Bio mass energy

Dayananda Sagar University

Reliable source of energy

Introduction

- Biomass Energy is one of the oldest fuel sources around.
- We have burned wood for a very long time.
- However today we have much more efficient ways to extract the energy.
- Biomass is stored solar energy that man can convert to electricity, fuel or heat.
- Through photosynthesis the energy from the sun is stored in the chemical bonds of the plant material.
- Photosynthesis is the making (synthesis) of organic structures and chemical energy stores by the action of solar radiation (photo).

- The material of plants and animals, including their wastes and residues, is called *biomass*
- It is organic, carbon-based, material that reacts with oxygen in combustion and natural metabolic processes to release heat
- The initial material may be transformed by chemical and biological processes to produce *biofuels*, i.e. biomass processed into a more convenient form, particularly liquid fuels for transport

Biomass resources fall into three categories

1) Biomass in its traditional solid mass(wood and agriculture residue, solid waste)
2) Liquid fuels
3) Gaseous fuels

Direct combustion for heat

Biomass is burnt to provide heat for cooking, comfort heat (space heat), crop drying, factory processes and raising steam for electricity production and transport.

Traditional use of biomass combustion includes

- (a) cooking with firewood, with the latter supplying about 10–20% of global energy use (a proportion extremely difficult to assess)
- (b) commercial and industrial use for heat and power, e.g. for sugarcane milling, tea or copra drying, oil palm processing and paper making. Efficiency and minimum pollution is aided by having dry fuel and controlled, high temperature combustion.

Domestic cooking and heating

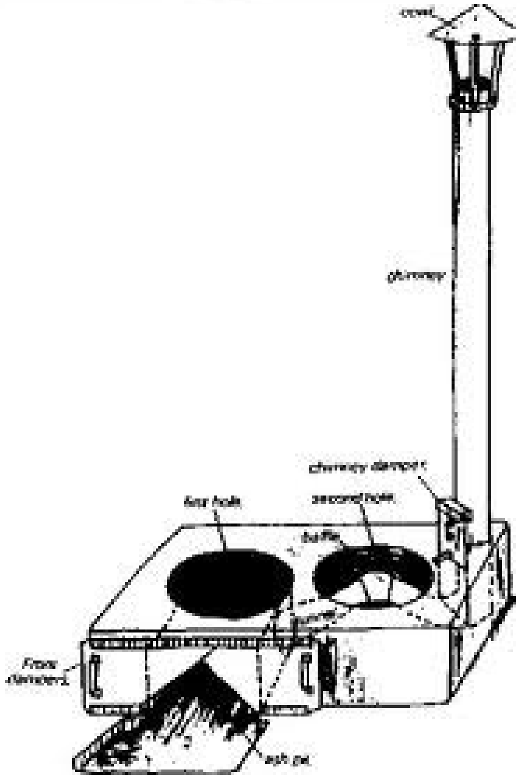
A significant proportion of the world's population depends on fuel wood or other biomass for cooking, heating and other domestic uses.

Average daily consumption of fuel is about 0.5–1 kg of dry biomass per person, i.e. 10–20MJper day ≈ 150W.
Multiplied by, say, 2×10^9 people, this represents energy usage at the very substantial rate of 300GW.

- Such a large consumption arises from the widespread use of inefficient cooking methods, the most common of which is still an open fire.

- This ‘device’ has a thermal efficiency of only about 5%. That is, only about 5% of the heat that could be released by complete combustion of the wood reaches the interior of the cooking pot.

- The rest is lost by incomplete combustion of the wood, by wind and light breezes carrying heat away from the fire, and by radiation losses, etc. resulting from the mismatch of fire and pot size


chimney
second hole
baffle

Cooking efficiency and facilities can be improved by

1 Using dry fuel.
2 Introducing alternative foods and cooking methods, e.g. steam cookers.
3 Decreasing heat losses using enclosed burners or stoves, and well-fitting pots with lids.
4 Facilitating the secondary combustion of un burnt flue gases.
5 Introducing stove controls that are robust and easy to use.
6 Explanation, training and management
7.Air preheating

With these improvements, the best cooking stoves using fuell wood and natural air circulation can place more than 20% of the combustion energy into the cooking pots.

Designs using forced and actively controlled ventilation, say with an electric fan, can be more efficient.

There are many scientifically based programs to improve cooking stoves, yet full market acceptability is not always reached, especially if cultural and gender factors are not considered adequately.

