. It is a gas mixture comprising around 60% methane and 40% carbon dioxide that is formed when organic materials, such as dung or vegetable matter are broken down by microbiological activity in the absence of air, at slightly elevated temperatures (most effective between 30 - 40°C or 50 - 60°C). This is the same process as that which occurs naturally at the bottom of ponds and marshes and gives rise to marsh gas or methane.

China has over 7.5 million household biogas digesters, 750 large- and medium-scale industrial biogas plants, and a network of rural 'biogas service centres' to provide the infrastructure necessary to support dissemination, financing and maintenance. India has also had a large programme, with about three million household-scale systems installed (Martinot 2003). Other countries in the South with active programmes include Nepal, Sri Lanka, Kenya, and several countries in Latin America. As carbon emission levels are becoming of greater concern and as people realise the benefits of developing integrated energy supply options, then biogas becomes an increasingly attractive option.

The biogas process is known as anaerobic (without air) digestion, and provides a clean cooking and lighting fuel that can be produced on a scale varying from a small household system to a large commercial plant of several thousand cubic metres. Biogas can be used for electricity generation and powering farm equipment. There are two main types of electricity generation equipment:

- Microturbines are small gas 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.
- 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. They work on a much larger scale, burn efficiently, and deliver between 1MW and 2 MW of electrical power.

The digestion of animal and human waste yields several benefits:

- The production of methane for use as a fuel, which reduces the amount of woodfuel required and thus reduces desertification.
- The waste is reduced to slurry that has a high nutrient content, making an ideal fertiliser.
- During the digestion process, dangerous bacteria in the dung and other organic matter are killed, which reduces the pathogens dangerous to human health.

Carbon emissions

In some cases, anaerobic digestion is used to produce fertiliser as the main product, and the biogas is merely a by-product which is vented from the digester. This has serious negative environmental impacts as methane is a damaging greenhouse gas. Conversely, 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), making it an attractive option for those seeking carbon funding for wide-scale dissemination.

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technical brief

Technical issues

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 cattle, 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.

Technical

- Sufficient raw feedstuffs must be available on a long-term basis and over the whole year, or supplies 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
- For fixed-dome type digesters, the quality of the building materials must be high as the biogas is held under pressure within the dome
- 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

Social

- It is more likely to succeed if there is a market for the fertilizer end product. This supply chain should be part of the planning stage of biogas introduction
- 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 is a sensitive cultural issue and even 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
- The use of 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
- NGO involvement can ensure that technologies are appropriate and acceptable to the target community

Financial / political

- Government promotion and involvement can assist in dissemination. This can be a win-win solution as it provides clean energy and reduces problems associated with waste.
- Private sector investment will support long-term sustainability
- Set-up costs are relatively high so may only be affordable to those on higher incomes Micro-credit can be used to reduce this problem. Credit schemes, or well-targeted subsidies, will 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.

Household-level technologies

The most widespread designs of digester are the Chinese fixed dome digester and the Indian floating cover biogas digester (shown in figures 1& 2). The digestion process is the same in each digester but the gas collection method is different. In the floating cover type, the water sealed cover of the digester is capable of rising as gas is produced, where it 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 have been designed for use with animal waste or dung.

The waste is fed into the digester via the inlet pipe 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 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.

From a household perspective, the gas should always be available, so those digesters which allow continuous addition of feedstock which displaces spent feedstock is likely to be the most appropriate and acceptable. Batch systems, which require the physical removal of slurry every few days and the addition of new feedstock are both labour intensive and disruptive to supply.

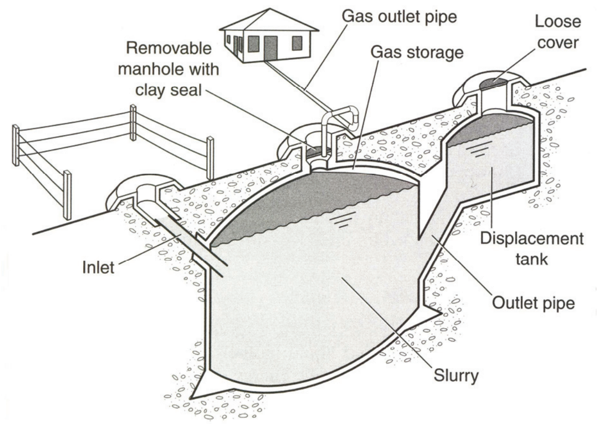

Figure 1: Fixed dome digester

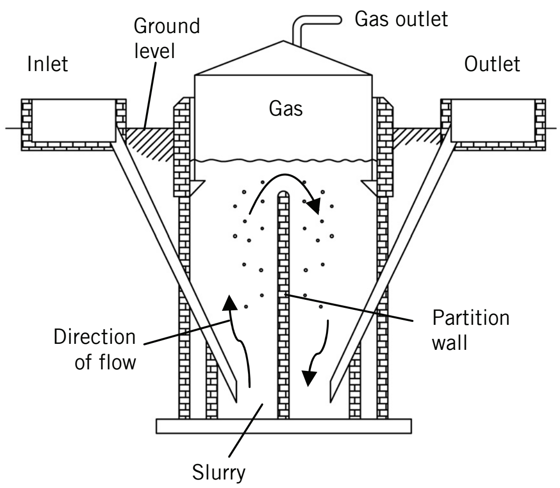

Figure 2: Floating cover digester

Biogas digesters where water is a constraint

This digester, developed by the Central Institute of Agricultural Engineering, Bhopal, India, is a modification of the fixed-dome type and it allows fresh undiluted cattle dung to be used. The modified design requires very little or no water for mixing with the cattle dung, generates about 50% more biogas for each kilogram of dung loaded into the system, and does not require slurry drying time before it can be used as fertiliser.

