18

Urban Energy Technical Note

Plastic Tubular Biogas Digester

One way of reducing energy consumption in residential and institutional buildings such as schools and hospitals is by use of a tubular biogas digester. Use of biogas eliminates the use of the more expensive electricity and/or liquefied petroleum gas (LPG). Organic materials are the feedstocks for a biogas system. Some organic materials will digest more readily than others. Restaurants fats, oils and grease; animal manures; wastewater solids; food scraps, and; by-products from food and beverage production are some of the most commonly digested materials. A single anaerobic digester may be built for a single material or a combination.

An anaerobic digester consists of one or more air tight tanks that can be equipped for mixing and warming organic material. Naturally occurring microorganisms thrive in the zero-oxygen environment and break down (digest) organic matter into usable products such as biogas and digested materials. The system will continually produce biogas and digested material as long as the supply of organic matter is continuous and the micro-organisms inside the system remain active.

Biogas is mainly methane, the primary component of natural gas and carbon dioxide, water vapour and other trace compounds. Biogas can replace natural gas in almost any application, but first it must be processed to remove non-methane compounds.

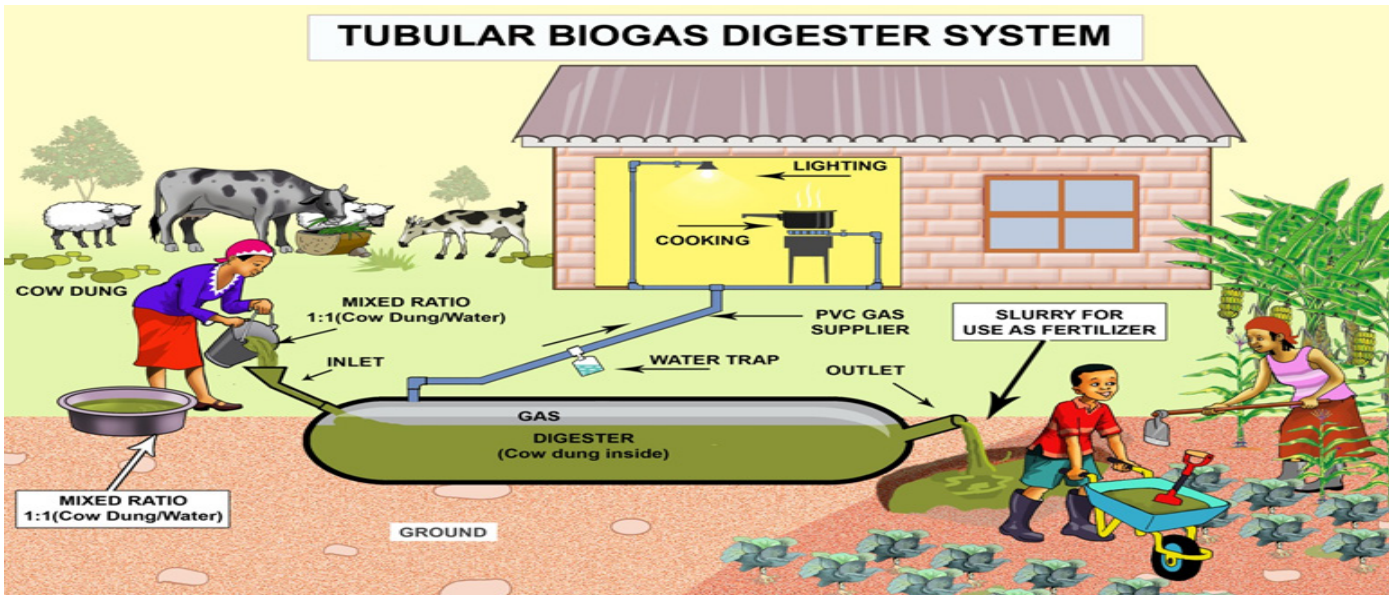
Biogas, also called bio-methane or renewable natural gas can be used to produce heat and electricity. In addition to biogas, digesters produce solid and liquid digested material containing valuable nutrients (i.e. nitrogen, phosphorus and potassium) and organic carbon. Typically, raw digested material or 'sludge' is processed into a wide variety of products such as fertilisers, compost, soil amendments, or animal bedding. These by-products can be sold to agricultural, commercial and residential customers.

