Energy Resources

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Today's Topic

- Biogas Production
- Types of Substrates
- Digester design
- Problems/Disadvantages

Biogas

- Biogas is clean environment friendly fuel.
- Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion.
- Biogas generally comprise of 55-65 % methane, 35-45 % carbon dioxide, 0.5-1.0 % hydrogen sulfide and traces of water vapour.
- The heating value of biogas is about 60% of natural gas and about 25% of propane. [Average calorific value of biogas is 20 MJ/m3].
- Biogas has corrosive nature and storage of biogas is not practical.

Why Biogas?

- Dealing with wastes has become a nightmare for various people all over the world and no doubt has brought about sanitation problems.
- Power has also become a major concern especially in the less privileged rural areas.
- Integration of these two problems would be a plus point for various communities.
- From Biogas, various components can be powered by properly making use of the gas obtained. Less pollutant manure can be obtained ultimately.


Waste
Manure
Crop wastes
Fertiliser
Energy
Organic wastes
Anaerobic digestion
Electricity and heat

Process Of Bio-digestion

- Anaerobic digestion is basically a simple process carried out in a number of steps that can use almost any organic material as a substrate.
- Conventional anaerobic digestion is a "liquid" process, where waste is mixed with water to facilitate digestion. Since biogas is a mixture of methane and carbon dioxide it is a renewable fuel.

Process Of Bio-digestion

Biogas production process (Anaerobic digestion) is a multiple-stage process in which some main stages are:

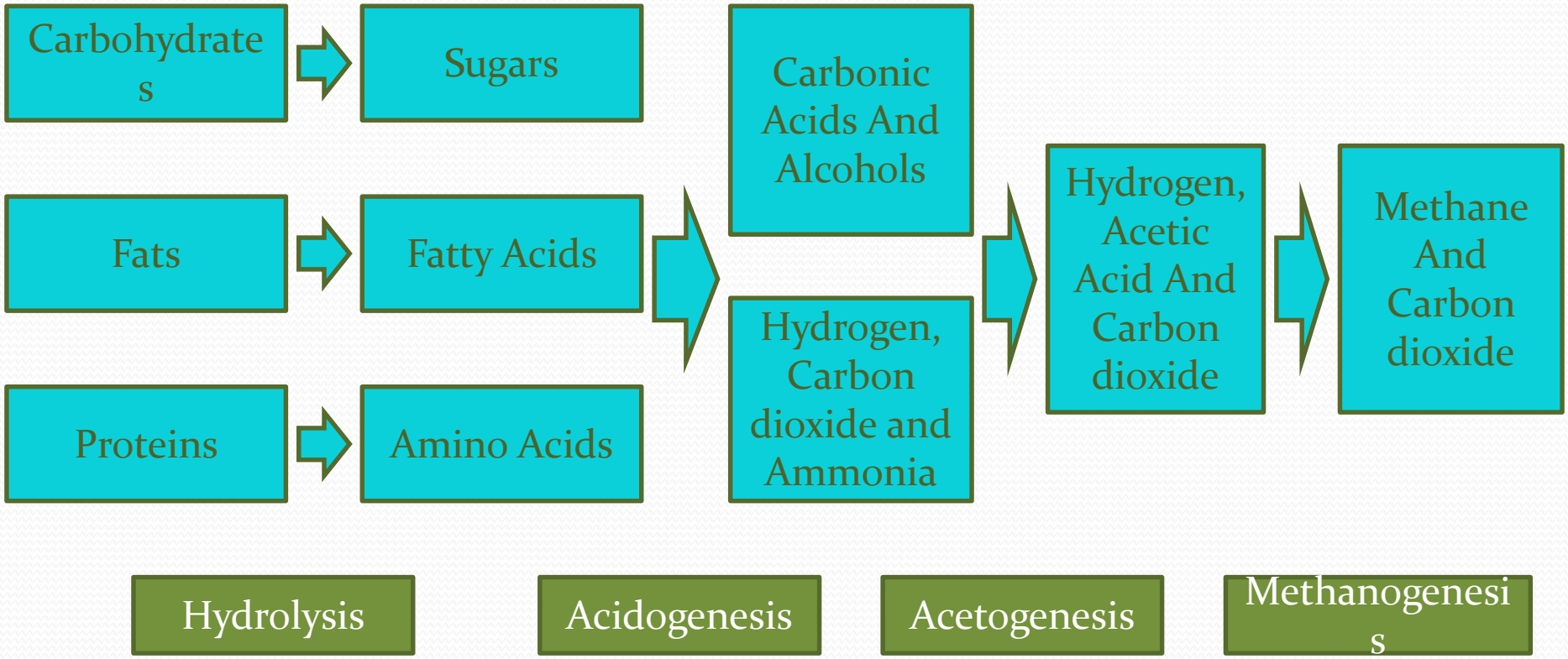
Liquefaction

Acid Production

Acetate Production

Methane Production

Process Of Bio-digestion



Process Of Biodigestion

(1) LIQUEFICATION

- Complex organic matter is degraded to basic structure by hydraulic bacteria.
  - Protein -> Polypeptide and Amino Acid
  - Fat -> Glycerin and Fatty Acid
  - Amylase -> Monosacride and Polysacride

(2) ACID PRODUCTION (Acidogenesis)

- Simple organic matters are converted into H_2 and CO_2
- Acting bacteria in this process are called hydrogen-producing bacteria and acid-producing bacteria.