The main changes to a conventional fixed dome digester are an increase in the bore of the inlet feed, greater reinforcement of the chamber to withstand the higher gas pressures, an enlarged slurry chamber outlet and a smooth widened outlet channel to streamline the flow of the slurry (Shyam, 2001).

Compact biogas digester using waste foodstuffs

For those without cattle or within urban centres, a conventional digester may not be appropriate. The Indian Appropriate Rural Technology Institute (ARTI) has introduced 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.

The compact plants are made from cut-down high-density polythene (HDPE) water tanks, which are adapted using a heat gun and standard HDPE piping. The standard plant uses two tanks, with volumes of typically 0.75 m^3 and 1 m^3. The smaller tank is the gas holder and is inverted over the larger one which holds the mixture of decomposing feedstock and water (slurry).

The feedstock must be blended so that it is smooth using a blender powered by electricity or by hand. Two kilograms of such feedstock produces approximately 500 g of methane, and the reaction is completed with 24 hours.

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. (ARTI, 2006)

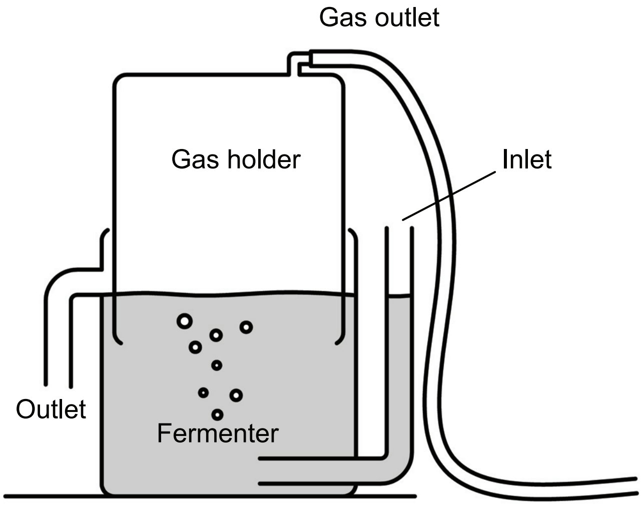

Figure 3: Compact biogas (Neil Noble/Practical Action)

Larger-scale biogas plants

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 economic 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 natural gas 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 in Germany, farmers who generate excess biogas on their farms, are using it to generate electricity; in 2005, biogas units produced 2.9 billion kilowatt-hours of electricity (NAWARO).

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 longterm (2030) growth in demand for automotive fuels will come from rapidly developing countries like India this is highly relevant and is currently in the research phase (Biopact).

Uses of biogas

Biogas has a wide variety of applications. It can be used directly for cooking and lighting, or for heat generation, and for electricity production and fuel for cars. Studies in China have shown that when it is used to heat and light greenhouses it boosts carbon dioxide levels, boosting photosynthesis by increasing the carbon dioxide concentration, which boosts photosynthesis in the greenhouse plants and increase yields.

Experiments in Shanxi Province have shown that increasing carbon dioxide four-fold between 6 am and 8 am boosts yields by nearly 70 percent. A biogas lamp gives both light and warmth to silkworm eggs, increasing their rate of hatching as well as cocooning over the usual coal heating.

At industrial level, the methane and carbon dioxide mix in biogas can be used to inhibit picked fruit from ripening too early as it inhibits metabolism, thereby reducing the formation of ethylene in fruits and grains. It also kills harmful insects, mould, and bacteria that cause diseases (Kangmin, L. & Ho, M-W).

Table 1 shows some approximate equivalents of various energy sources compared to $1m^3$ of biogas.

Table 1: Biogas fuel equivalents (@ 15°c & atm pressure)

Energy Source	Equivalent to $1m^3$ of biogas
Petrol	0.53 - 0.75L
Diesel	0.48 - 0.68L
Firewood	1.50kg
Electricity	1.20kW/h
LPG	0.46kg

Source: Biogas Technology Center (BTC), Chiang Mai University & (FAO, 1992)

Social impacts of using biogas

- Biogas is a clean fuel, thus reducing the levels of indoor air pollution, a major cause of ill-health for those living in poverty
- Lighting is a major social asset, and already there are estimated to be over 10 million households with lighting from biogas (Martinot, 2003). Improved lighting is associated with longer periods for work or study
- Where biogas is substituted for woodfuel, there are two benefits: a reduction in the pressures on the forest, and a time-saving for those who have to collect wood – usually women and children
- If a biogas plant is linked to latrines in a sanitation programme, it is a positive way of reducing pathogens and converting the waste into safe fertilizer
- Where biogas is linked with sales of the resultant fertilizer, it is an excellent source of additional income
- Fertilizer can be used on crops to increase their yield
- In China and India biogas plants are produced in great numbers by local artisans. In Kenya, where biogas technology is still in its early stages of dissemination, local manufacturers have been quick to realise the potential and get involved with the production of biogas plants.
- Biogas can be used to generate electricity, bringing with it the possibilities of improved communications; telephone, computer, radio and television for remote communities

- Fuel produced locally is not so vulnerable to disruption as, for example, grid electricity or imported bottled gas

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