General Benefits of Biogas

1. Waste treatment benefits

- Natural waste treatment process
- Mature technology
- Smaller physical footprint (compared to composting)
- Reduces volume of waste for transport, land application

Fig. 01: **Plastic Tubular Biogas Digester System**



- Very efficient decomposition
- Complete biogas capture
- Nutrient recovery and recycling

2. Energy benefits

- Net-energy generating process
- Biogas generated can be used for:
  - Heat-only
  - Electric-only
  - Combined heat and power
  - Pipeline quality bio-methane
  - Transportation fuel
- Consistent energy release compared to other intermittent energy sources such as wind and solar
- Distributed generation (which means lower transmission / transportation costs and higher reliability)
- Direct replacement for non-renewable fossil fuels

3. Environmental benefits

- Dramatic odour reduction
- Reduced pathogen levels
- Reduced greenhouse gas emissions
- Platform for reducing nutrient run-off
- Increased crop yield

4. Economic benefits

- Reduced generation of odours from organic waste materials
- Turns cost item (i.e. waste treatment) into revenue-generating opportunity
- Can operate in conjunction with composting operations
- Improves rural infrastructure and diversifies rural income streams

Plastic Tubular Digester (PTD)

Plastic tubular digester biogas technology uses organic waste to produce energy for heating, cooking and lighting. The organic waste, which includes cow dung, goat and chicken droppings, is mixed with water (in a 1:3 ratio) and kept in an anaerobic environment – a large tube made of sheet plastic to ferment and produce gas that can be used for cooking. Cow dung is the ideal feedstock for bio-digesters because it is not acidic. If livestock wastes and garbage have to be used, cattle dung should be used as a starter substrate.

Fig. 02: **The PTD should be protected with a perimeter fence**

Plastic tubular biogas digesters are ideal for peri-urban areas where the city council by-laws do not apply. Moreover, they are very affordable, i.e. for a two-cow system it will cost approximately US$75.

A 2009 study by the Kenya Agricultural Research Institute (KARI) assessed the socio-economic and environmental impacts of plastic tubular digester technology. They concluded that the adoption of a plastic tubular digester reduces household energy and labour costs, reduces deforestation, as well as having the following advantages:

- Plastic tubular digester increases crop productivity because the waste slurry can be used as organic fertilizer for farming.
- Majority (80%) of respondents in the study said it improved the cooking environment in the kitchen as it is smoke-free.
- Plastic tubular digester is more affordable for small-scale farmers than other types of biogas systems. Installation costs vary, but a 'two cow' unit costs around US$75 – about 10% of a conventional floating or fixed-dome biogas units.

Benefits of Plastic Tubular Digester

The following are direct benefits of using the plastic tubular digester biogas system:

- Improved cooking environment that is smoke free
- Ability to cook meals faster
- Cheaper cost of cooking in terms of time and money
- Saving of time spent gathering and transporting firewood
- Reduced need to cut down trees

"...I have reduced firewood consumption and the money (USD 40 monthly) I used for buying firewood; I am saving for family projects. I am also able to serve my customers with clean food cooked from a smoke free environment. Before I started using biogas, I was having recurring chest congestion but this problem has ceased and I can attribute this to using biogas since it does not smoke. I have always been worried when I see changing rain patterns. I now feel good to be a key player in mitigating climate change''.

Organic waste such as cow dung, goat or chicken droppings is mixed with water and poured into an airtight space such as the plastic sheeting tubes which are often used in making silage. The mixture is allowed to sit for 1 to 7 days depending on the ambient air temperature, during which the process of anaerobic respiration sets in. A highly inflammable gas – methane is produced during this process. This gas can be used to cook and even run electric generators.

