MODULE-04

(a) Biomass Energy;

I. Biomass Production; ** V Imp.

Plant matter created by the process of photosynthesis is called biomass. Photosynthesis is a natural radiation. The final reaction of this process can be represented as follows :

$$\boxed{6H_2O + 6CO_2 + \text{solar light energy} \rightarrow C_6H_{12}O_6 + 6CO_2}$$

In this reaction process, water & carbon dioxide are converted into organic material.

Biomass has the advantage of controllability and availability when compared to many other renewable energy options. Biomass production broadly classified as two methods namely,

1. Direct Method;

Raw materials that can be used to produce biomass energy are available throughout the world in following forms

(i) Forest wood & wastes
(ii) Agricultural crops & residues
(iii) Residential food wastes
(iv) Industrial wastes
(v) Human & animal wastes
(vi) Energy crops.

Biomass energy obtained by raw meterials has Low energy density, however find application is cooking leads environmental pollution problems & unsuitable for efficient & effective use.

Enhancing usefulness of biomass, some kind of pre-processing & conversion technology is necessary.

2. Indirect Methods:

Biomass can also be used indirectly by converting it either into electricity & heat or into a convenient usable fuel in solid, liquid or gaseous form.

The efficient conversion processes are as follows

(i) Thermo-electrical conversion;

(ii) Biomass conversion to fuel.

→ Thermo-chemical conversion includes processes such as destructive distillation, pyrolysis & gassification.

→ Biological conversion includes processes such as fermentation & anaerobic digestion.

Indirect Method are efficient & environmental pollution reduced.

II ENERGY PLANTATION:

* An approach for the Large-scale planned use of wood is the "energy plantation".

* In this approach, selected species of trees are planted & harvested over regular intervals of time in a phased manner so that wood is continuously available for cooking or allied purposes.

* Energy plantation includes, amongst others, pine, cottonwood, hybrid poplar, sweetgum & eucalyptus.

* Commercial energy plantations management system in varied climatic conditions has emerged during the past 4-5 decades, improving planting, cultivation methods - species matching, biogenetics & pest.

* The technology of biomass-based electric power plants is well established in the USA & Europe & there are over 500 such plants use wood, wood waste & various type of agricultural waste.

III Biomass Gassification: ** vv Imp.

* Biomass gassification is a process of partial combustion in which solid biomass usually in the form of pieces of wood or agricultural residue is converted into a combustible gas mixture.
* A gaseous mixture of carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), hydrogen (H_2) & nitrogen (N_2) called producer gas. [gassification].

  producer gas can be used
  - i) To run internal combustion engines
  - ii) Furnace oil in direct heat applications
* Gassification processes involved with biomass are as follows
  - i) Drying of fuels
  - ii) Pyrolysis
  - iii) Combustion
  - (iv) Cracking
  - (v) Reduction.
* Two types of gassification

  1) Low temperature gassification: When gassification of biomass is carried out at 750°C to 1100°C it is referred as Low temperature gassification. It is used directly to burn for steam production & generate electricity. It is mixture of CO, CO_2, H_2, CH_4 & nitogen from air.

  2) High Temperature gassification: It is carried out in temperature range of 1200°C – 1600°C & it referred as synthesis gas. It contains high proportion of CO & H_2 & convertible to high quality synthetic diesel biofuel compatible for use in diesel engines.

* The average energy conversion efficiency of gasification is defined as

$$\eta_{gs} = \frac{\text{Calorific value of } \frac{gas}{kg} \text{ of fuel}}{\text{Average calorific value of } kg \text{ of fuel}}$$

IV Theory of Gasification: ※※ v.imp.

* Gasification may be considered as a special case of pyrolysis where destructive decomposition of biomass by heat is converted to charcoal, oils, tars & combustible gas.
* The reactor used for gasification is called a gasifier
* The complete combustion of biomass produces biomass gasses that generally contain.

Nitrogen N_2 : 50% – 54%

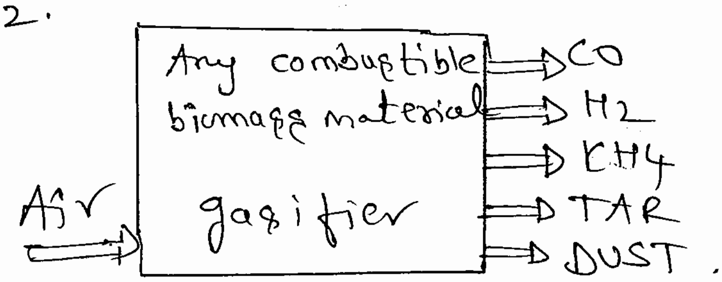
Carbon monoxide CO : 20% – 22%

Hydrogen H_2 : 15% – 18%

Methane CH_4 : 2% – 4% &

Carbon dioxide CO_2 : 9% – 11%

* The production of all these gases is obtained by the reaction of water vapour & carbon dioxide through a glowing layer of charcoal.
* Thus, key to gassifier design is to create conditions such that
  (i) Biomass is reduced to charcoal
  (ii) Charcoal is converted at suitable temperature to produce CO & H_2.



V Gasifier & their Classifications:

* Biomass gassifier may be considered as a chemical reactor in which biomass goes through several complex physical & chemical processes & producer is produced & removed.
* There are two distinct types of gasifier.

