

Types of Biogas Plants

A total of seven different types of biogas plant have been officially recognised by the MNES.

1. the floating-drum plant with a cylindrical digester (KVIC model),
2. the fixed-dome plant with a brick reinforced, moulded dome (Janata model)
3. the floating-drum plant with a hemisphere digester (Pragati model)
4. the fixed-dome plant with a hemisphere digester (Deenbandhu model)
5. the floating-drum plant made of angular steel and plastic foil (Ganesh model)
6. the floating-drum plant made of pre-fabricated reinforced concrete compound units
7. the floating-drum plant made of fibre-glass reinforced polyester.

Small Scale Biogas Digester

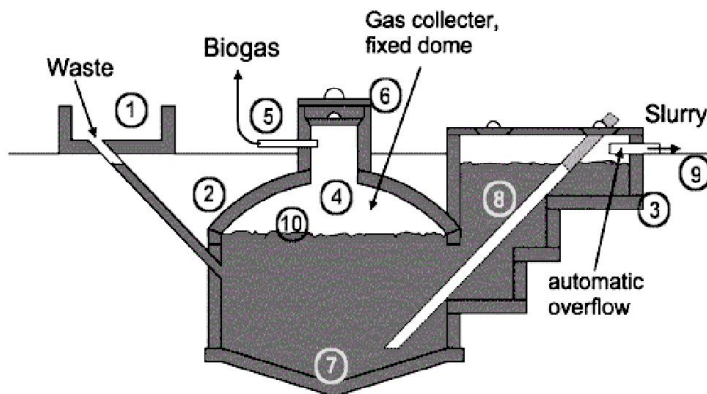
1. Fixed-dome Plants

A fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester. When gas production starts, the slurry is displaced into the compensation tank. Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank.

The costs of a fixed-dome biogas plant are relatively low. It is simple as no moving parts exist. There are also no rusting steel parts and hence a long life of the plant (20 years or more) can be expected. The plant is constructed underground, protecting it from physical damage and saving space. While the underground digester is protected from low temperatures at night and during cold seasons, sunshine and warm seasons take longer to heat up the digester. No day/night fluctuations of temperature in the digester positively influence the bacteriological processes.

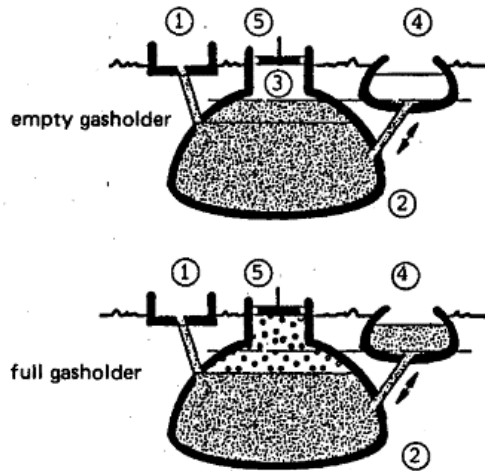
The construction of fixed dome plants is labor-intensive, thus creating local employment. Fixed-dome plants are not easy to build. They should only be built where construction can be supervised by experienced biogas technicians. Otherwise plants may not be gas-tight (porosity and cracks).

The basic elements of a fixed dome plant (here the **Nicarao Design**) are shown in the figure below.



Fixed dome plant Nicarao design:

1. Mixing tank with inlet pipe and sand trap.
2. Digester.
3. Compensation and removal tank.
4. Gasholder.
5. Gaspipe.
6. Entry hatch, with gastight seal.
7. Accumulation of thick sludge.
8. Outlet pipe.
9. Reference level.
10. Supernatant scum, broken up by varying level.



Basic function of a fixed-dome biogas plant, 1 Mixing pit, 2 Digester, 3 Gasholder, 4 Displacement pit, 5 Gas pipe

Function - A fixed-dome plant comprises of a closed, dome-shaped digester with an immovable, rigid gas-holder and a displacement pit, also named 'compensation tank'. The gas is stored in the upper part of the digester. When gas production commences, the slurry is displaced into the compensating tank. Gas pressure increases with the volume of gas stored, i.e. with the height difference between the two slurry levels. If there is little gas in the gas-holder, the gas pressure is low.

Digester - The digesters of fixed-dome plants are usually masonry structures, structures of cement and ferro-cement exist. Main parameters for the choice of material are:

- Technical suitability (stability, gas- and liquid tightness);
- cost-effectiveness;
- availability in the region and transport costs;
- availability of local skills for working with the particular building material.

