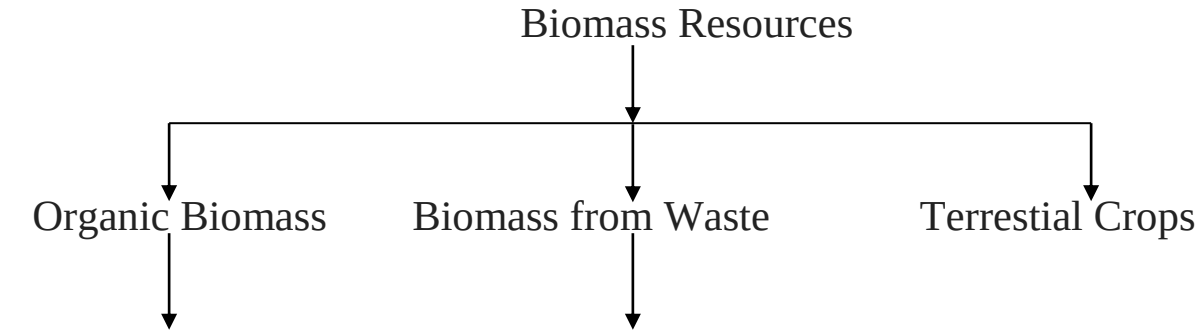
UNIT 05 : BIO-ENERGY SYSTEMS

- BIOMASS ENERGY RESOURCES:

✓ Biomass is organic material that comes from plants and animals, and it is a renewable source of energy. Biomass contains stored energy from the sun.

✓ Plants absorb the sun's energy in a process called photosynthesis. Biomass can be burned directly or converted to liquid biofuels or biogas that can be burned as fuels.

- Biomass Resources & its classification:



1.Cultivated Fields
2.Crops
3.Forests
4.Organism living both on land & water
5.Algae

1.Muncipal Waste
2.Animal & Human Waste
3.Sewage Waste
4.forest Waste
5.Industrial Waste

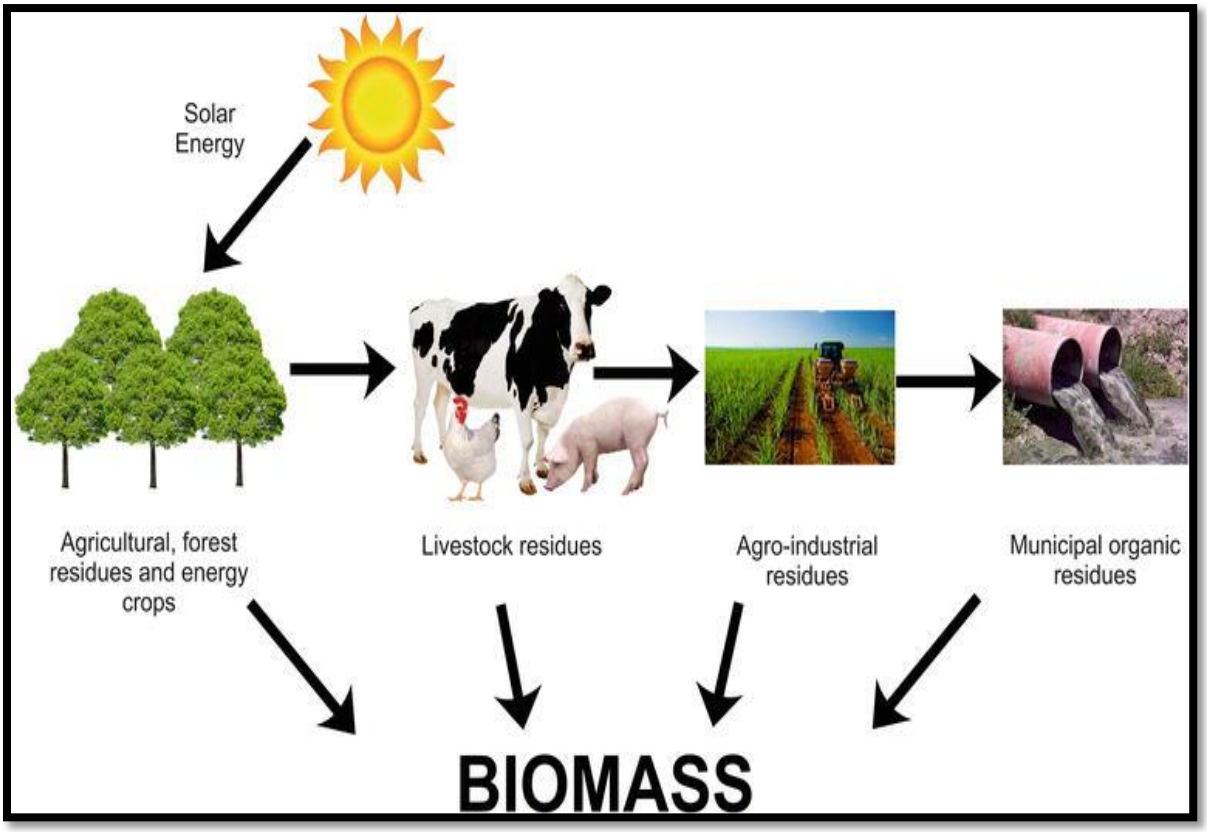
- Photosynthesis Process:

✓ Photosynthesis is a process used by plants and other organisms to convert light energy into chemical energy that can later be released to fuel the organisms' activities.