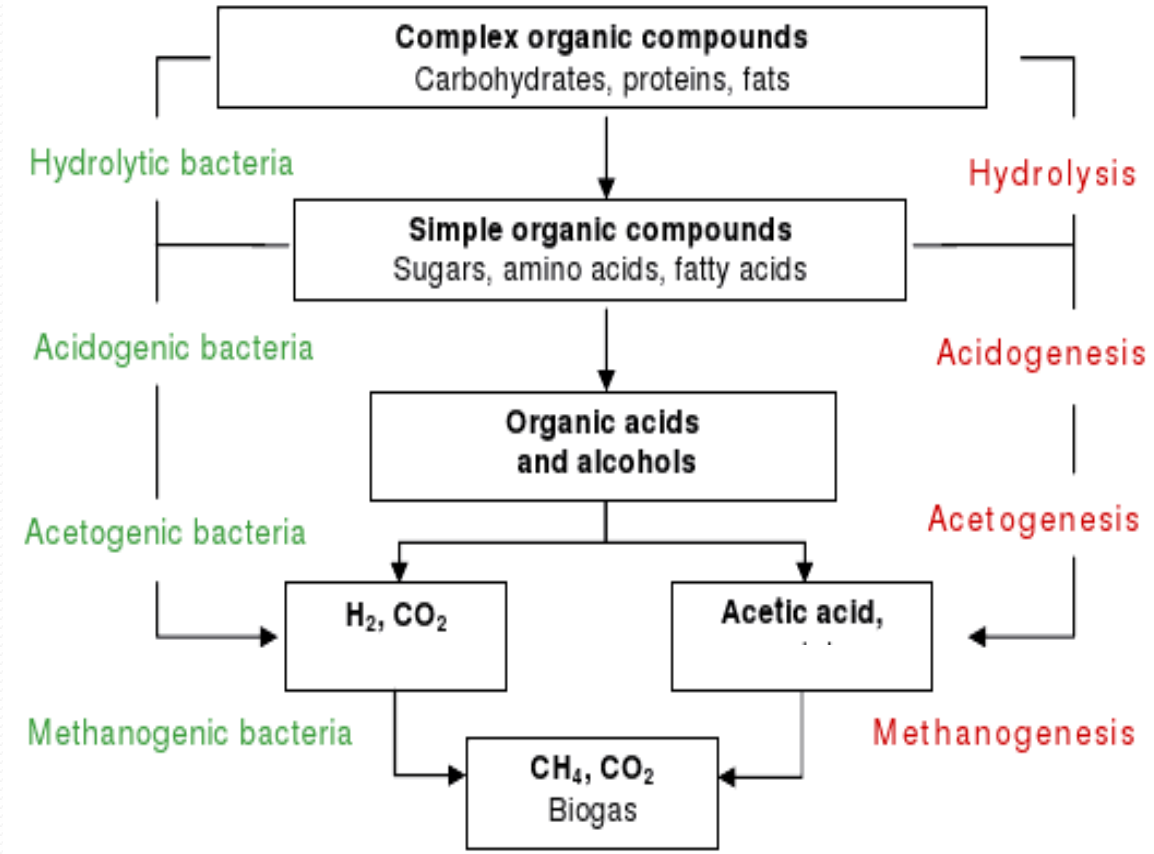
Process Of Bio-digestion

(4)ACETATE PRODUCTION (Acetogenesis)

- The short-chain fatty acids are metabolized by synthrophic acetogenic and homoacetogenic bacteria into acetate, carbon dioxide, and hydrogen.

(5)METHANE PRODUCTION (Methanogenesis)

- In this process, acetic acid, H_2, CO_2, are converted into CH_4.
- Methane-producing bacteria have strict pH requirement and low adaptability to temperature.

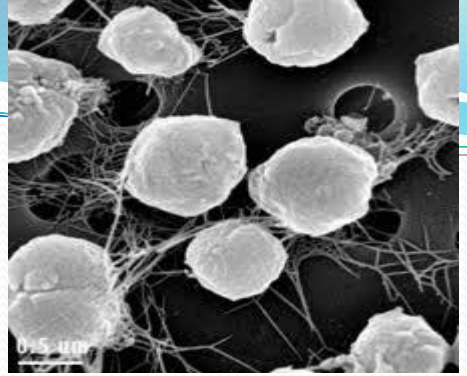

Complex organic compounds
Carbohydrates, proteins, fats
Hydrolytic bacteria
Hydrolysis
Simple organic compounds
Sugars, amino acids, fatty acids
Acidogenic bacteria
Acidogenesis
Organic acids
and alcohols
Acetogenic bacteria
Acetogenesis
H2, CO2
Acetic acid,
Methanogenic bacteria
Methanogenesis
CH4, CO2
Biogas

Methanogenic bacteria.

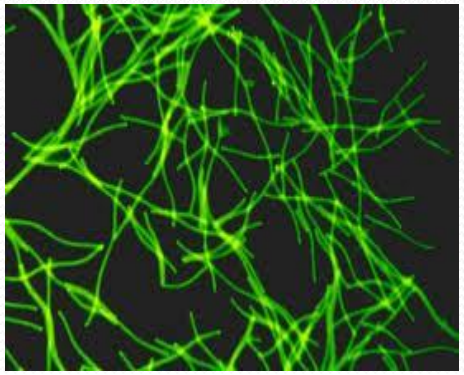
- Create methane from the final products of acetogenesis as well as from some of the intermediate products from hydrolysis and acidogenesis .