A major difficulty of ‘efficient’ stoves may be the difficulty of obtaining rapid heat.

The combustion of firewood is a complex and varying process.

Much depends on the type of wood and its moisture content.

Initial combustion releases CO, which itself should burn in surplus air.

At temperatures greater than 370C, calcium oxalate in the wood breaks down with the release of some oxygen, so improving combustion and reducing particulate and combustible emissions.

Crop drying

Process heat and electricity

Steam process heat is commonly obtained for factories by burning wood or other biomass residues in boilers, perhaps operating with fluidized beds

It is physically sensible to use the steam first to generate electricity before the heat degrades to a lower useful temperature.

The efficiency of electricity generation from the biomass may be only about 20–25% due to low temperature combustion, so 75–80% of the energy remains as process heat and a useful final temperature is maintained.

Frequently the optimum operation of such processes treats electricity as a by-product of process heat generation, with excess electricity being sold to the local electricity supply agency, as in modern sugarcane mills

Thermal Gasification of Biomass

Gasification I implies converting a solid or liquid into a gaseous fuel

Gasifier: It is an equipement which can gasify a variety of biomass such as wood waste, agriulture waste like stalks and roots of various crops,maize cobs etc.

The gasifier is essentially a chemical reactor where various complex physical and physical and chemical process take place .
Biomass gets dried , heated ,pyrololised, partially oxidised and reduced as it flows through it

Thermal gasification of biomass

In which solid fuel is converted by a series of thermochemical processes like drying, pyrolysis, oxidation and reduction to a gaseous fuel called producer gas

When atmospheric air is supplied in limited the gas produced essentially consists of mainly

Carbon monoxide	18-22%
Hydrogen	13-19%
Methane	1-5%
Heavier hydrocarbons	0.2-0.4%
Carbon dioxide	9-12%
Nitrogen	45-55%
Water vapor	4%

Classification of biomass gasifier

1) The direction of gas flow
2) Out put capacity of the gasifier (small upto 10kW, large 50-300kW)
3) Type of bed, fixed or fludized

Fixed bed gasifiers

1)Up draught
2)Down draught
3)Cross draught

Updraft Gasifiers (counter current)

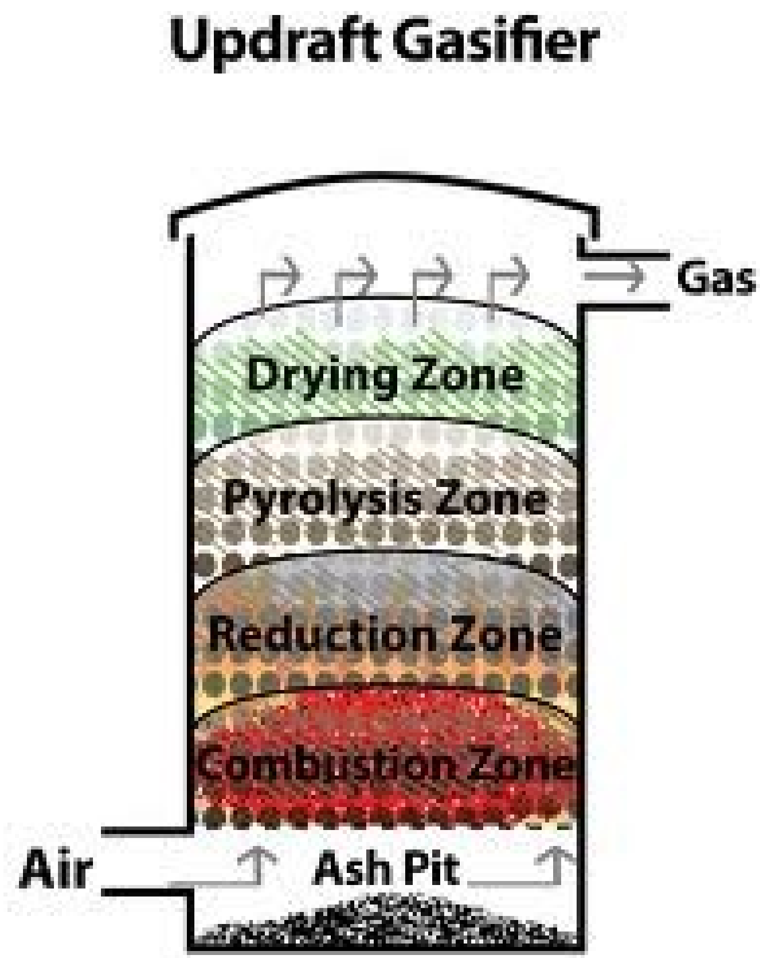
In updraft gasifiers, gas is drawn out of the gasifier from the top of the fuel bed while the gasification reactions take place near the bottom.