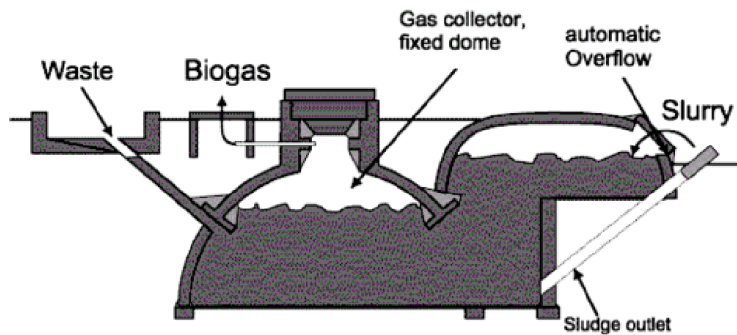
Fixed dome plants produce just as much gas as floating-drum plants, *if they are gas-tight*. However, utilization of the gas is less effective as the gas pressure fluctuates substantially. Burners and other simple appliances cannot be set in an optimal way. If the gas is required at constant pressure (e.g., for engines), a gas pressure regulator or a floating gas-holder is necessary.

Gas Holder - The top part of a fixed-dome plant (the gas space) must be gas-tight. Concrete, masonry and cement rendering are not gas-tight. The gas space must therefore be painted with a gas-tight layer (e.g. 'Water-proofer', Latex or synthetic paints). A possibility to reduce the risk of cracking of the gas-holder consists in the construction of a weak-ring in the masonry of the digester. This "ring" is a flexible joint between the lower (water-proof) and the upper (gas-proof) part of the hemispherical structure. It prevents cracks that develop due to the hydrostatic pressure in the lower parts to move into the upper parts of the gas-holder.

Types of Fixed Dome Plants

- **Chinese fixed-dome plant** is the archetype of all fixed dome plants. Several million have been constructed in China. The digester consists of a cylinder with round bottom and top.
- **Janata model** was the first fixed-dome design in India, as a response to the Chinese fixed dome plant. It is not constructed anymore. The mode of construction lead to cracks in the gasholder - very few of these plant had been gas-tight.

- **Deenbandhu**, the successor of the Janata plant in India, with improved design, was more crack-proof and consumed less building material than the Janata plant. with a hemispherical digester
- **CAMARTEC model** has a simplified structure of a hemispherical dome shell based on a rigid foundation ring only and a calculated joint of fraction, the so-called weak / strong ring. It was developed in the late 80s in Tanzania.



CAMARTEC model

Climate and Size - Fixed-dome plants must be covered with earth up to the top of the gas-filled space to counteract the internal pressure (up to 0,15 bar). The earth cover insulation and the option for internal heating makes them suitable for colder climates. Due to economic parameters, the recommended minimum size of a fixed-dome plant is 5 m³. Digester volumes up to 200 m³ are known and possible.

Advantages: Low initial costs and long useful life-span; no moving or rusting parts involved; basic design is compact, saves space and is well insulated; construction creates local employment.

Advantages are the relatively low construction costs, the absence of moving parts and rusting steel parts. If well constructed, fixed dome plants have a long life span. The underground construction saves space and protects the digester from temperature changes. The construction provides opportunities for skilled local employment.

Disadvantages: Masonry gas-holders require special sealants and high technical skills for gas-tight construction; gas leaks occur quite frequently; fluctuating gas pressure complicates gas utilization; amount of gas produced is not immediately visible, plant operation not readily understandable; fixed dome plants need exact planning of levels; excavation can be difficult and expensive in bedrock.

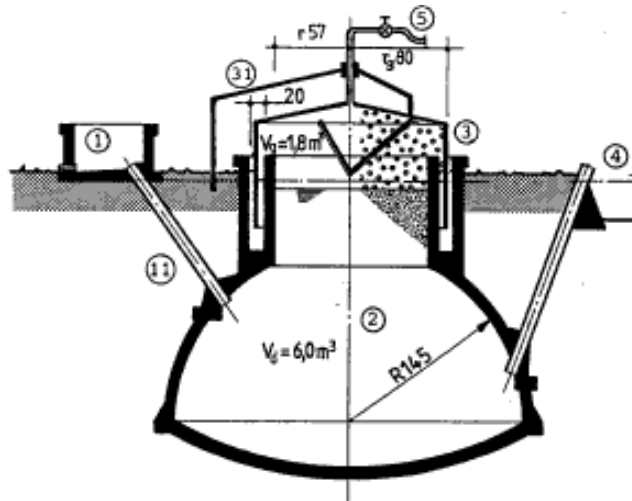
Disadvantages are mainly the frequent problems with the gas-tightness of the brickwork gas holder (a small crack in the upper brickwork can cause heavy losses of biogas). Fixed-dome plants are, therefore, recommended only where construction can be supervised by experienced biogas technicians. The gas pressure fluctuates substantially depending on the volume of the stored gas. Even though the underground construction buffers temperature extremes, digester temperatures are generally low.