Genus	*Morphology*
Methanobacterium	Long rods or filaments
Methanomicrobium	Short rods
Methanogenium	Irregular, small cocci
Methanococcus	Irregular, small cocci
Methanobrevibacter	Lancet-shaped cocci or short rods
Methanospirillum	Short to long spiral
Methanosarcina	Pseudosarcina

- Cocci



- Spirilli

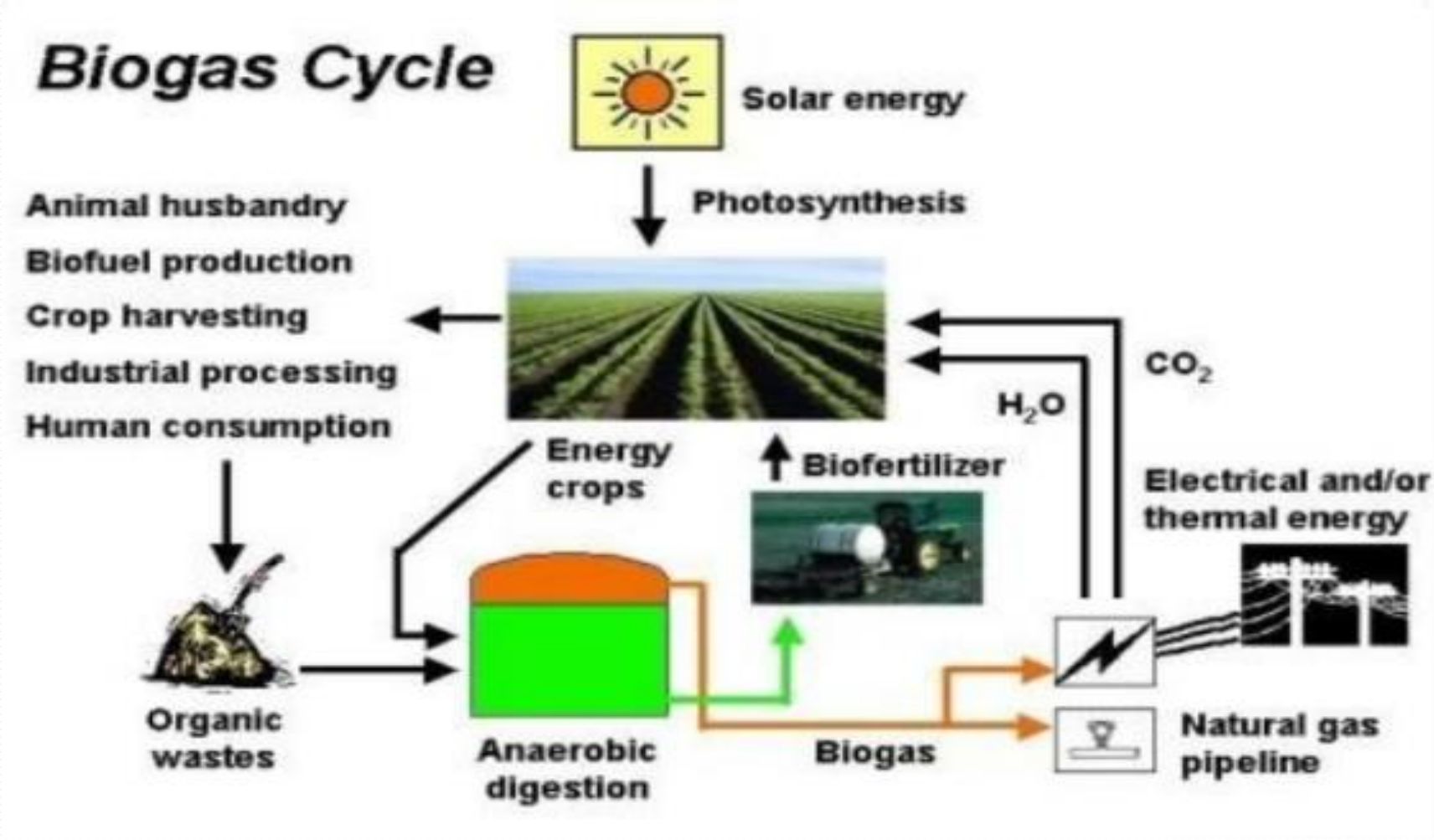


- sarcina

Cocci forming colonies in cubical packets of eight or more are called sarcina

- Methanogens are a diverse group of organisms that can live in a wide range of environments.

- They have been found in a range of salinity from freshwater to hypersaline.


Biogas Cycle
Solar energy
Photosynthesis
Animal husbandry
Biofuel production
Crop harvesting
Industrial processing
Human consumption
CO_2
H_2O
Energy crops
Biofertilizer
Electrical and/or thermal energy
Organic wastes
Anaerobic digestion
Biogas
Natural gas pipeline

Raw materials (Substrates)

- Forms of biomass listed below may be used along with water.
- Animal dung
- Poultry wastes
- Plant wastes (Husk, grass, weeds etc.)
- Human excreta
- Industrial wastes(Saw dust, wastes from food processing industries)
- Domestic wastes (Fruits & Vegetable peels, waste food materials)

Biogas Production Potential From Different Wastes

	Raw Material	Biogas Production Liters/Kg	Methane Content in biogas %
1	Cattle Dung	40	60.0
2	Green leaves and twigs	100	65.0
3	Food Waste	160	62.0
4	Bamboo Dust	53	71.5
5	Fruit waste	91	49.2
6	Bagasse	330	56.9
7	Dry Leaves	118	59.2
8	Non edible Oil Seed Cakes	242	67.5