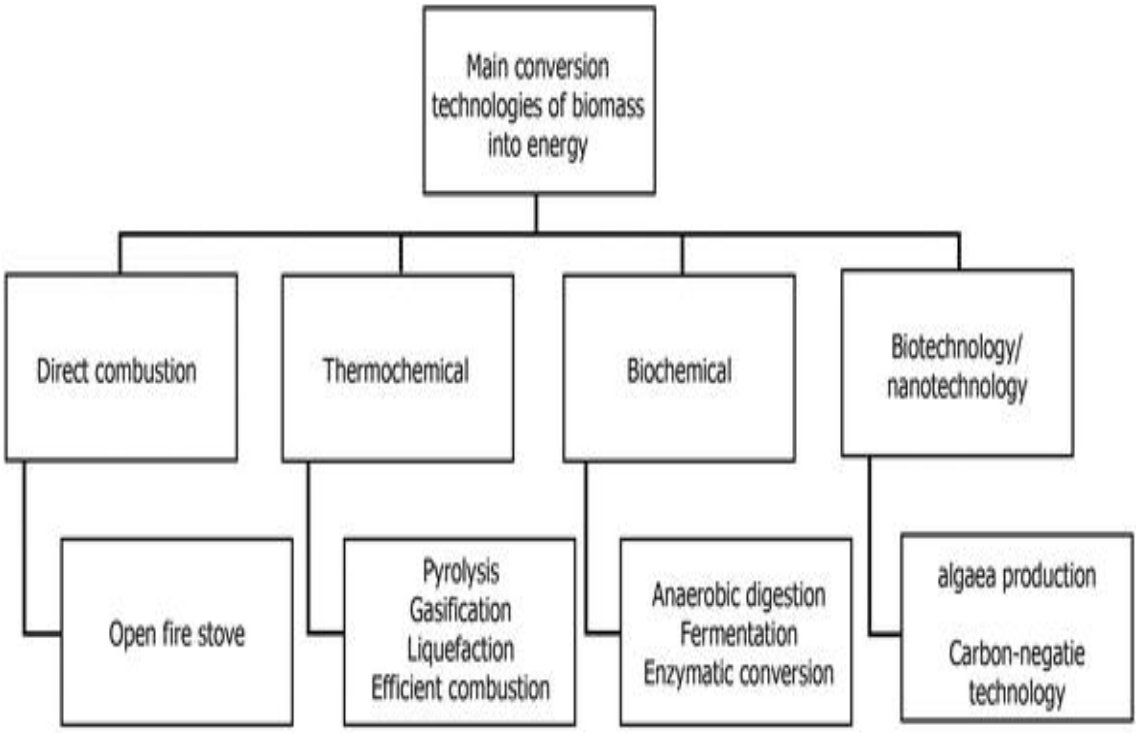
✓ In these light-dependent reactions, some energy is used to strip electrons from suitable substances, such as water, producing oxygen gas.

✓ The photosynthesis equation is as follows: $6CO2 + 6H20 + (energy) \rightarrow C6H12O6 + 6O2$

- ✓ An animal that eats plants takes advantage of the stored energy from these and generates biomass.
- ✓ Biomass works as a type of storage (battery) of solar energy transferred from one level to another. The transfer of energy is evident in all processes of living beings.



- Biomass Conversion Process:



1.Direct combustion

- ✓ One of the oldest uses in which biomass has been utilized for energy in the world is through the burning wood (combustion). This action represents a traditional use of biomass, particularly in rural zones.
- ✓ It is considered an essential resource to the economic development of societies. Nevertheless, when the wood is burnt in an open fire stove, around 80% energy is lost .
- ✓ Recently, technologies suggest the use of energy efficiency stoves, which not only has a better thermal efficiency but also avoids indoor air pollutions. Other specialized equipment involves furnaces, boilers, steam turbines, and turbogenerator.
- ✓ The combustion of biomass allows the recovery of the chemical energy stored.
- ✓ In general, combustion processes involve direct oxidation of matter in air, that is, ignition or burning of organic matter in an air atmosphere sufficient to react with oxygen fuel.

2. Thermochemical Process

- ✓ Thermochemical process, as the direct combustion, has a core axis, the temperature. One of the main differences is an induced atmosphere in which conversion of biomass took place.
- ✓ This oxidation process can occur in the presence or absence of a gasifying medium. The conversion of biomass depends on temperature and pressure variables.
- ✓ For example, if the substrate to transform is in the presence of a gas such as oxygen, water vapor, or hydrogen, producing fuel is performed through gasification. If, however, material degradation occurs in the absence of oxygen, that is, nitrogen, under controlled pressure and temperature, then the process is called pyrolysis.

3. Biochemical Conversion of Biomass

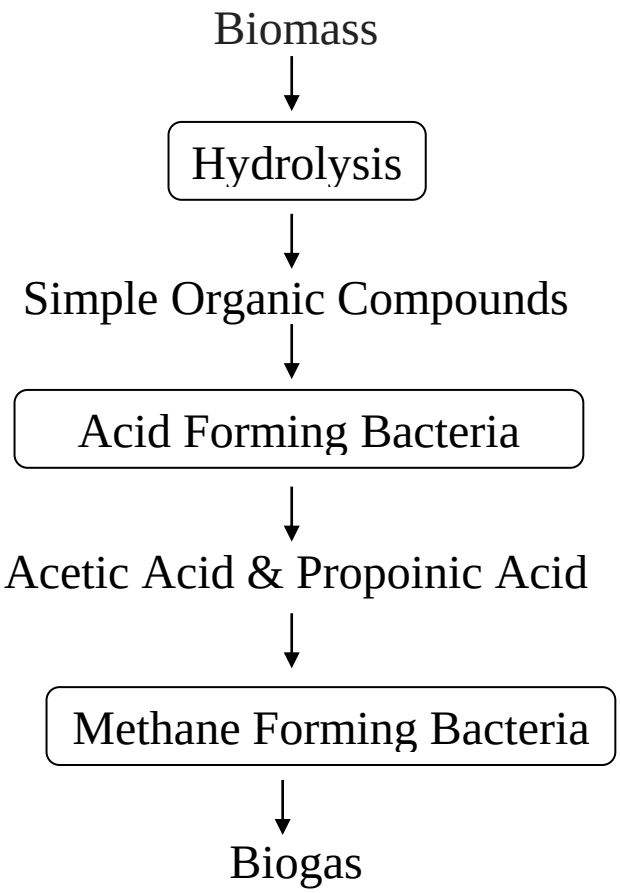
- ✓ Biochemical conversion of biomass involves use of bacteria, microorganisms and enzymes to breakdown biomass into gaseous or liquid fuels, such as biogas or bioethanol.
- ✓ The most popular biochemical technologies are anaerobic digestion (or biomethanation) and fermentation.
- ✓ Anaerobic digestion is a series of chemical reactions during which organic material is decomposed through the metabolic pathways of naturally occurring microorganisms in an oxygen depleted environment.
- ✓ Anaerobic Digestion

  Anaerobic digestion is the natural biological process which stabilizes organic waste in the absence of air and transforms it into biofertilizer and biogas.

  Anaerobic digestion is a reliable technology for the treatment of wet, organic waste. Organic waste from various sources is biochemically degraded in highly controlled, oxygen-free conditions circumstances resulting in the production of biogas which can be used to produce both electricity and heat.