As the producer gas passes through the fuel bed, it picks-up volatile matter (tars) and moisture from the fuel.

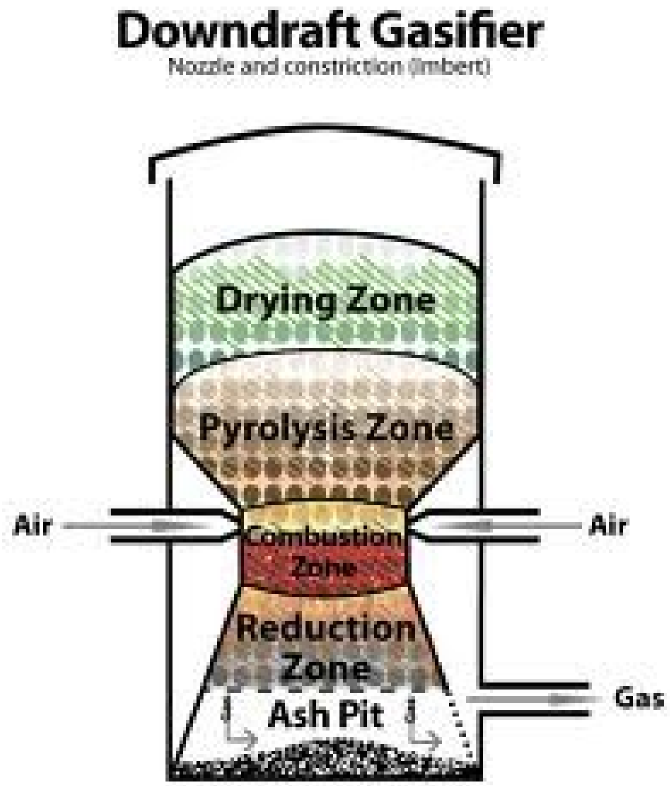
Therefore, the gas from the updraft gasifier contains condensable volatiles.

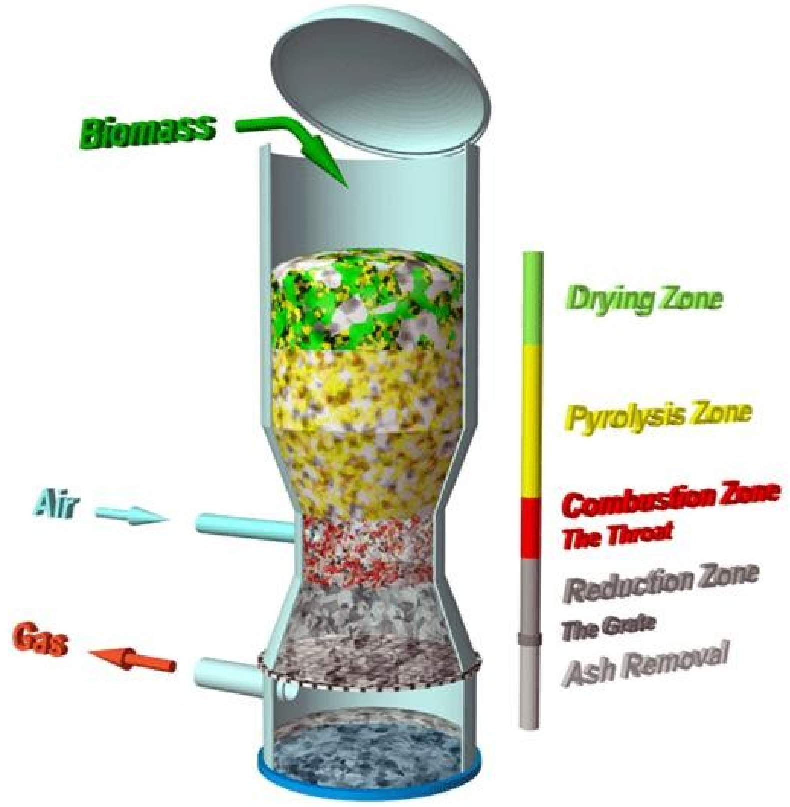
The design and operation of the gasifiers is such that the gas comes out at 200-400 C temperature.