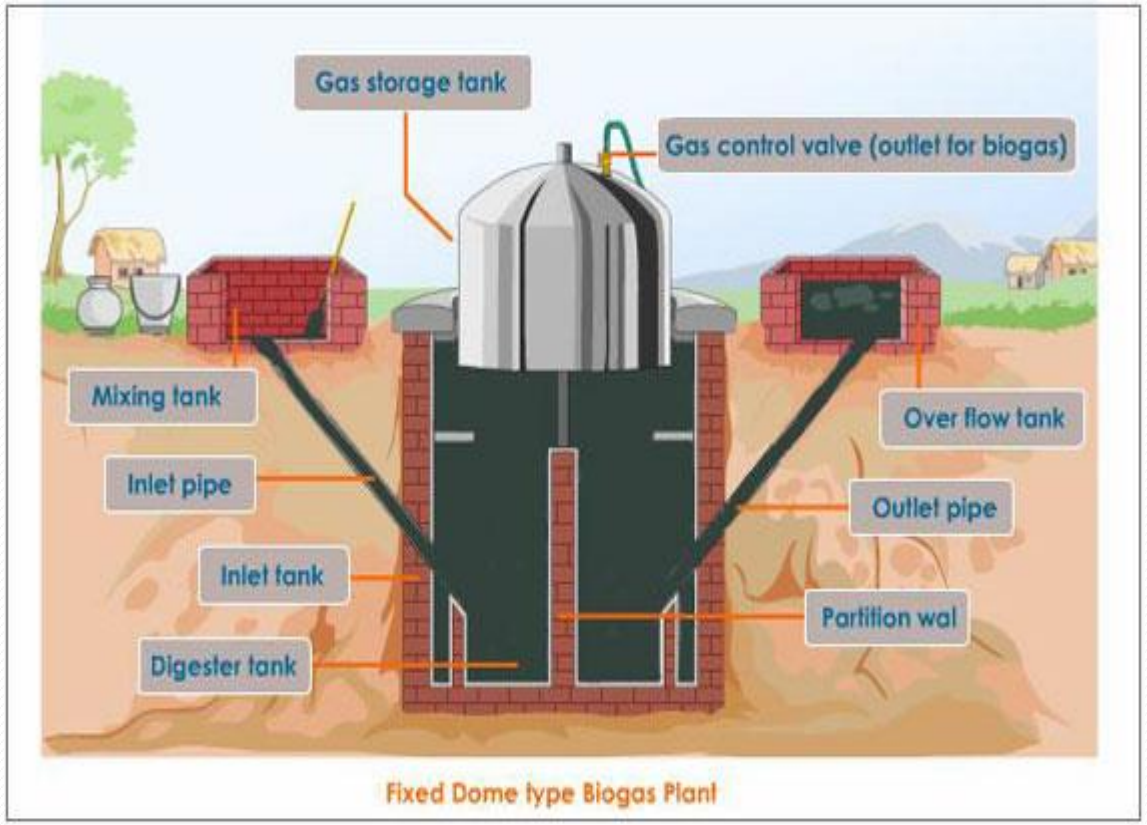
Production of Biogas - The biogas plants

There are two types of biogas plants in usage for the production of biogas. These are:

- The fixed- dome type of biogas plant
- The floating gas holder type of biogas plant

Parts of biogas plant

- Digester
- Gas holder
- Inlet
- Outlet



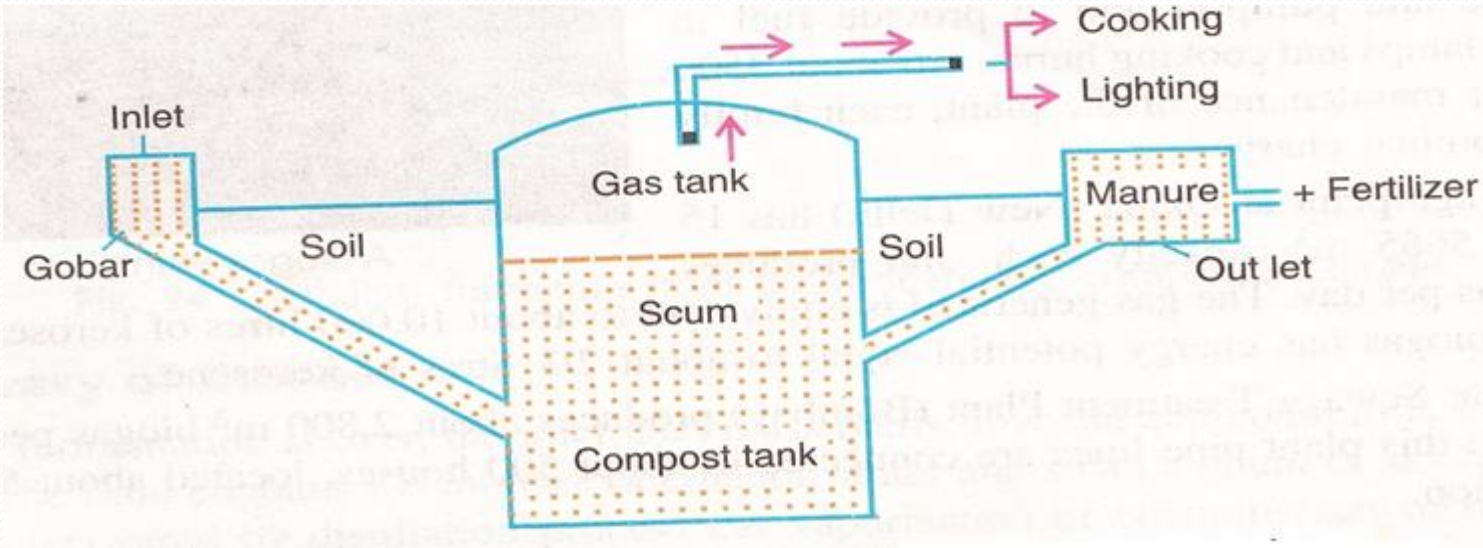
Inlet chamber

- To supply cow dung to the digester
- It is made at the ground level so that the cow dung can be poured easily.
- made up of bricks, cement and sand.
- The outlet wall of the inlet chamber is made inclined so that the cow dung easily flows to the digester.

