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Flexi Biogas systems: inexpensive, renewable energy for developing countries

Biogas is a clean, renewable energy obtained from biodegradable organic material such as kitchen, animal and human waste. In the past, biogas digesters have been considered mainly as a means of producing combustible gas. The waste is put into a sealed tank (a digester) where it is heated and agitated. In the absence of oxygen, anaerobic bacteria consume the organic matter to multiply and produce biogas.

The most common type of biogas system, and the most widely adopted in China and India, is a fixed dome system. Its construction requires skilled technical expertise and complex logistics, making installation expensive and time-consuming. Fixed dome systems are permanent installations, so secure land tenure is a prerequisite. These challenges make it difficult to adopt fixed dome systems in developing countries, particularly in Africa. As a result, many systems have failed and adoption rates have been low.

Another type of biogas system, manufactured in Kenya, is Flexi Biogas, a flexible above-ground system that is simpler and less costly to build and operate. This system does not require agitation and the digester is not a sealed tank but simply a 6m x 3m plastic bag made of PVC tarpaulin.

Operation of the Flexi Biogas system

The Flexi Biogas system is portable and expandable. It has a shorter retention period (the time it takes for organic material to break down) than fixed dome systems. Similar to an open-ended pillow case, it consists of a plastic digester bag housed in a greenhouse tunnel. The tunnel acts like an insulated jacket, trapping heat and keeping the temperature between 25 and 36 degrees Celsius. The combination of the tunnel and the plastic bag increases the volume of gas production and reduces the retention time, ensuring a high rate of fermentation and gas production.



As microbes digest the organic material, biogas bubbles up from the mixture, inflating the plastic bag. Sitting above the ground in the sun, the system quickly heats up, promoting rapid production of methane gas. It is then piped through a PVC tube connected to an appliance or piece of equipment such as a gas stove for cooking.

The tunnel fabric serves as an ultraviolet shield, further extending the life of the digester. During the day the tunnel captures solar radiation, increasing the temperature of the organic waste material (substrate) in the digester. Normally biogas is used for cooking or lighting, but it can also be used to operate electricity generators and agricultural machinery such as chaff cutters, water pumps and milking machines.

Fixed dome digesters can be inadvertently overloaded, but the cross-flow design of the Flexi Biogas system prevents this problem. This

is a significant benefit when compared with the crusting (scum formation) that can occur in fixed dome systems in the absence of an agitator, stirrer or water pump. Experience with Flexi systems has shown that, since the digester bag is placed above ground (and thus the volume of gas is visible), it takes farmers one week to understand how much and which materials to use in the system.

The Flexi Biogas system in Kenya

In Kenya, Biogas International has installed 200 Flexi Biogas systems since 2011. Since April 2012, IFAD has worked in partnership with Biogas International to install nine systems on dairy farms as part of the IFAD-supported Smallholder Dairy Commercialization Programme in Nakuru and four systems in an orphanage school in Naivasha. At the school the systems use kitchen and human waste to produce electricity for lighting and to provide Internet access.

These systems have been installed as part of a project titled *Making Biogas Portable: Renewable Technologies for a Greener Future*, under the Initiative for Mainstreaming Innovation. The initiative is funded through IFAD by the UK Department for International Development. IFAD has also facilitated South-South cooperation between Kenyan engineers and the Indian Institute of Technology, which has provided a platform for scaling up the system internationally.

Electricity per cow: The potential of the Flexi Biogas system

One cow produces 15 to 30 kg of dung each day. Estimates suggest that about 20 kg of fresh cow dung will yield 1,000 litres of cooking gas in the Flexi Biogas system, enough for a household of five to seven members. Adding an extra 20 kg of dung to the system will run a 5-horsepower engine for one hour. This could be coupled to an automotive alternator, which will charge a battery (using a chaff cutter) and a converter to run small items such as lights, a computer or a television set.



So far, operating and maintenance costs have been close to zero. Gas production rates have allowed farmers to make a daily batch of the local kidney bean and maize dish *githeri*, which takes about three hours to cook (see table 1).

High-quality plastic and rubber are expensive in Kenya, raising the cost of fabrication. Previously, to keep costs down, inexpensive plastic digester bags were used in the Flexi Biogas system. Because these cost just US\$40 each, the total price for the whole system was US\$180. However, experience showed that this plastic tore when the system was moved, and due to normal wear and tear it had to be replaced after two years. The systems now use a PVC tarpaulin bag that lasts at least 10 years. As a result of this and other improvements, the smallest system now costs US\$410, including installation (see table 2).

Costs could be lowered further if the systems were produced in countries such as China or India, where the price of raw materials is less than half of what it is in Kenya.

Fixed dome versus Flexi Biogas systems

Each system has advantages and disadvantages, as shown in table 3.

The disadvantage of fixed dome biogas systems in Africa results primarily from their complexity. The specific negatives include:

- High cost and time-intensive installation requiring skilled labour
- Difficulty accessing complex parts such as gas pressure regulators or floating gas-holders
- Need for secure land tenure.

Table 1:
Time and cost of cooking *githeri* with different fuels

Fuel	Amount required	Cost (US dollars)
Firewood	7-8 kg	0-0.70*
Charcoal	5 kg	2
LPG	1 000 litres	1.17
Biogas	1 000 litres	Free

* Depending on whether wood is collected or purchased

Table 2:
Construction cost of a Flexi Biogas system

Item	Cost (US dollars)
Digester bag (PVC tarpaulin)	160
Greenhouse tunnel (polyethylene plastic)	20
Inlet/outlet pipes and 15m gas delivery pipe	70
Single burner	20
Personnel (2 technicians)	50
Profit mark-up	70
Office overheads	20
Total	US\$410

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But these systems also have advantages, including:

- Compact and well-insulated design
- Long life span of 20 years or more
- Labour-intensive construction, creating local employment
- Underground digester, offering protection from temperature fluctuations.

Flexi Biogas systems offer the following benefits:

- Inexpensive to build from locally available materials
- Lightweight (10 kg) and portable, capable of being transported on a bicycle or motorbike
- Easy and quick (about 8 hours) to install on a level patch of ground
- Easily relocated - no need for secure land tenure
- Easy to load, unblock and empty due to the open-ended tube
- Pressure safety system that prevents structural damage when over-gassed
- Simple and easy to operate.

However, they too have some disadvantages:

- High cost of good-quality plastic, increasing the price of fabrication
- Easily stolen or vandalized
- Short life of greenhouse tunnel, requiring replacement every five years.

With the growing emphasis on sustainable use of natural resources and the need to reduce greenhouse gas emissions and integrate livestock and farming systems, biogas energy offers numerous benefits. The Flexi Biogas system is an affordable solution that provides household energy while making use of waste products that would otherwise add to emissions. It has great potential for the household, the community and the environment.



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Table 3:
Fixed dome versus Flexi Biogas systems

	Fixed dome system	Flexi Biogas system
Costs (in Kenya)	US\$1 000	US\$410
Time to install (days)	21	1
Start-up load (tons of manure)	5	1
Retention time (days)	45	15
Temperature	19°C	36°C
Durability (years)	20+	10