At this temperature, most of the volatile hydrocarbons are in vapor form, which add to the energy content of the gas.



It is most appropriate to utilize updraft gasifiers in close-coupled-hot gas mode for direct heating applications. However, if the application warrants, the scrubbing of gas to remove the volatiles/tars is also carried out.



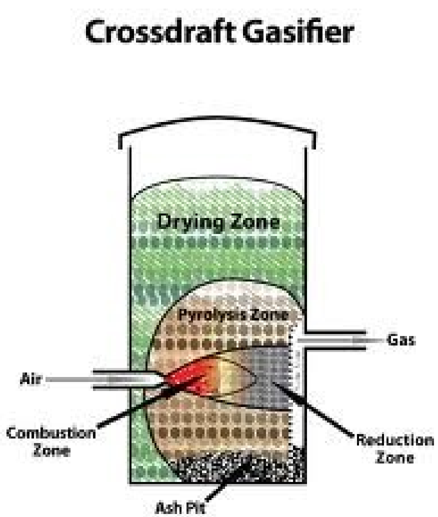


The air enters at the combustion zone and the gas produced leaves near the bottom of the gasifier.
In this type of gasifier the volatile and tar produced from the descending fixed bed have to pass through the reduction zone where they are cracked and gasified
The gas produced contains less tar and more ash

Cross Draught Gasifier

In this type of gasifier the gas produced passes upwards in the similar annular space around the gasifier

In a cross draft gasifier the air enters from one side of gasifier reactor and gas is taken out from other side.The cross draft gasifier is one of the simplest gasifier designs. It has a quick start time and reaches high temperatures which may require air or water cooled nozzles.



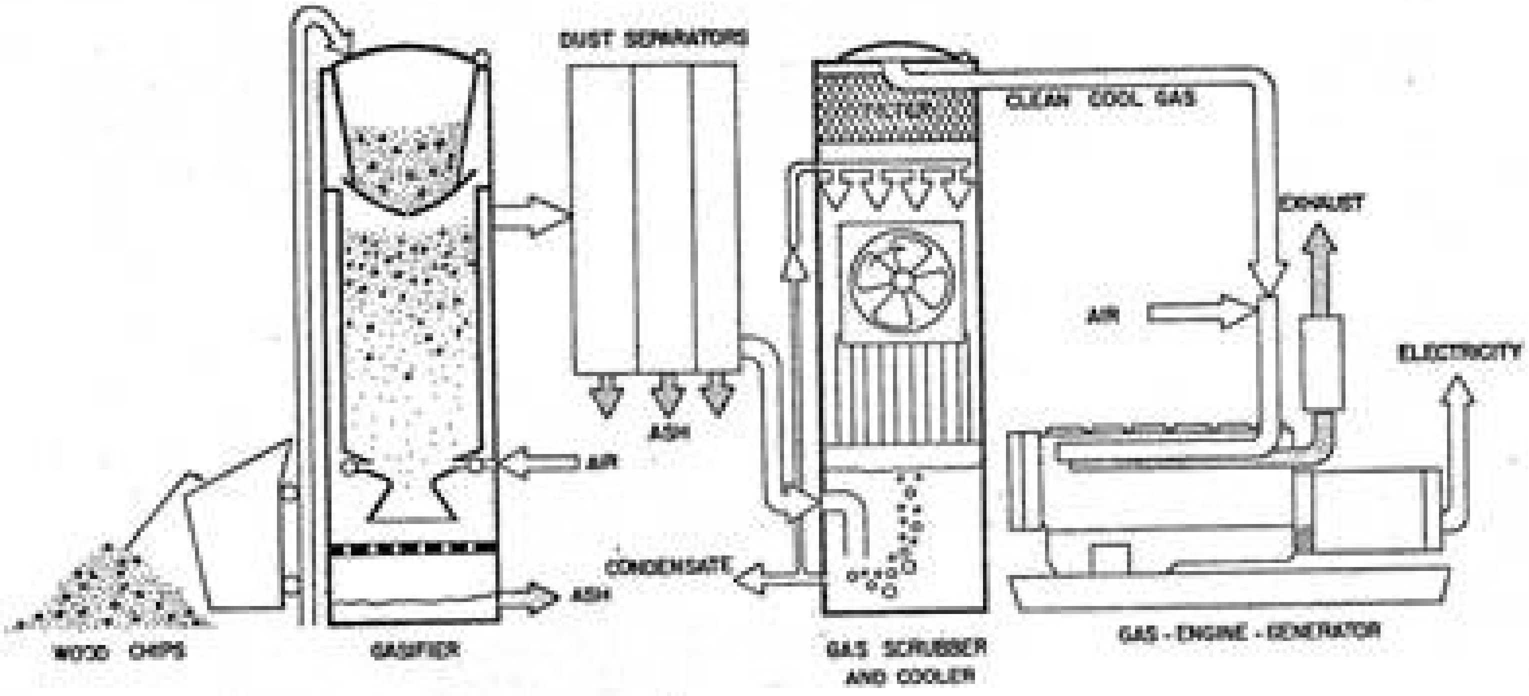
A slightly different approach to equilibrium calculations is the equivalence ratio:

$$ER = \frac{\text{weight of oxidant/weight of dry fuel}}{\text{oxidant/fuel (stochiometric weight ratio)}}$$

It is observed that for effective gasification , E R should be in the range of 0.2-0.4 .
Below ER value of 0.2 pyrolysis predominates
Above an ER value of 0.4 Combustion predominates

On an average 1 kg of biomass produces about 2.5 m^3 of producer gas at S.T.P. In this process it consumes about 1.5 m^3 of air for combustion . For complete combustion of wood about 4.5 m^3 of air is required. Thus biomass gasification consumes about 33% of theoretical stoichiometeric ratio for wood burning.

Biomass gasifier engine system



However in order for the gas to be used for any of the above applications it should be cleaned of tar and dust and be cooled. As previously mentioned cooling and cleaning of the gas is one of the most important processes in the whole gasification system.

The temperature of gas coming out of generator is normally between 300-500^{0}C. This gas has to be cooled in order to raise its energy density. Various types of cooling equipment have been used to achieve this end

Most coolers are gas to air heat exchangers where the cooling is done by free convection of air on the outside surface of heat exchanger. Since the gas also contains moisture and tar, some heat exchangers provide partial scrubbing of gas. Thus ideally the gas going to an internal combustion engine should be cooled to nearly ambient temperature.

Bio chemical conversion

a) An aerobic digestion

Bacterial decomposition, Air tight tank

b) Fermentation

Anaerobic Digestion (AD) is a natural process in which microorganisms break down organic matter, in the absence of oxygen, into biogas (a mixture of carbon dioxide (CO2) and methane) and digestate (a nitrogen-rich fertiliser).

The biogas can be used directly in engines for Combined Heat and Power (CHP), burned to produce heat, or can be cleaned and used in the same way as natural gas or as a vehicle fuel. The digestate can be used as a renewable fertiliser or soil conditioner

AD can play an important role as a means of dealing with organic waste and avoiding, by more efficient capture and treatment, the greenhouse gas emissions that are associated with its disposal to landfill. It also offers other benefits, such as recovering energy and producing valuable biofertilisers.

The biogas can be used to generate heat and electricity, converted into biofuels or cleaned and injected into the gas grid.

Bio gas is a mixture containing 55-65% methane, 30-40% carbon dioxide, and rest being H_2, H_2S, and some N_2
Can be produced from animal, plant and human waste.
Caloric value between 5000 to 5500kcal/kg or 38131 kJ/m3,
Directly used for cooking and CHP applications

Bacteria can be divided into two groups

Based on their oxygen requirement

When organic matter undergoes fermentation through anaerobic mode produces bio gas

It produces CO_2,CH_4,H_2, and traces of other gasses
Main aim is to generate methane

Complex organic molecules are broken to sugar, alcohols, pesticides and amino acids by acid producing bacteria

These products are then used to produce methane by another category of bacteria

A D takes place in three phases

1) Enzymatic hydrolysis: where starches, fats and protiens contained in the cellulosic biomass broken down to simple comounds

2) Acid formation

The biological process of acidogeniss results in further breakdown of the remaining components by acidogenic (fermentative) bacteria.