Digester

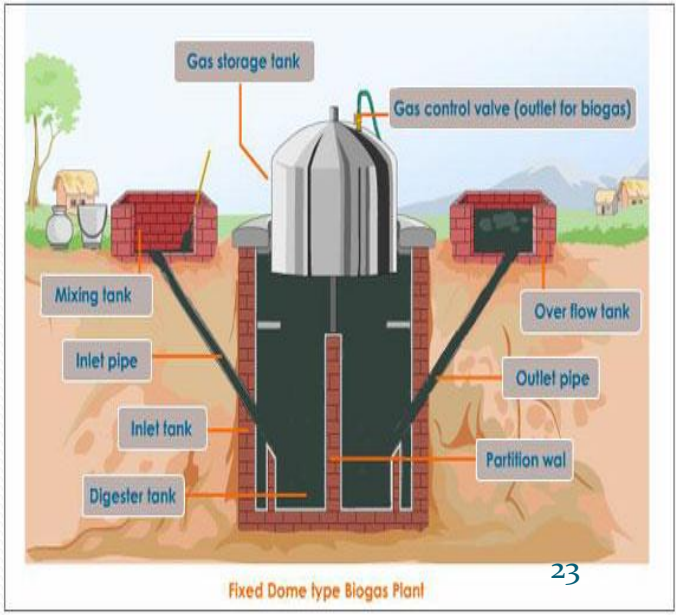
- Most important part of biogas plant
- Fermentation takes place - fermentation tank.
- Built underground – insulated,airtight
- Made up of bricks, sand and cement.

- Almost at the middle of the height of digester, two openings are provided on the opposite sides for inflow of fresh cow dung and outflow of used cow dung.



Gas holder

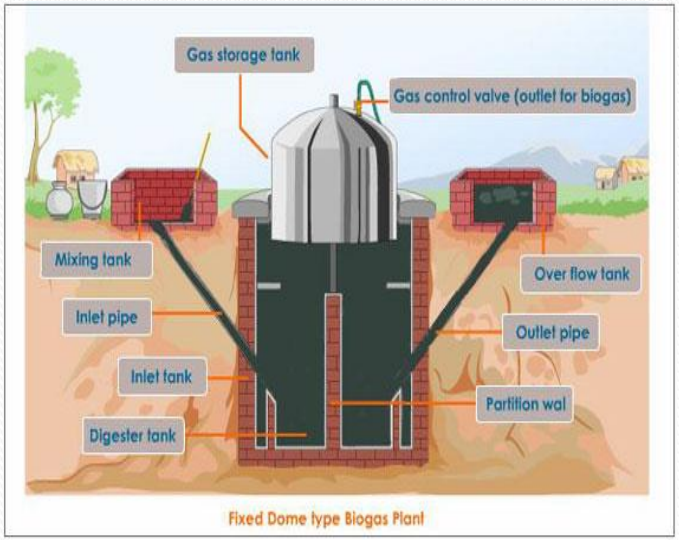
- Cylindrical container
- Above digester
- Collect gas
- The gas pipe carries the biogas to the place where it is consumed.



Outlet Chamber

- Digested slurry from which the biogas has been generated is removed from the biogas plant.

- The outlet chamber is also at the ground level.



Types

- **GAS HOLDER**
- Fixed dome type
- Floating drum type

FREQUENCY OF FILLING

SUBSTRATE

Batch type

Continuous type

Fixed dome type

- A fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester.

Floating-drum type

- **Batch type**
- Filled once,sealed.
- Emptied when raw materials stop producing gas.

- **Continuous type**
- Fed with a definite quantity of wastes at regular intervals
- Gas production continuous & regular

Fixed dome type of Biogas Plant

Construction

The biogas plant is a brick and cement structure having the following five sections:

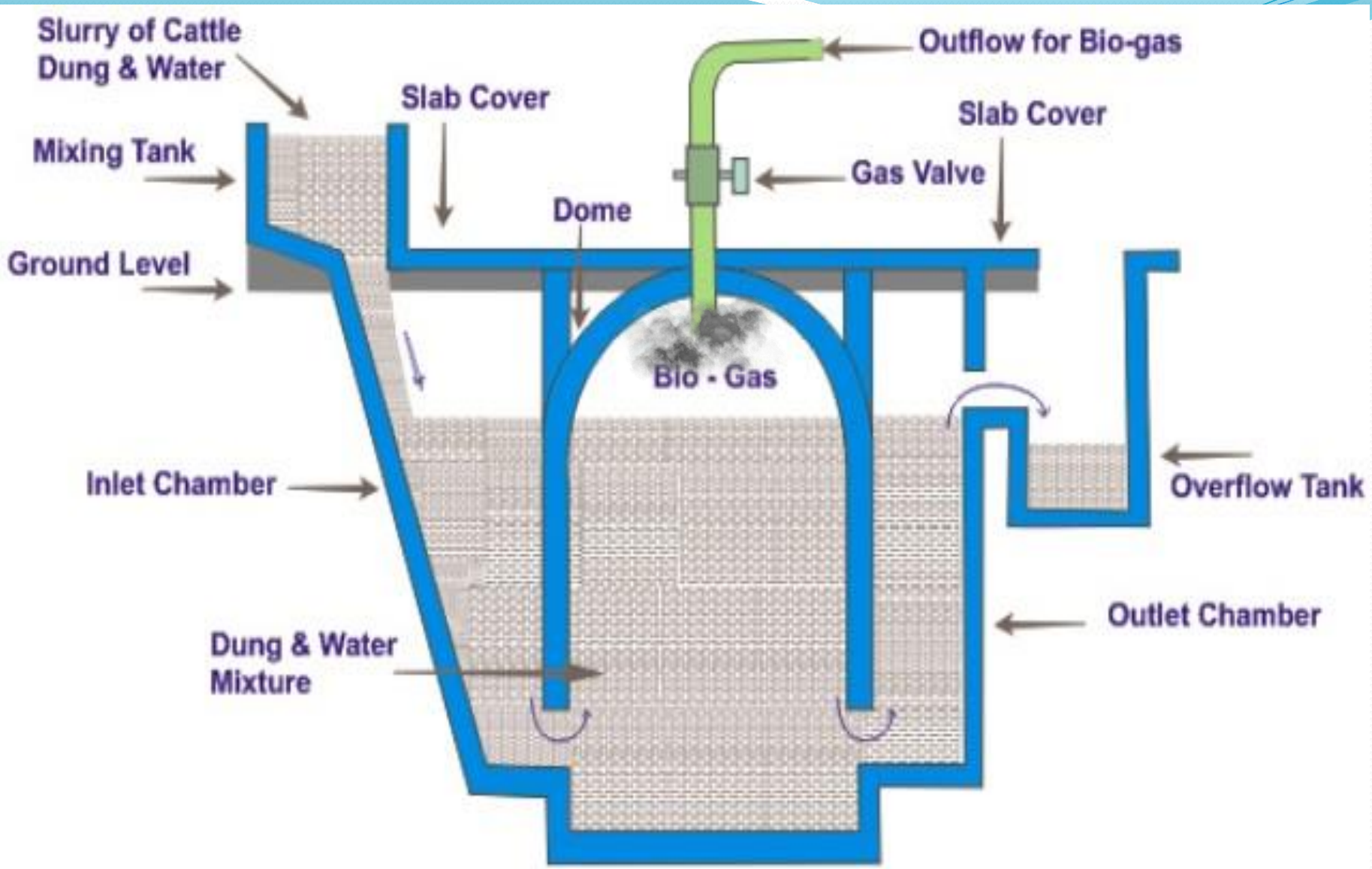
- **Mixing tank** present above the ground level.
- **Inlet tank**: The mixing tank opens underground into a sloping inlet chamber.
- **Digester:** The inlet chamber opens from below into the digester which is a huge tank with a dome like ceiling. The ceiling of the digester has an outlet with a valve for the supply of biogas.
- **Outlet tank**: The digester opens from below into an outlet chamber.
- **Overflow tank**: The outlet chamber opens from the top into a small over flow tank.