Fixed dome plants can be recommended only where construction can be supervised by experienced biogas technicians.

Variations: Some companies are now looking into small pre-fab fixed dome plants made of fibreglass which appears to be a low cost alternative to construction intensive masoned plants. A custom made plant can be produced in 2 days and -after transport- installed in less than 1 day!

2. Floating Drum Plants

Floating-drum plants consist of an underground digester and a moving gas-holder. The gas-holder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. The gas drum is prevented from tilting by a guiding frame. If the drum floats in a water jacket, it cannot get stuck, even in substrate with high solid content.



Drum - In the past, floating-drum plants were mainly built in India. A floating-drum plant consists of a cylindrical or dome-shaped digester and a moving, floating gas-holder, or drum. The gas-holder floats either directly in the fermenting slurry or in a separate water jacket. The drum in which the biogas collects has an internal and/or external guide frame that provides stability and keeps the drum upright. If biogas is produced, the drum moves up, if gas is consumed, the gas-holder sinks back.

Size - Floating-drum plants are used chiefly for digesting animal and human feces on a continuous-feed mode of operation, i.e. with daily input. They are used most frequently by small- to middle-sized farms (digester size: 5-15m³) or in institutions and larger agro-industrial estates (digester size: 20-100m³).

Disadvantages: The steel drum is relatively expensive and maintenance-intensive. Removing rust and painting has to be carried out regularly. The life-time of the drum is short (up to 15 years; in tropical coastal regions about five years). If fibrous substrates are used, the gas-holder shows a tendency to get "stuck" in the resultant floating scum.

Water Jacket Floating Drum Plant

Water-jacket plants are universally applicable and easy to maintain. The drum cannot get stuck in a scum layer, even if the substrate has a high solids content. Water-jacket plants are characterized by a long useful life and a more aesthetic appearance (no dirty gas-holder). Due to their superior sealing of the substrate (hygiene!), they are recommended for use in the fermentation of night soil. The extra cost of the masonry water jacket is relatively modest.

Material of Digester and Drum

The digester is usually made of brick, concrete or quarry-stone masonry with plaster. The gas drum normally consists of 2.5 mm steel sheets for the sides and 2 mm sheets for the top. It has welded-in

braces which break up surface scum when the drum rotates. The drum must be protected against corrosion. Suitable coating products are oil paints, synthetic paints and bitumen paints. Correct priming is important. There must be at least two preliminary coats and one topcoat. Coatings of used oil are cheap. They must be renewed monthly. Plastic sheeting stuck to bitumen sealant has not given good results. In coastal regions, repainting is necessary at least once a year, and in dry uplands at least every other year. Gas production will be higher if the drum is painted black or red rather than blue or white, because the digester temperature is increased by solar radiation. Gas drums made of 2 cm wire-mesh-reinforced concrete or fiber-cement must receive a gas-tight internal coating. The gas drum should have a slightly sloping roof, otherwise rainwater will be trapped on it, leading to rust damage. An excessively steep-pitched roof is unnecessarily expensive and the gas in the tip cannot be used because when the drum is resting on the bottom, the gas is no longer under pressure.

Floating-drums made of glass-fiber reinforced plastic and high-density polyethylene have been used successfully, but the construction costs are higher compared to using steel. Floating-drums made of wire-mesh-reinforced concrete are liable to hairline cracking and are intrinsically porous. They require a gas-tight, elastic internal coating. PVC drums are unsuitable because they are not resistant to UV.

Guide Frame

The side wall of the gas drum should be just as high as the wall above the support ledge. The floating-drum must not touch the outer walls. It must not tilt, otherwise the coating will be damaged or it will get stuck. For this reason, a floating-drum always requires a guide. This guide frame must be designed in a way that allows the gas drum to be removed for repair. The drum can only be removed if air can flow into it, either by opening the gas outlet or by emptying the water jacket.