❖ Principals of Biogas Production from Waste Biomass:

- The biogas production from waste biomass is achieved by the action of anaerobic bacteria in presence of moisture & in absence of oxygen.
- The conversion process is called as biodigestion or anaerobic fermentation.



STEP-01 Hydrolysis:

Biomass having complex compounds such as facts , proteins , carbohydrates etc are broken down into simple water soluble organic compounds through the influence of water called hydrolysis.

STEP-02 Acid Formation:

The micro-organism of anaerobic & facultative group which grows in absence of O_2 called acid forming bacteria produce mainly the acetic acid & propoinic acid at low temperature of about 25^0c which releases co_2.

In certain cases the acid may be produced in such large quantities that all are biological activity is arrested. Thus it becomes necessary to control PH value of mixture.

STEP-03 Methane Formation:

Here anaerobic bacteria called as methane formers which converts organic acids organic acids formed in stage 2 into biogas having its main constituents as methane & co_2.These methane formers are sensitive to PH changes.

- Classification of Biogas Plants:

  The biogas plants are built in different sizes & shapes depending on the process carried out. These plants are mainly classified as:

1. Continous or batch type.
2. Dome type.

1.Continous Type Biogas Plants :

In continuous type of biogas plant the biomass is fed regularly to the digester & it delivers the biogas continuously.

These are again classified as:

i)Single stage continous type biogas plant.

ii)Two stage continous type biogas plant.

I) Single Stage Continous Type Biogas Plant:

In this type of plants the entire process of conversion of biomass into biogas are carried out in the single chamber or digester without barrier. Such plants are simple in construction , easy to operate & control. It does not need any skilled workers.

ii) TwoStage Continous Type Biogas Plant:

These plant have two chambers for digestion of biomass. In the first chamber the biomass is fed in which the

Stage 1. of acid formation takes place. Then the diluted acids are only fed into the second chamber where the

Stage 2. of methane formation is carried out. So produced is collected from the second chamber.

II) Batch Type Biogas Plant:

Batch type biogas plants are appropriate where daily supplies of raw waste materials are difficult to be obtained. A batch loaded digester is filled to capacity sealed and given sufficient retention time in the digester.

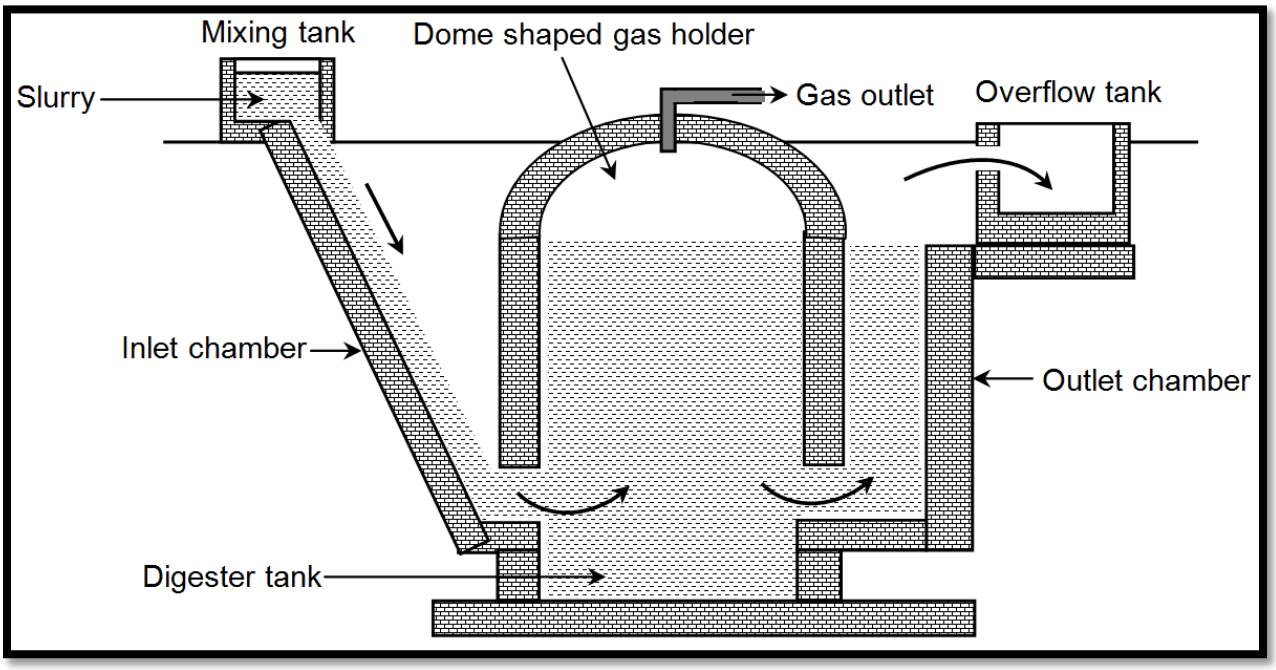
After completion of the digestion, the residue is emptied and filled again.

Gas production is uneven because bacterial digestion starts slowly, peaks and then tapers off with growing consumption of volatile solids.

This difficulty can overcome by having minimum to digester so that at least one is always in operation. This problem can also minimize by connecting batch loaded digester in series and fed at different times so that adequate biogas is available for daily use.