Working of Fixed Dome type Biogas Plant

- The various forms of biomass are mixed with an equal quantity of water in the mixing tank. This forms the **slurry**.
- The slurry is fed into the digester through the inlet chamber.
- When the digester is partially filled with the slurry, the introduction of slurry is stopped and the plant is left unused for about two months.
- During these two months, anaerobic bacteria present in the slurry decomposes or ferments the biomass in the presence of water.
- As a result of anaerobic fermentation, biogas is formed, which starts collecting in the dome of the digester.

Cont..

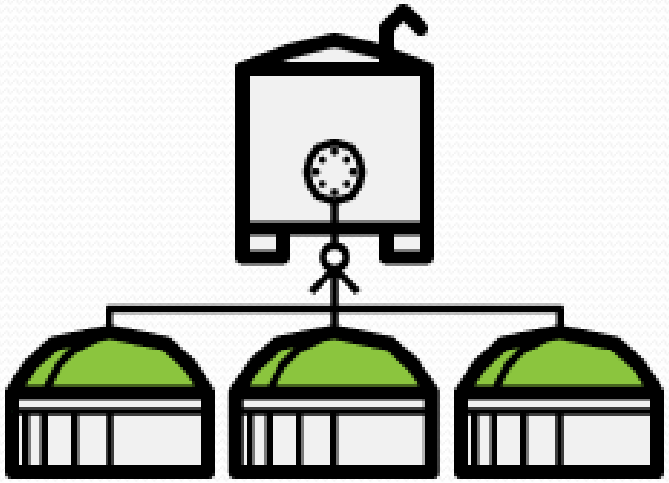
- As more and more biogas starts collecting, the pressure exerted by the biogas forces the spent slurry into the outlet chamber.
- From the outlet chamber, the spent slurry overflows into the overflow tank.
- The spent slurry is manually removed from the overflow tank and used as manure for plants.
- The gas valve connected to a system of pipelines is opened when a supply of biogas is required.
- To obtain a continuous supply of biogas, a functioning plant can be fed continuously with the prepared slurry.



Fixed Dome type Bio-gas Plant

Advantages of fixed dome type of biogas plant

- Requires only locally and easily available materials for construction.
- Inexpensive.
- Easy to construct.

