Biogas

Summary

Biogas plants operate using anaerobic digestion, a process where bacteria consume organic material in the absence of oxygen, producing methane and carbon dioxide gas. The biogas can be collected and used for cooking, lighting or generating electricity. There are a range of biogas plant designs, each of which has different advantages in terms of cost, ease of construction and durability. The feedstock for the plant is often cow or pig dung, but sewage and food wastes are also widely used.

The first biogas plants were used 150 years ago, and the more modern designs have been available for 50 years. Several million plants are installed worldwide, with particular concentrations in South Asia and China, but also a few thousand large-scale plants in developed countries.

The main benefit of the biogas plant is that it replaces other fuels for cooking - in rural areas this is usually firewood, and in urban areas LPG or kerosene. When firewood is replaced the health of women is improved as they no longer have to breath in wood smoke, and as it takes much less time to feed a biogas plant than it does to collect firewood there are considerable time-savings. Other benefits of biogas plants include the ability to connect a latrine, so improving sanitation, and the effluent produced, which is a good-quality fertiliser.

The countries where biogas plants have been successful on a large scale have had some level of government support, but as fossil fuel prices have been rising and carbon offsetting has become more popular the economic viability of biogas plants has been improving.

Technology background

Biogas plants use bacteria to turn wet organic matter into methane and carbon dioxide. A biogas plant consists of a container to store a large volume of slurry (finely divided solid organic waste in water) and a means to collect the gas and exclude air. Air must be excluded because the methane-producing bacteria are anaerobic, i.e. they do not work when oxygen is present. The most common source of these bacteria is a cow's gut, so cattle dung is a favoured feedstock; a small amount is often used to start the digestion process if the main feedstock will be other types of organic matter. The bacteria work best at 35°C, so in colder climates the container must be insulated or heated to maintain this temperature.

The cheapest biogas plant designs are made mainly of masonry, either brick or concrete. The key to strength and gas containment is using curved shapes – cylinders and domes – and making sure that the plant is impermeable to gas. Steel and plastic (high-density-polythene, HDPE, and glass-reinforced-plastic, GRP) are used in some designs, which can be pre-fabricated and thus installed very quickly, but cost more.

Another design that has proved popular in Vietnam and a few other places is the bag digester. The simplest version is a long plastic tube, with a feed pipe at one end and a pipe for the semi-solid residue to come out at the other. The slurry in the tube generates gas, which inflates the tube. Other versions use a plastic tent over a slurry pit to collect the gas. This design is very cheap, but the plastic can fail after only a few months. Other materials, such as butyl rubber, last longer but cost more.

Sewage plants use anaerobic digestion to reduce the volume of solid wastes and reduce the smell. In recent years, many UK water companies have and reduce the smell. In recent years, many UK water companies have recognised the potential of the gas produced and generate electricity from it to use on-site or sell to the grid. Food wastes in landfill also generate biogas and this is now also being captured and used to generate electricity on many sites.

History

Biogas was originally developed in India in 1859 and inspired the use of sewage plants in the UK and elsewhere. In the 1950s, Ram Bux Singh designed a biogas plant for farmers, using cattle dung as the feedstock. These early domestic models used a floating steel drum to collect the gas. In the 1970s, people in China developed the displacement gas collecting system, in which the slurry is displaced from a fixed dome into a separate reservoir as gas collects This model is now the widely used in many places. A typical plant requires a container between 3 and 6 m3 in volume to contain the slurry and gas, and costs about £190.

Community biogas schemes, in which people provide dung or their own food waste to a central plant and share the gas, have seldom been successful. People seem to be unwilling to share the work and benefits equitably. However, the development of systems that use food waste as the main feedstock and supply gas to fuel an engine to generate electricity have potential, especially if the scheme can be financed through the avoided cost of waste disposal.

The number of domestic biogas plants in the world is very difficult to estimate. In the early 1980s, China boasted of the installation of eight million plants, but these were of low quality and appear not to have lasted. The programme in China has continued, with a better quality design but at a slower rate. India has moved more slowly and an estimate of plants built was over two million in the year 2000. Nepal, with 156,000 biogas plants in 2005, claims to have more per capita than India. There are programmes in many other parts of the world, such as Vietnam, Brazil and Tanzania, but they are smaller. People have attempted to set up projects in Kenya, for example, but have met with limited success.

Benefits

The main benefit of a biogas system is that other fuels for cooking are replaced. In rural areas, biogas usually replaces firewood, which is often in short supply, and can save people up to four hours per day as they no longer have to collect wood and light a fire. Collecting dung and feeding it to the plant takes less than half an hour and does not need to be done early in the morning, so there is time to give children a meal before school. Biogas burns with a very clean flame, so women do not have to breathe wood smoke, which is a major cause of respiratory and eye disease. In urban areas, biogas replaces fossil fuels such as LPG or kerosene.

Use in developing countries

The large-scale biogas programmes in South Asia and China supply plants to individual farmers, who feed them daily with a mixture of water and dung from their own animals (two to four cows or five to ten pigs) and use the gas produced for cooking. Many plants, especially those in China, have a latrine attached, so provide sanitation as well as cooking gas. The semi-solid residue that comes from the plant is a good fertiliser with minimal smell, so is used to improve crop production and reduce the use of artificial fertilisers. The fertiliser value can be enhanced by mixing the residue with crop waste to make compost. This can be further improved with vermi-culture – feeding it to earth worms for additional processing.

Food wastes and sewage can also be used to generate biogas. If a family or community building (school or hostel) rely on their own wastes, they can save between 25% and 50% of the LPG they use for cooking. If the users can supplement the feed with other materials, such as leftovers from a food processing enterprise, they can completely replace LPG. Food waste produces processing enterprise, they can completely replace LPG. Food waste produces gas more quickly than dung, so these plants are smaller (typically 1 m3 in volume), and thus suitable for urban homes. The typical cost of such plants is £120 in India.

The economic viability of biogas technology depends on the cost of the fuel being replaced, and whether there are other economic benefits (for instance, avoided waste disposal costs). Government schemes enabled the programmes in India, China and Nepal to succeed. With the increase in costs of fossil fuels and the potential for carbon-offset finance, biogas is becoming more viable financially. The Nepal programme received CDM (Clean Development Mechanism) finance, and other projects are receiving support from the voluntary carbon-offset finance sector.

Use in developed countries

In the UK, there was a farm-scale biogas programme run by DTI in the early 1980s. About 200 plants were built, but people lost interest once the oil price went back down. Of these plants, about 50 are still running. However, interest is reviving, with seven new farm-scale plants recently built in South-West Scotland to reduce agricultural pollution in a sensitive area.

There is a large programme in Germany, encouraged by high feed-in tariffs for electricity generated on farms, with about 3,500 farm-scale plants installed. There is keen interest in Scandinavia, with buses and even a small train running on biogas in Sweden. Large cattle and pig feed-lots in USA have started to cover their slurry lagoons with butyl sheets to collect the gas produced for energy.

Ashden Award winners using biogas

Prakratik Society, India (2004)
KIST, Rwanda (2005)
Biogas Sector Partnership, Nepal (2005)
Shaanxi Mothers, China (2006)
Appropriate Rural Technology Institute, India (2006)
VK-Nardep, India (2006)
BIOTECH, India (2007)
SKG Sangha (2007)