Here, VFAs are created, along with ammonia, carbon dioxide, and hydrogen sulfide as well as other byproducts.] The process of acidogenesis is similar to the way milk sours

Process takes place for about two weeks

3. Methane formation

The terminal stage of anaerobic digestion is the biological process of methanogensis
Here, methanogens use the intermediate products of the preceding stages and convert them into methane, carbon dioxide, and water.

These components make up the majority of the biogas emitted from the system.

Methanogenesis is sensitive to both high and low pHs and occurs between pH 6.5 and pH 8.

The remaining, indigestible material the microbes cannot use and any dead bacterial remains constitute the digestate.

Factors affecting generation bio gas

- PH or hydrogen –ion concentration

In the initial acid formation PH is around 6 or less and much of CO_2 given off

The digester is usually buffered with 6.5 to 7 initially In this range microorganisms will be very active If between 4-6 and 9-10 both are deter mental

Temperature :
The two conventional operational temperature levels for anaerobic digesters are determined by the species of methanogens in the digesters
Mesophilic digestion takes place optimally around 30 to 38 °C, or at ambient temperatures between 20 and 45 °C, where mesophiles are the primary microorganism present.
Thermophilic digestion takes place optimally around 49 to 57 °C, or at elevated temperatures up to 70 °C, where thermophiles are the primary microorganisms present

Total solid content: The total solid content should be 8-10%

Loading rate: Amount of raw material fed into the digester per day per unit volume.
Municipal sewage plants operate at a loading rate 0.5 to 1.6 kg of volatile solids per day

If a digester is loaded with too much raw material at a time acid will accumulate and fermentation will stop

Seeding:

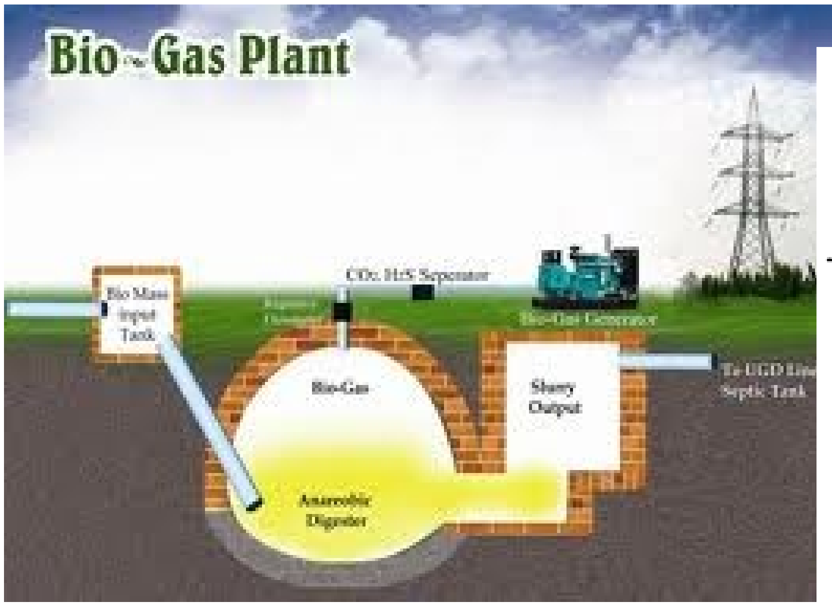
It would be adavntageous to increase the the number of methane formers by artificial seeding by digested sludge that is rich in methane formers. But beyond certain range gas production will decerse

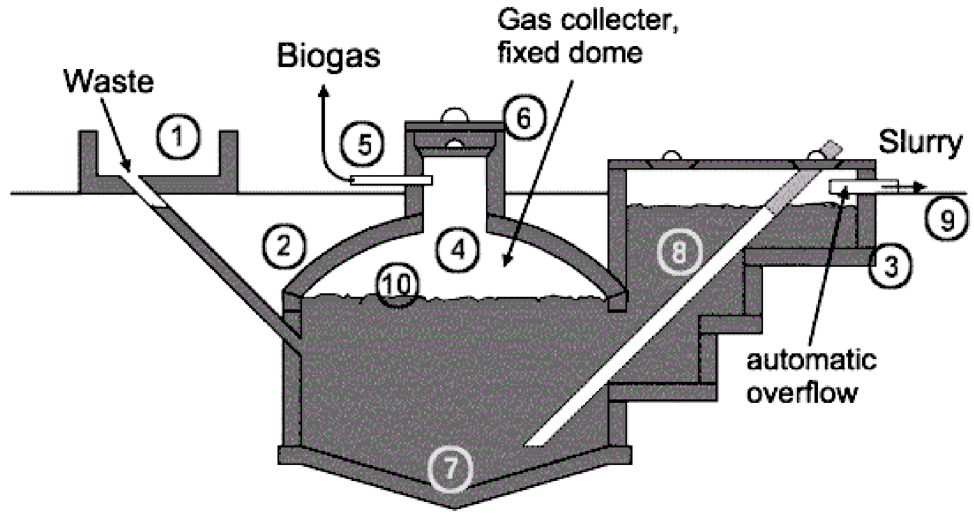
Carbon to nitrogen ration:
Bacteria use carbon 30 times faster than notrogen. C/N should be present at proper proportion.
The optimim C/N ration sholud be 30
Diameter to depth ratio: The optimum value is 0.66 to 1
Mixing stirring and agitation: bacteria should get sufficient food