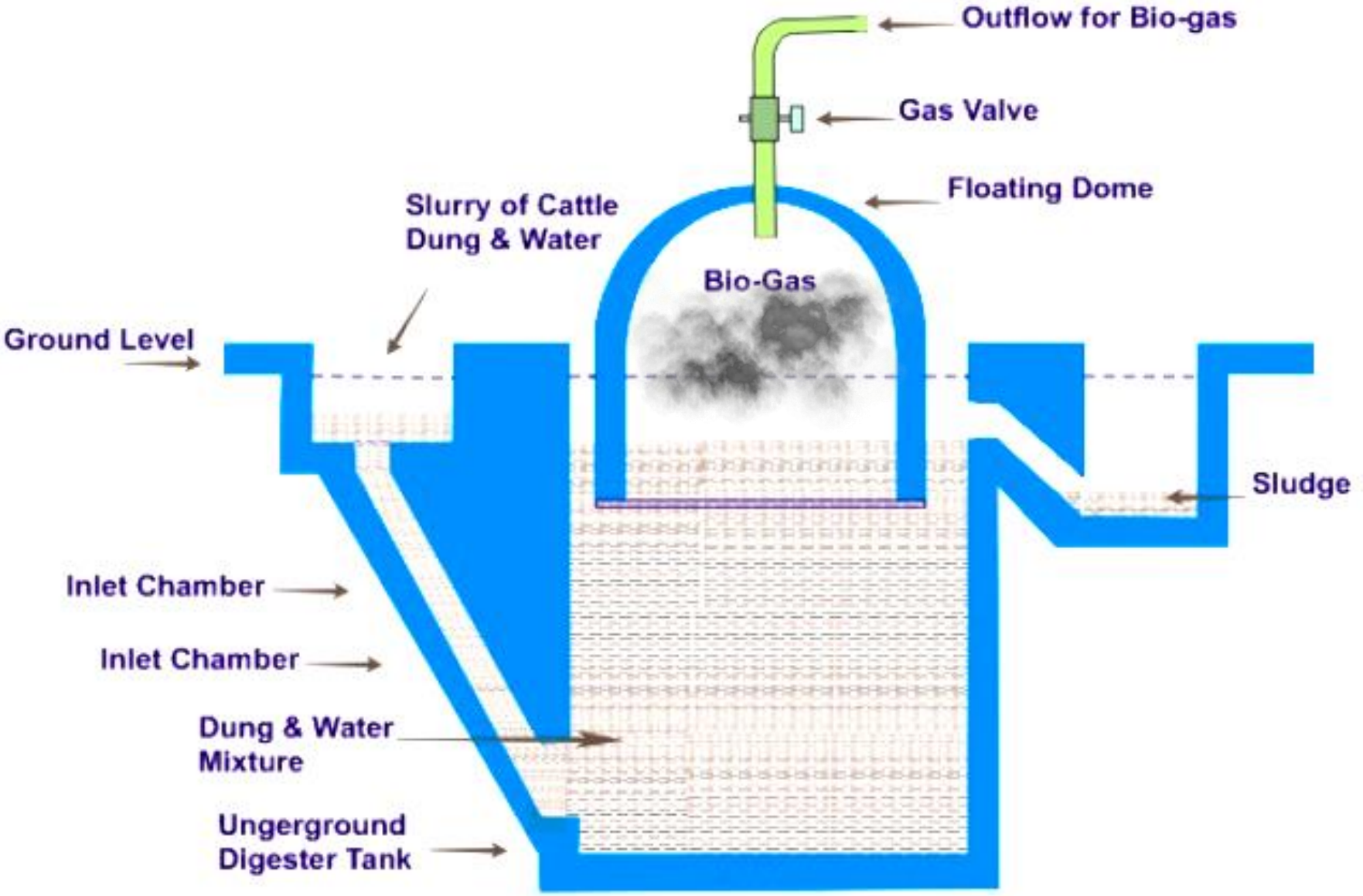


Floating gas holder type of biogas plant

Construction

The floating gas holder type of biogas plant has the following chambers/ sections:

- **Mixing Tank** - present above the ground level.
- **Digester tank** - Deep underground well-like structure. It is divided into two chambers by a partition wall in between.
- It has two **long cement pipes**
  - i) **Inlet pipe opening** into the inlet chamber for introduction of slurry.
  - ii) **Outlet pipe opening** into the overflow tank for removal of spent slurry.
- **Gas holder** - an inverted steel drum resting above the digester. The drum can move up and down i.e., float over the digester. The gas holder has an outlet at the top which could be connected to gas stoves.
- **Over flow tank** - Present above the ground level.



Floating Dome type Bio-gas Plant

Working

- Slurry (mixture of equal quantities of biomass and water) is prepared in the mixing tank.
- The prepared slurry is fed into the inlet chamber of the digester through the inlet pipe.
- The plant is left unused for about two months and introduction of more slurry is stopped.
- During this period, anaerobic fermentation of biomass takes place in the presence of water and produces biogas in the digester.
- Biogas being lighter rises up and starts collecting in the gas holder. The gas holder now starts moving up.

Cont..

- The gas holder cannot rise up beyond a certain level. As more and more gas starts collecting, more pressure begins to be exerted on the slurry.
- The spent slurry is now forced into the outlet chamber from the top of the inlet chamber.
- When the outlet chamber gets filled with the spent slurry, the excess is forced out through the outlet pipe into the overflow tank. This is later used as manure for plants.
- The gas valve of the gas outlet is opened to get a supply of biogas.
- Once the production of biogas begins, a continuous supply of gas can be ensured by regular removal of spent slurry and introduction of fresh slurry.

Disadvantages of floating gas holder type biogas plant

- Expensive
- Steel drum may rust
- Requires regular maintenance

Fixed dome	Floating drum
• masonry of concrete structure entirely	masonry digester with steel, plastic or composite based gas holder
• low costs	high costs (20-30 per cent higher)
• low maintenance	frequent maintenance
• low reliability	high reliability
• high masonry and supervisory skill required	low masonry and fabricating skills
• variable gas pressure complicates appliance design	constant gas pressure simplifies appliance design and usage

Utilization Of Biogas

- **Cooking:** A biogas plant of 2 cubic meters is sufficient for providing cooking fuel needs of a family of about five persons.
- **Lighting:** Biogas is used in silk mantle lamps for lighting purposes. The requirement of gas for powering a 100 candle lamp (60 W) is 0.13 cubic meter per hour.
- **Power Generation:** Biogas can be used to operate a dual fuel engine to replace up to 80 % of diesel-oil. Diesel engines have been modified to run 100 per cent on biogas. Petrol and CNG engines can also be modified easily to use biogas.
- **Transport Fuel:** After removal of CO_2, H_2S and water vapor, biogas can be converted to natural gas quality for use in vehicles.

Benefits Of Biogas

- Availability of power at affordable rates
- Reduces pollution
- Reduces time wastage while collecting firewood
- Reduces reliance on fossil fuels
- Saves on the environment (Reduces deforestation)
- Improves living standards in rural areas
- Reduces global warming
- Produces good quality enriched manure to improve soil fertility.
- Effective and convenient way for sanitary disposal of organinc wastes, improving the hygienic conditions.
- As a smokeless domestic fuel it reduces the incidence of eye and lung diseases.