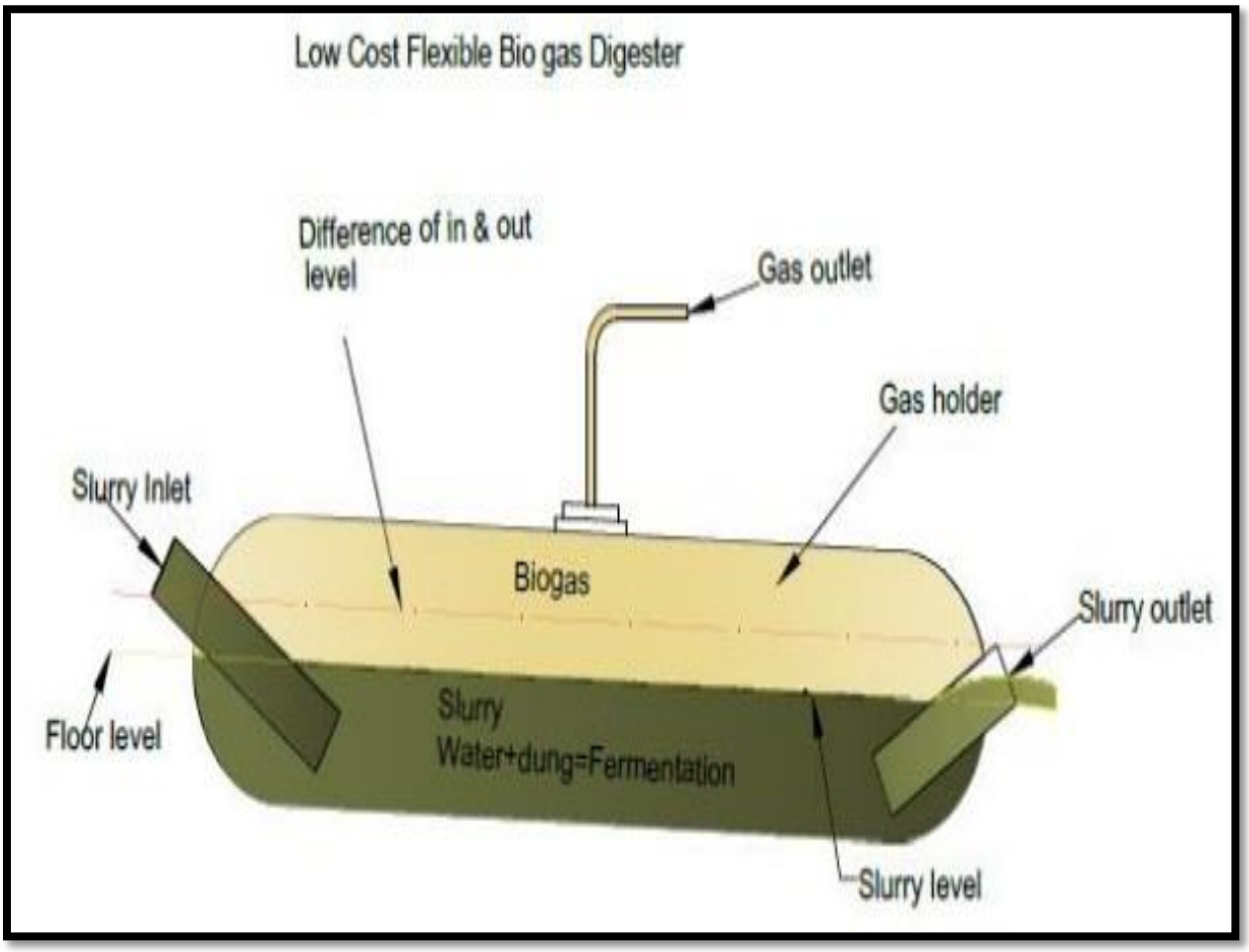
♦ FIXED DOME TYPE BIOGAS PLANT:

- ✓ The fixed dome type bio gas plant consists of a closed underground digester tank made up of bricks which has a dome shaped roof also made up of bricks.
- ✓ This dome shape roof of the digester tank functions as gas holder and has an outlet pipe at the top to supply gas to homes.
- ✓ Slurry is prepared by mixing water in cattle dung in equal proportion in mixing tank. The slurry is then sent into the digester tank with the help of inlet chamber.
- ✓ It should be noted that slurry is fed into the digester tank up to the point where the dome of the roof starts.
- ✓ Inside the digester tank, the complex carbon compounds present in the cattle dung breaks into simpler substances by the action of anaerobic microorganisms in the presence of water.
- ✓ This anaerobic decomposition of complex carbon compounds present in cattle dung produces bio gas and gets completed in about 60 days.
- ✓ The bio gas so produced starts to collect in dome shaped roof of bio gas plant and is supplied to homes through pipes.
- ✓ The spent slurry is replaced from time to time with fresh slurry to continue the production of bio gas.



♦ FIEXIBLE BAG TYPE BIOGAS PLANT:

- ✓ A balloon digester consists of a plastic or rubber digester bag, in the upper part of which the gas is stored.
- ✓ The inlet and outlet are attached directly to the skin of the balloon. The gas is moved from the balloon to where it will be used by the pressure build up inside the balloon and can be enhanced by placing weights on the balloon.
- ✓ The fermentation slurry is agitated slightly by the movement of the balloon skin.
- ✓ This is favourable to the digestion process. Even difficult feed materials, such as water hyacinths, can be used in a balloon plant.
- ✓ The balloon material must be UV-resistant.



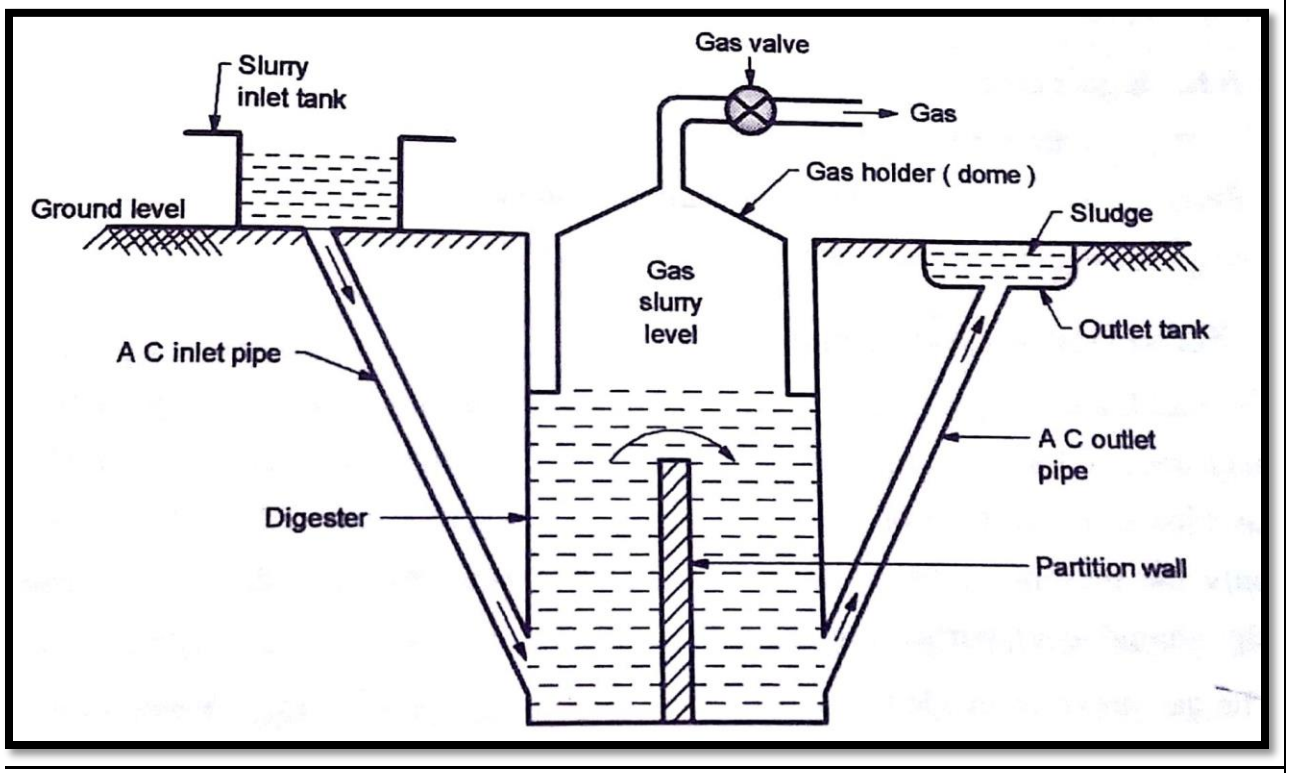
Advantages:

- ✓ Low cost, ease of transportation, low construction and installation (important if the water table is high), high digester temperatures, uncomplicated cleaning, emptying and maintenance. An ideal cheap system to generate methane for cooking stoves.

Disadvantages:

- ✓ Short life (about five years), easily damaged, does not create employment locally, little scope for self-help. Balloon plants can be recommended wherever the balloon skin is not likely to be damaged and where the temperature is even and high.
- ✓ In addition, the low gas pressure may require gas pumps and scum or sludge inside the balloon cannot be removed during operation.

♦ KVIC Gobar Gas Plant:



- ✓ These are small scale gas production. It consist of slurry inlet tank, gas value, dome, outlet tank ac inlet pipe, digester, partition wall. The plant consist of digester made of masonry construction in the form a well below the ground level and the floating gas holder also called as dome, made of mild steel.

Working :-

- ✓ From the above, in the inlet tank animal waste slurry is prepared containing cow dung and waste in the ratio as 1:1 to 1:1.25 the feeding of animal waste slurry is usually done once in a day.
- ✓ The sludge comes out with the built up of gas pressure in the dome above the partition wall & flows out to the outlet tank the th' A C outlet pipe. This sludge is an excellent fertilizer which can be again fed to the soil. At the top of the gas holder , the accumulated gas is drawn from the pipe through gas value. The bifurcation of digestion chamber through a partition wall providers optimum conditions for growth of acid formers & methane forms as the PH valve requirement for these bacteria are different. Therefore, this gives a good yield of biogas. It operates naturally under constant pressure. The diameter of the digester of a gas plant rangers from 1.2 to 6m & its height varies from 3m to 6m.
- ✓ The mild steel gas holders are prone to corrosion thus needs painting at regular intervals. This problem can be overcome by using fiber glass reinforced plastic (FRP) material for construction of gas holders.

Advantages of KVIC Plant:-

- ✓ High gas yield.
- ✓ No problem of gas leakage.
- ✓ Works under constant pressure naturally.
- ✓ No problem of mixing of biogas with external air, thus no danger of explosion.

Dis-Advantages *of KVIC Plant*:-

- ✓ It has higher cost.
- ✓ Requires painting of drum to avoid corrosion at least twice a year.
- ✓ Requires maintenance of pipes & joints.

♦ GASIFICATION OF BIOMASS:

* **Biomass gasification** is a process of converting solid **biomass** fuel into a gaseous combustible gas (called producer gas) through a sequence of thermo-chemical reactions.
* Biomass gasification is thermo-chemical conversion of biomass into a combustible gas mixture (producer gas) through a partial combustion route with air supply restricted to less than that theoretically required for full combustion.
* A gasifier system basically comprises of a reactor where the gas is generated, and is followed by a cooling and cleaning train which cools and cleans the gas.

- Types of Gasifier:

There are various types of gasifier such as:

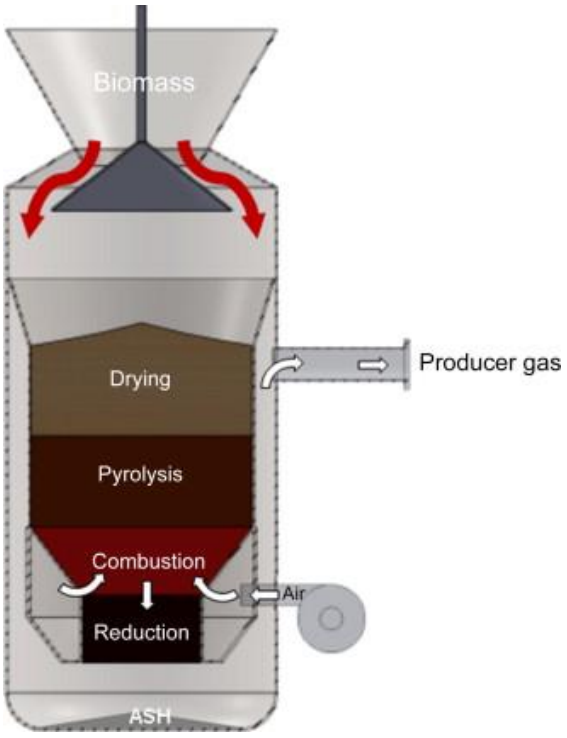
1.Downdraft Gasifier

2.Updraft Gasifier

3.Cross Draft Gasifier

4.Fluidized Bed Gasifier

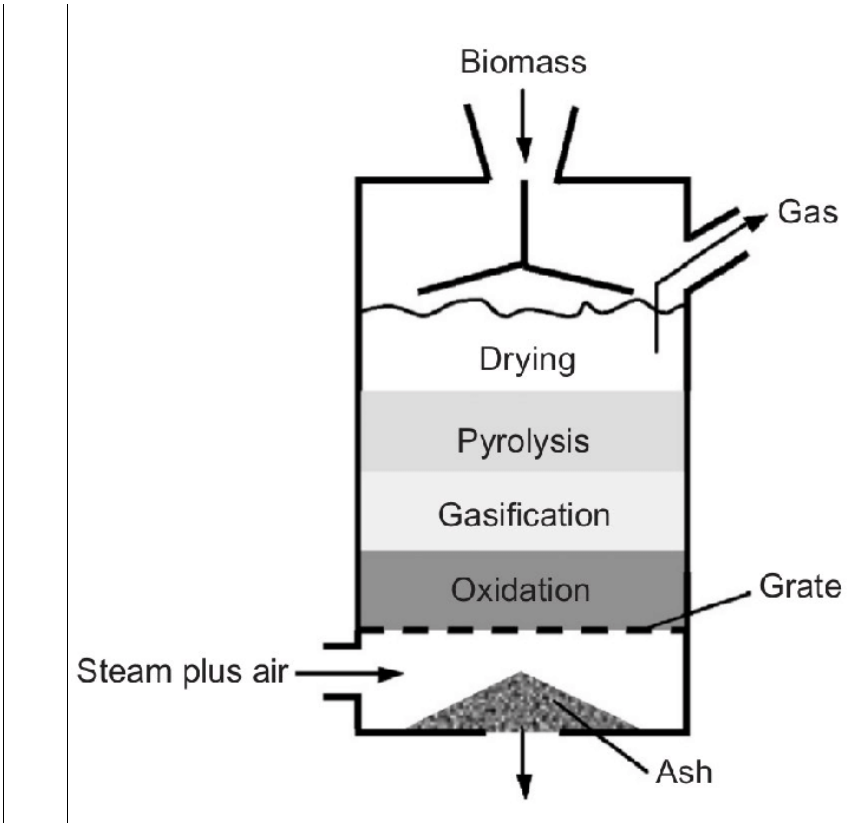
1.Downdraft Gasifier:



* A downdraft gasifier is a gasification reactor with four distinct zones: (a) upper drying zone, (b) upper-middle pyrolysis section, (c) lower-middle oxidation zone, and (d) lower reduction zone.
* A downdraft gasifier is a co-current reactor where air enters the gasifier at a certain height below the top. The product gas flows downward (giving the name *downdraft*) and leaves through a bed of hot ash .Since it passes through the high-temperature zone of hot ash, the tar in the product gas finds favorable conditions for cracking (see Chapter 4). For this reason, a downdraft gasifier, of all types, has the lowest tar production rate.
* The gasification agent enters the gasifier at a certain height below the top, and it mixes with the pyrolysis gas products while flow downward in parallel with the solids (char and ash) through the oxidation and gasification zones. The drying and

pyrolysis zones lie above the oxidation zone and they are maintained at the required temperature by conduction of the heat generated from the combustion of pyrolysis vapors (including tar precursors). The gases leaving the oxidation zone, mainly CO2 and H2O, are reduced into CO and H2 on the glowing char in the gasification area.

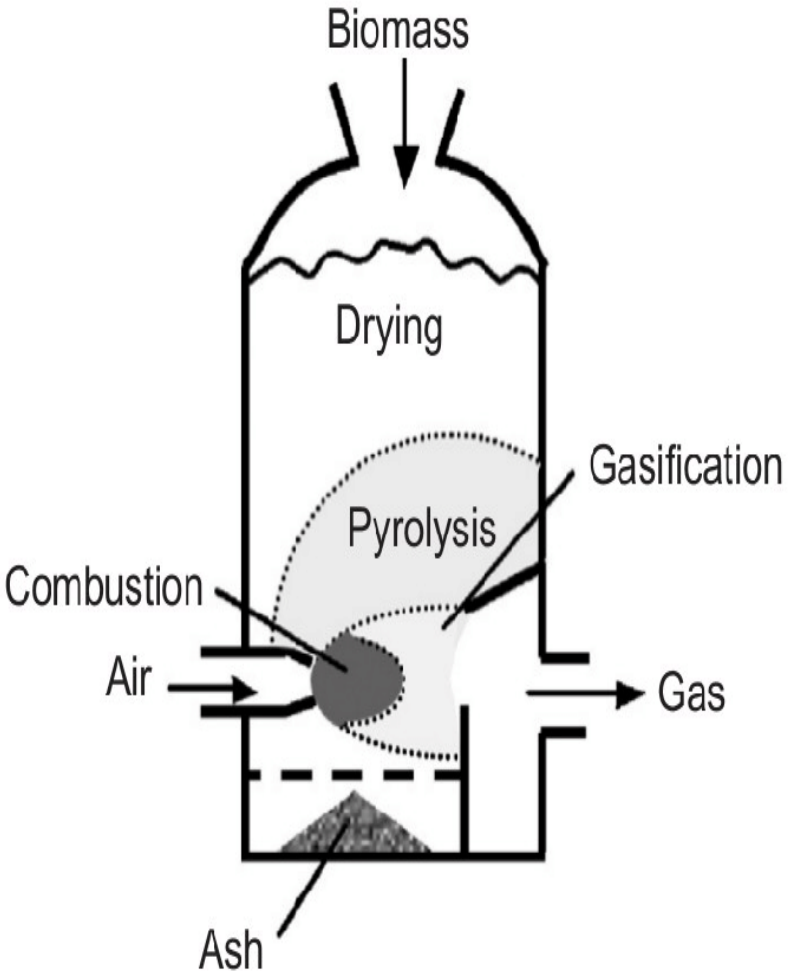
2. Updraft Gasifier:



* This one is oldest and simplest of all gasifier types. The air comes in at the bottom and produced syn gas leaves from the top of the gasifier. Near the grate at the bottom combustion reaction occurs, above that reduction reaction occurs.
* In the upper part of the gasifier heating and pyrolysis of the feedstock occurs as a result of heat transfer by forced convention and radiation from the lower zones. Tars and volatile produce produced during the reaction will leave along with the syn gas at the top of the gasifier. Which will be later separated by use of cyclone and candle filter.

* The major advantages of this type of gasifier are its simplicity, high charcoal burn out and internal heat exchange leading to low temperature of exit gas and high equipment efficiency. This gasifier can work with several kind of feedstock ranging from Coal to Biomass.
* Inlet of coal can be decided based on the type of gasification process selected to be used in this gasifier.