Retention Time: Proper retention time is required for bio gas production

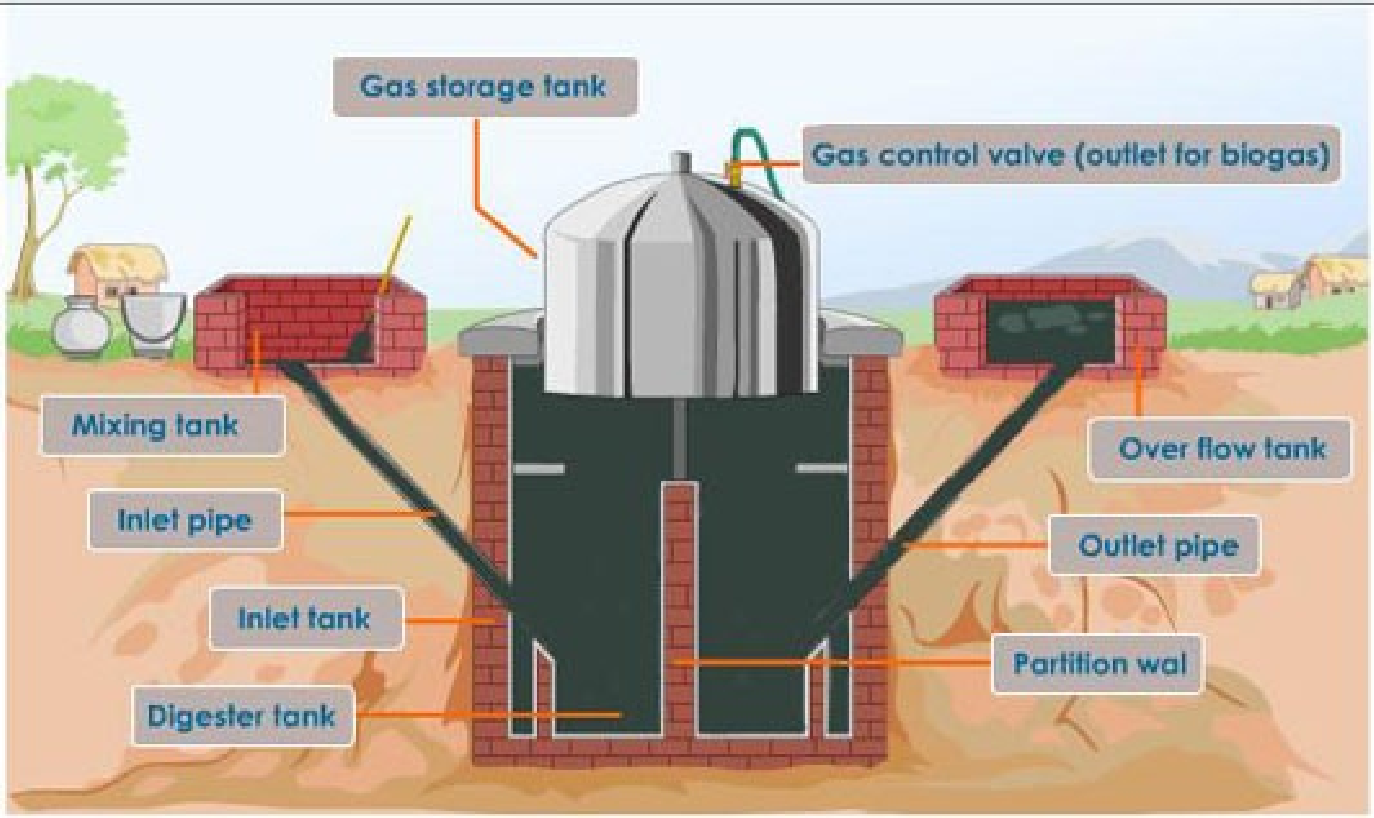
1) Cow and buffelo dung; 50 days
2) pig dung 20 days
3) Poultry droppings 20 days
4) Night soli 30 days