Applications

A biogas bus, Sweden

The Biogas Train “Amanda” Sweden

Advantages of biogas plants

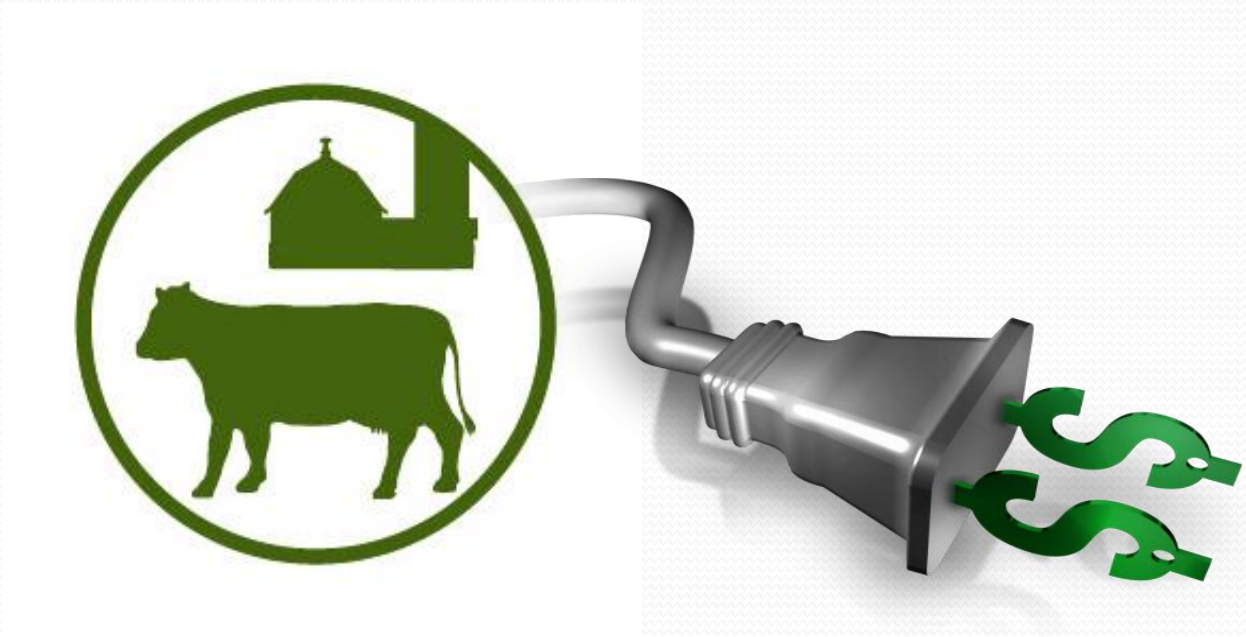
- Reduces burden on forests and fossil fuels
- Produces a clean fuel - helps in controlling air pollution
- Provides nutrient rich (N & P) manure for plants
- Controls water pollution by decomposing sewage, animal dung and human excreta.

Processing Options

Technology	Key parameter	Options
Feeding system	Digester type and matter content of feedstock	• Discontinuous feeding for batch digesters • Continuous or semi-continuous feeding for plug-flow or CSTR digesters • Solid or liquid feeding system depending on dry matter content of the substrate
Reactor type	Dry matter content of feedstock	• CSTR for liquid substrates • Plug-flow or batch digester for solid substrates
Reactor temperature	Risk for pathogens	• Mesophilic temperature when no risk for pathogens • Thermophilic temperatures when risk for pathogens (organic household waste)
Number of phases	Composition of substrates, acidification risk	• One phase systems when no acidification risk • Two-phase system for substrates with a high content of sugar, starch or proteins

Limitations of biogas plants

- Initial cost of installation of the plant is high.
- Number of cattle owned by an average family of farmers is inadequate to feed a biogas plant.



Factors affecting methane formation.

- pH
- Temperature
- Nitrogen concentration
- C:N ratio
- Creation of anaerobic conditions

pH

- 6-8
- Acidic medium lowers methane formation.

- **Temperature**

- Fluctuation ↓ methane formation – inhibit growth of methanogens.
- 30-40°C

Nitrogen concentration

- ↑ N_2 - ↓ growth of bacteria - ↓ CH_4

C:N ratio

- Micro organisms in a biogas plant needs both N nitrogen and C carbon.
- Research has shown that the methanogenic bacteria work best with a C/N ratio 30:1.

Creation of anaerobic conditions

- CH_4 production takeplace in strictly anaerobic condition.

- Digesters – airtight, burried under soil.

Recent Developments

- With the many benefits of biogas, it is starting to become a popular source of energy and is starting to be used more and more.
- On 5 October 2010, biogas was injected into the UK gas grid for the first time. As of September 2013, there are about 130 non-sewage biogas plants in the UK.
- Germany is Europe's biggest biogas producer and the market leader in biogas technology.
- To create awareness and associate the people interested in biogas, the Indian Biogas Association was formed. India's Ministry of New and Renewable Energy offers some subsidy per model constructed.

Disadvantages Of Biogas

- The process is not very attractive economically on a large industrial scale.
- It is very difficult to enhance the efficiency of biogas systems.
- Biogas contains some gases as impurities, which are corrosive to the metal parts of internal combustion engines.
- Not feasible to set up at all the locations.

Problems Relate to Biogas Plants:

In biogas plants some problems are natural and some are created by humans but all are controllable.

- **Handling of effluent slurry** is a major problem if the person is not having sufficient open space to get the slurry dry.
- **The gas forming methanogenic bacteria are very sensitive towards the temperature** compared to those of non-methanogenic . As in winter the temperature falls there is a decrease in the activity of the bacteria. Which indirectly decrease the gas production rate.
- Due to lack of proper training a lot of problems arises. It has been noticed that many persons increase the loading rate and some also do not try to mix the cattle dung with water, keeping in mind more gas production. Due to this the slurry from inlet towards outlet is very slow or even stops. This may cause accumulation of acids and drop in the PH and then failure of the digester.
- This can be reduced by use of solar heated hot water to make slurry, manual or auto stirring of digester slurry, addition of various nutrients for bacteria, covering of biogas plants by bags during night hours.

Conclusion

- Biogas is a clean source of energy.
- Biogas plants have been in operation for a long period of time, especially in rural areas around the globe.
- The research organizations should focus on newer efficient low cost designs.
- The governments can play important role by introducing different legal frameworks, education schemes and the availability of technology and simultaneously creating more awareness and providing more subsidies.

Thank You