The floating gas drum can be replaced by a balloon above the digester. This reduces construction costs but in practice problems always arise with the attachment of the balloon to the digester and with the high susceptibility to physical damage.

Types of Floating Drum Plants

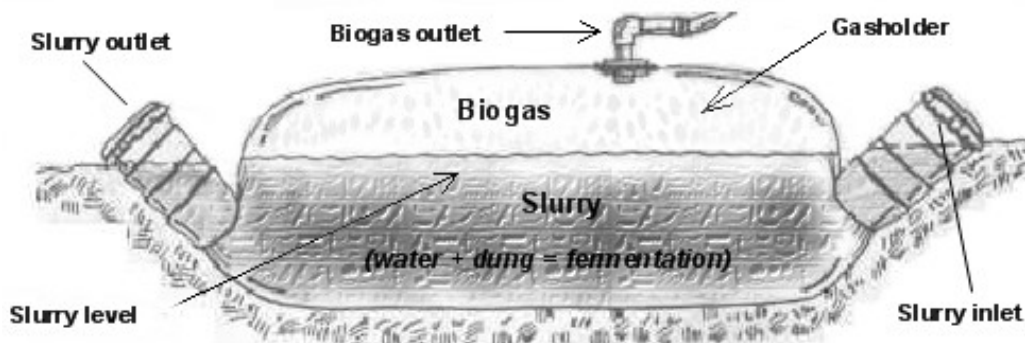
- **KVIC model** with a cylindrical digester, the oldest and most widespread floating drum biogas plant from India.
- **Pragati model** with a hemisphere digester
- **Ganesh model** made of angular steel and plastic foil
- floating-drum plant made of pre-fabricated reinforced concrete compound units
- floating-drum plant made of fibre-glass reinforced polyester
- low cost floating-drum plants made of plastic water containers or fiberglass drums: ARTI Biogas plants
- **BORDA model:** The BORDA-plant combines the static advantages of hemispherical digester with the process-stability of the floating-drum and the longer life span of a water jacket plant.

Advantages: Advantages are the simple, easily understood operation - the volume of stored gas is directly visible. The gas pressure is constant, determined by the weight of the gas holder. The construction is relatively easy, construction mistakes do not lead to major problems in operation and gas yield.

Disadvantages: Disadvantages are high material costs of the steel drum, the susceptibility of steel parts to corrosion. Because of this, floating drum plants have a shorter life span than fixed-dome plants and regular maintenance costs for the painting of the drum.

3. Low Cost Polyethylene Tube Digester

Digester - In the case of the Low-Cost Polyethylene Tube Digester model which is applied in Bolivia (Peru, Ecuador, Colombia, Centro America and Mexico), the tubular polyethylene film (two coats of 300 microns) is bended at each end around a 6 inch PVC drainpipe and is wound with rubber strap of recycled tire-tubes. With this system a hermetic isolated tank is obtained.



One of the 6" PVC drainpipes serves as inlet and the other one as the outlet of the slurry. In the tube digester finally, a hydraulic level is set up by itself, so that as much quantity of added prime matter (the mix of dung and water) as quantity of fertilizer leave by the outlet. Because the tubular polyethylene is flexible, it is necessary to construct a "cradle" which will accommodate the reaction tank, so that a trench is excavated.

Gas Holder and Gas Storage Reservoir - The capacity of the gasholder corresponds to 1/4 of the total capacity of the reaction tube. To overcome the problem of low gas flow rates, two 200 microns tubular polyethylene reservoirs are installed close to the kitchen, which gives a 1,3 m³ additional gas storage.



4. Balloon Plants - A balloon plant consists of a heat-sealed plastic or rubber bag (balloon), combining digester and gas-holder. The gas is stored in the upper part of the balloon. The inlet and outlet are attached directly to the skin of the balloon. Gas pressure can be increased by placing weights on the balloon. If the gas pressure exceeds a limit that the balloon can withstand, it may damage the skin. Therefore, safety valves are required. If higher gas pressures are needed, a gas pump is