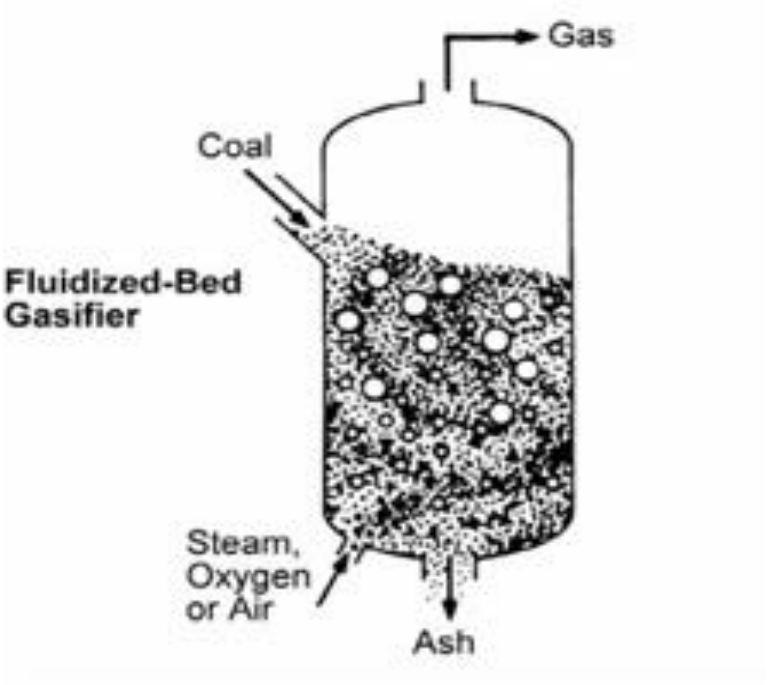
3.Cross Draft Gasifier:



* Cross draft gasification is one of the simplest types of gasification; the reactor for this gasification is much like the updraft gasifier in that the fuel will enter from the top and the thermochemical reaction will occur progressively as this fuel descends into the reactor.

* The crucial difference is that the air will be entering the gasifier from the side of the reactor, rather than from the top or the bottom.
* The start-up time for this reactor is relatively short, and high temperatures can be attained using this type of gasification.

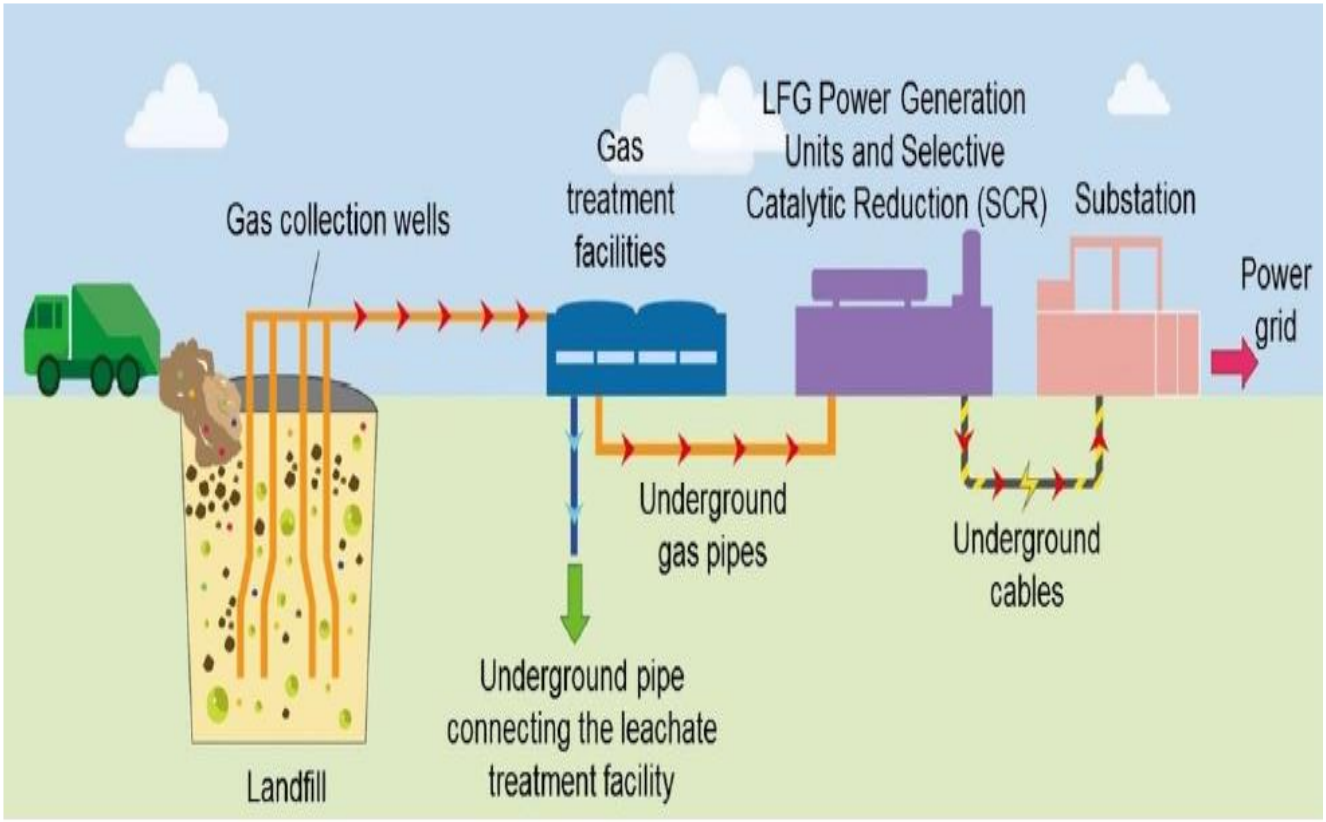
4.Fluidized Bed Gasifier:



* Fluidized-bed gasifiers suspend feedstock particles in an oxygen-rich gas so the resulting bed within the gasifier acts as a fluid. These gasifiers employ back-mixing, and efficiently mix feed coal particles with coal particles already undergoing gasification.
* To sustain fluidization, or suspension of coal particles within the gasifier, coal of small particles sizes (<6 mm) is normally used. Coal enters at the side of the reactor, while steam and oxidant enter near the bottom with enough velocity to fully suspend or fluidize the reactor bed.
* Due to the thorough mixing within the gasifier, a constant temperature is sustained in the reactor bed. The gasifiers normally operate at moderately high temperature to achieve an acceptable carbon conversion rate (e.g., 90-95%) and to