Plastic Tubular Digester Construction Materials

The following is a list of materials required for the construction of a plastic tubular digester:

- Two polythene tubes of 0.2mm thickness (Gauge 1000), 90-120 cm diameter and 8-10 m length (for digester)
- Polythene tube of 0.2mm thickness (Gauge 1000), 90-120 cm diameter and about 3-4 m length (for gas reservoir)
- A PVC pipe of 1.2cm diameter and one meter long for tapping the gas from the digester
- Two pieces of PVC pipe of 10-15cm diameter and one meter length to serve as inlet and outlet pipes
- A plastic gas pipe of 1.2 cm diameter and as long as the distance to the point of gas use
- 3 PVC "T " pieces each attached to a 1.2-cm diameter, 30-cm long pipe (for gas storage and water trap)
- Rubber straps to tie all the joints to make them airtight

Installation of the Plastic Tubular Digester

The digester requires a trough-shaped trench with a top width of 65 cm, a bottom width of 50 cm, a depth of 65 cm and variable length, depending on the number of animals. For a 2-cow or 8-pig unit, 8-10 m is adequate. The trench should have a flat floor, firm sides and a gentle slope (about 5%) to ensure overflow of exhausted slurry.

One of the 2 polythene tubes is inserted into the other to create a double layer for added strength. Each of the 2 openings of the plastic tube is folded around the one-meter, 10-15-cm diameter PVC pipe and an airtight joint is formed using tyre-tube straps to ensure air-tightness. One end becomes the inlet while the other becomes the outlet. A small hole (about one centimetre in diameter) is punctured through the 2 walls about 1 meter from the inlet end. A piece of 1.2 cm diameter, 30 cm long PVC pipe is then inserted into the dome and an airtight joint made. The gas pipe is fitted to the external end of this pipe. The gas pipe passes through the 1.2 cm diameter PVC "T" whose stem is a 30 cm PVC pipe.

The 3 - 4m polythene tube is sealed on one end by folding and tying it into an airtight joint while the other end is folded and connected to the stem of the PVC "T", thus completing the gas storage structure. The gas tube then passes on to yet another PVC "T" whose stem dips into a container of water to allow bubbling of gas in excess of the gas storage capacity. The gas tube is finally connected to a 1.2cm diameter piece of pipe which is equipped with a gas control valve and connected to the gas burner or stove.

To set the system in motion, the digester is laid horizontally in the trough-like tunnel with the inlet, outlet and gas tube facing upwards. Animal waste/water mixture in the ration of 3:1 is fed into the digester until it is about 75% full. The system is then given about 1 week to activate, after which the gas can be used. To keep the system active, it should be fed with a thoroughly stirred mixture of one-20-litre bucket of animal waste and 3 similar buckets of water as often as necessary, but most often daily.

Management of the Plastic Tubular Digester

Underfeeding reduces the amount of gas produced while overfeeding results in incomplete digestion and hence less gas production. Green effluent suggests overloading. A 5m^3 digester requires 19 kg of waste and 47-57 litres of water to produce enough gas for a day

The digester should be covered with grass straw, crop stover, and canvas or galvanised iron sheets to protect it from direct sun rays (ultra-violet radiation). A fence of fine wire mesh should be used

Fig. 03: **PTD components (on the left) and inlet of the PTD (Right)**

to protect the digester from damage by children, pets and livestock.

The amount of gas produced is a function of the size of the bio-digester, its feeding regime, type of substrate and environmental conditions such as air temperature. The mean volume of a 2-cow bio-digester is about 5 m^3. This will produce enough gas to cook for about 3 hours. Within this period, gas pressure drops and it is necessary to hang an object weighing 3 - 5kg at the bottom of the gas reservoir to increase pressure.

Maximum gas production will occur at 35-40°C. Methane bacteria operate best within 20-40°C. Gas production declines as temperature drops and will cease at 10°C. Tubular plastic bio-digesters are therefore not suitable for the cold highland areas.

Where to Get a Plastic Tubular Biogas Digester

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Fig. 04: **The gas generated is applied in cooking and the sludge is a soil additive**

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Executed by UN-Habitat with the support of GEF and UNEP

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