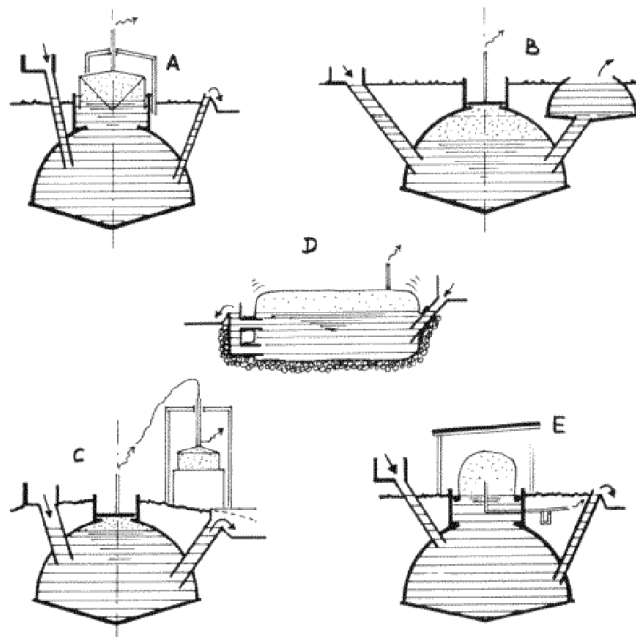
required. Since the material has to be weather- and UV resistant, specially stabilized, reinforced plastic or synthetic caoutchouc is given preference. Other materials which have been used successfully include RMP (red mud plastic), Trevira and butyl. The useful life-span does usually not exceed 2-5 years.

Advantages: Standardized prefabrication at low cost, low construction sophistication, ease of transportation, shallow installation suitable for use in areas with a high groundwater table; high digester temperatures in warm climates; uncomplicated cleaning, emptying and maintenance; difficult substrates like water hyacinths can be used.

Balloon biogas plants are recommended, if local repair is or can be made possible and the cost advantage is substantial.

Disadvantages: Low gas pressure may require gas pumps; scum cannot be removed during operation; the plastic balloon has a relatively short useful life-span and is susceptible to mechanical damage and usually not available locally. In addition, local craftsmen are rarely in a position to repair a damaged balloon. There is only little scope for the creation of local employment and, therefore, limited self-help potential.

Variations: A variation of the balloon plant is the channel-type digester, which is usually covered with plastic sheeting and a sunshade. Balloon plants can be recommended wherever the balloon skin is not likely to be damaged and where the temperature is even and high.



Simple biogas plants. Floating-drum plant (A), fixed-dome plant (B), fixed-dome plant with separate gas holder (C), balloon plant (D), channel-type digester with plastic sheeting and sunshade (E).

5. Horizontal Plants - Horizontal biogas plants are usually chosen when shallow installation is called for (groundwater, rock). They are made of masonry or concrete.

Advantages: Shallow construction despite large slurry space.

Disadvantages: Problems with gas-space leakage, difficult elimination of scum.

6. Earth Pit Plants - Masonry digesters are not necessary in stable soil (e.g. laterite). It is sufficient to line the pit with a thin layer of cement (wire-mesh fixed to the pit wall and plastered) in order to prevent seepage. The edge of the pit is reinforced with a ring of masonry that also serves as anchorage for the gas-holder. The gas-holder can be made of metal or plastic sheeting. If plastic sheeting is used, it must be attached to a quadratic wooden frame that extends down into the slurry and is anchored in place to counter its buoyancy. The requisite gas pressure is achieved by placing weights on the gas-holder. An overflow point in the peripheral wall serves as the slurry outlet.

Advantages: Low cost of installation (as little as 20% of a floating-drum plant); high potential for self help approaches.

Disadvantages: Short useful life; serviceable only in suitable, impermeable types of soil.

Earth-pit plants can only be recommended for installation in impermeable soil located above the groundwater table. Their construction is particularly inexpensive in connection with plastic sheet gas-holders.

7. Ferrocement Plants - The ferro-cement type of construction can be applied either as a self-supporting shell or an earth-pit lining. The vessel is usually cylindrical. Very small plants (Volume under 6 m³) can be prefabricated. As in the case of a fixed-dome plant, the ferrocement gasholder requires special sealing measures (proven reliability with cemented-on aluminium foil).

Advantages: Low cost of construction, especially in comparison with potentially high cost of masonry for alternative plants; mass production possible; low material input.

Disadvantages: Substantial consumption of essentially good-quality cement; workmanship must meet high quality standards; uses substantial amounts of expensive wire mesh; construction technique not yet adequately time-tested; special sealing measures for the gas-holder are necessary. Ferrocement biogas plants are only recommended in cases where special ferro-cement know-how is available.

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