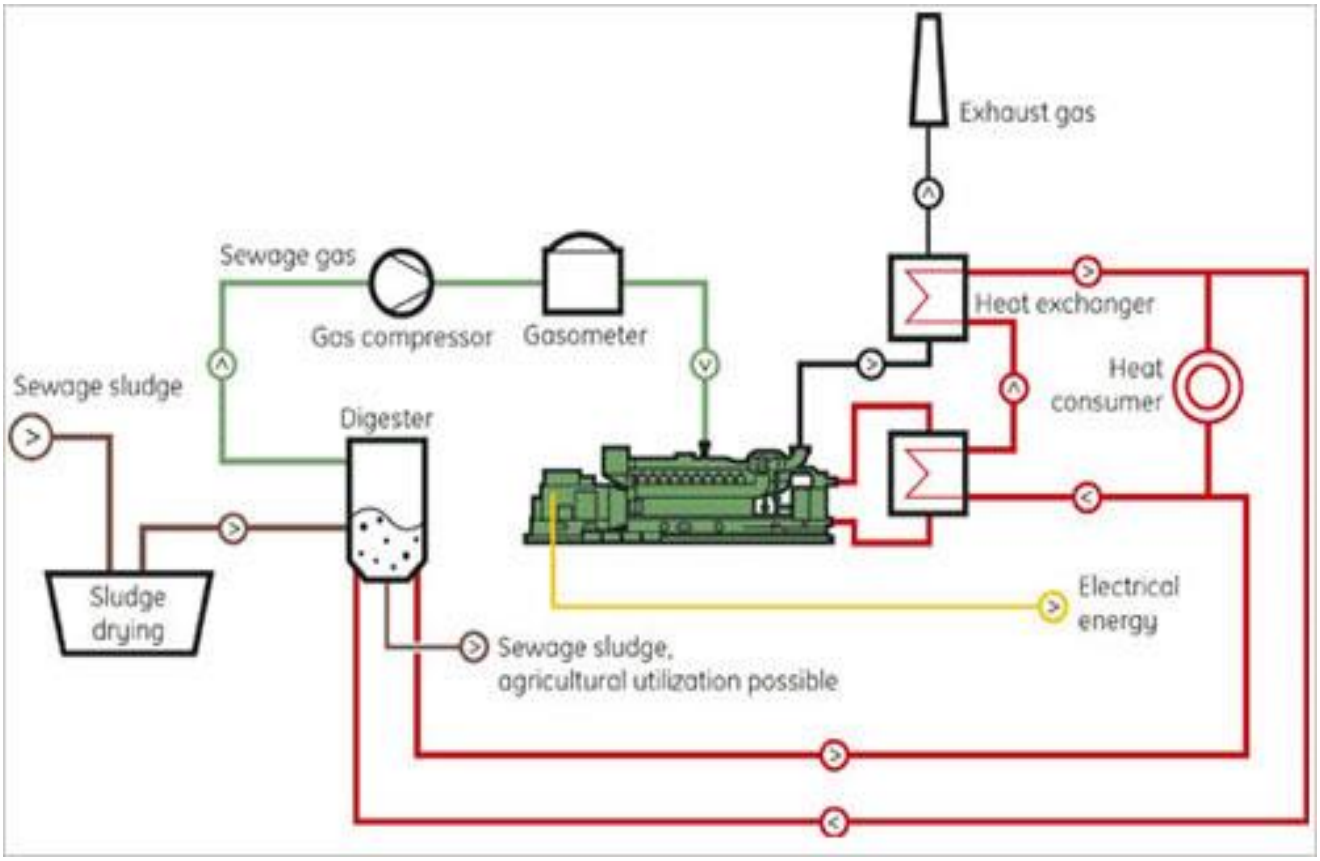
decompose most of the tar, oils, phenols, and other liquid byproducts.

♦ Power Generation from Landfill Gas Using Muncipal Waste:



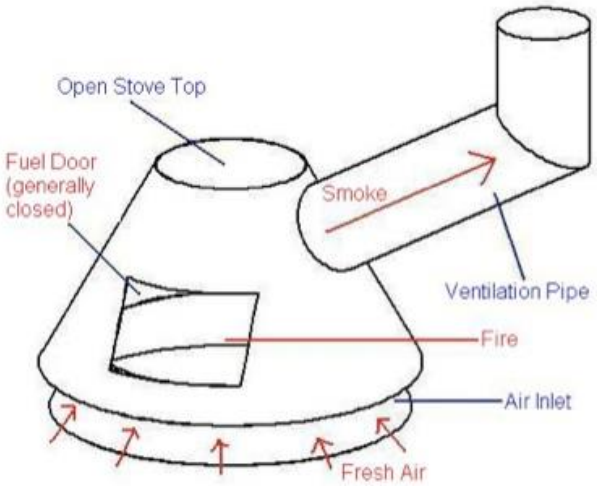
* LFG consists of methane (CH4), carbon dioxide (CO2) and trace amounts of nitrogen, hydrogen, ammonia, sulphur dioxide and carbon monoxide produced by the decomposition of municipal solid waste. It is flammable, making it a suitable fuel for power generation, and is regarded as a valuable renewable energy source.
* Currently, the operator of the site converts some of the LFG to generate electricity for onsite facilities and for waste water treatment, while the remaining gas is flared off according to regulation.
* LFG collected in the gas wells at the landfill would be transported to a treatment facility to remove any liquid condensate and vapor contaminants before it is transferred for power generation. The electricity generated would be sent to the power grid of CLP Power.

♦ Power Generation from Sewage:



* Sewage can be used to produce sewage gas using anaerobic digestion. The block diagram is shown in figure , at the end of this process we can obtain power from sewage.
* The sewage gas can be used either for cooking , heating , or for power generation.

♦ Smokeless Chulha:



* The traditional method of cooking in rural areas is on Chulah The fuel is burnt under cooking pot. Teh thermal efficiency of this chulah is about 5 to 15 percent. It requires large quantity of fuel. The smoke makes the cooking ports dirty and increases the work load of women.
* The smokes also create the problem of eye and chest diseases in women take more time to cook. Smoke entering into the kitchen room leads to Indoor Air Pollution.
* Smokless chulha doesnot mean that without smoke. It generate smoke but is vented out of the room using pipe. The idea of smokeless chulha is nto let all of the smoke come out and get on your face while cooking.