Bio digester:



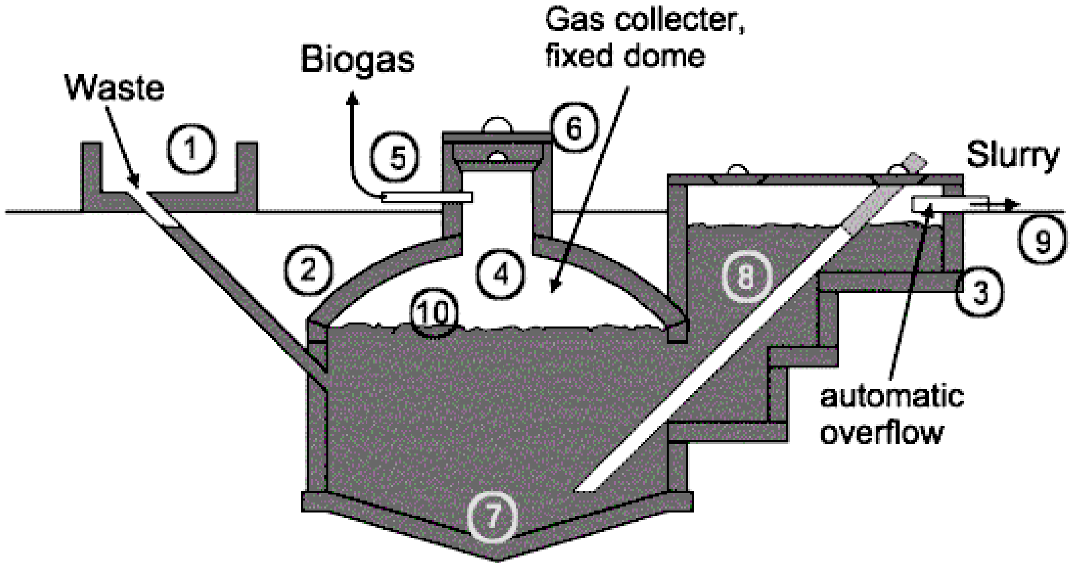


1. Mixing tank with inlet pipe and sand trap. 2. Digester. 3. Compensation and removal tank. 4. Gasholder. 5. Gaspipe. 6. Entry hatch, with gastight seal. 7. Accumulation of thick sludge. 8. Outlet pipe. 9. Reference level.



Fixed Dome type Biogas Plant

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

Digester

The digesters of fixed-dome plants are usually masonry structures, structures of cement and ferro-cement exist.

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.

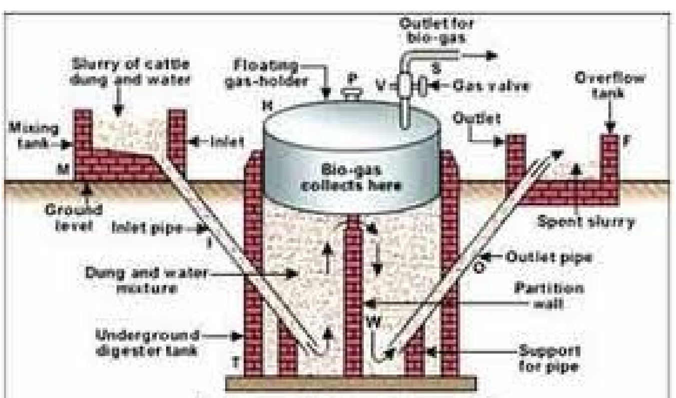
Janata model was the first fixed-dome design in India, as a response to the Chinese fixed dome plant. It is not constructed anymore. The mode of construction lead to cracks in the gasholder - very few of these plant had been gas-tight.

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 hemisphere 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 Tanzana.

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.



Floating gas-holder type bio-gas plant.

Types of Floating-drum Plants

<u>There are different types of floating-drum plants:</u>

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.