1) Fixed bed gasifier: In this gasifier, biomass fuels move either countercurrent or concurrent to the flow of gasification medium as the fuel is converted to fuel gas.

It is relatively simple to operate & have reduced erosion.

There are three types of fixed bed gasifier.

(a) Down draft gasifier: In the downdraft gasifier, the air is passed from the Layers in the downdraft direction.

* High quality gas
* Suitable for IC engines & thermal applications
* It is sensitive to ash content moisture content & size variation i fuel

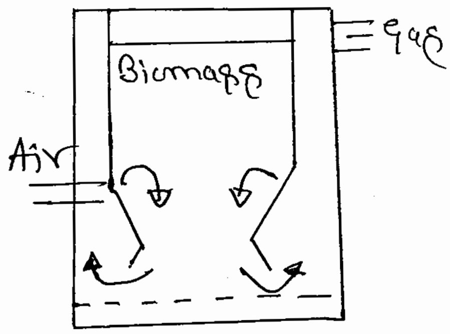


fig: Downdraft.

(b) Updraft gasifier: Updraft gasifier has air passing through the biomass from bottom & the combusitible gases come out from the top of the gasifier.

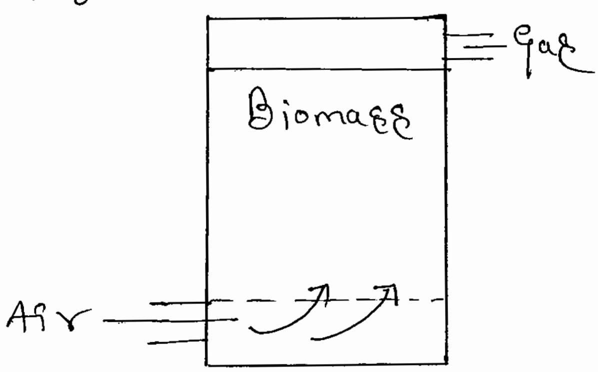


fig: updraft

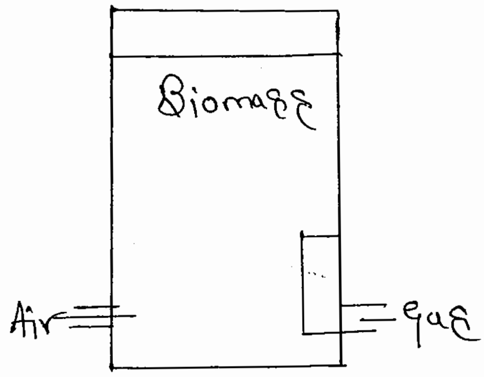


fig. cross draft.

(c) Cross draft gasifier:- It is a very simple gasifier & is highly suitable for small outputs. with slight variation, almost all the gasifiers fall in the abovementioned categories.

* Good quality gas
* Flexible gas production
* Air enter from one side of the gasifier & fuel is released from the opposite side.

2. Fluidized Bed gasifier: In fluidized bed gassifier, an inert material (such as sand, ash or char) is utilized to make bed & that acts as a heat transfer medium.

VI. Chemistry of Reaction process in Gasification.

Four distinct processes take place in a gasifier when fuel makes its way to gasification:

1. Drying zone of fuel: In this zone, the moisture content of biomass is removed to obtain the dry biomass. Some organic acids also come out during the drying process. These acids give rise to corrosion of gasifiers.

2. Pyrolysis zone: In this zone, the tar & other volatiles are driven off. The products depend upon temperature, pressure, residence time & heat losses.

(a) Up to the temperature of 200°C, only water is driven off.

(b) Between 200°C & 280°C carbon dioxide, acetic acid & water are given off.

(c) Real pyrolysis take place between 280°C – 500°C.

(d) Between 500°C & 700°C, the gas production is small & contains hydrogen.

3. Combustion (oxidation) zone: In this zone, carbon from the fuel combust & forms carbon dioxide with the oxygen in the air by the reaction

$$C + O_2 \rightarrow CO_2 + Heat$$

4. Reduction zone: The hot gas passes through the reduction zone after the combustion zone. In this no ~~free~~ oxygen, that causes inflammable carbon dioxide gas to react with the carbon in the fuel & forms. flammable carbon monoxide gas.

$$C + CO_2 + heat \rightarrow 2CO \rightarrow (1)$$

$$C + H_2O + Heat \rightarrow CO + H_2 \rightarrow (2)$$

equ^n (1) & (2) are main reduction reactions, being endothermic have the capability of reducing gas temperature

The temparature in the reduction zone normally 800°C – 1000°C.

$$CO + H_2O - Heat \rightarrow CO_2 + H_2 \rightarrow (3)$$

equ^n (3) lower the reduction zone temperature (~700°C – 800°C), lower the calorific value of gas.

Although there is a considerable overlap of the processes, each can be assumed to occupy a separate zone where fundamentally different chemical & thermal reactions take place.

VII. Updraft, Downdraft & Cross Draft gassifier ✕ vv Imp.

1. UPDRAFT Gasifiers: The oldest & simplest type of gasifier is the counter current or updraft gassifier shown schematically in Figure 1.

* The air intake is at the bottom & gas leaves at the top.

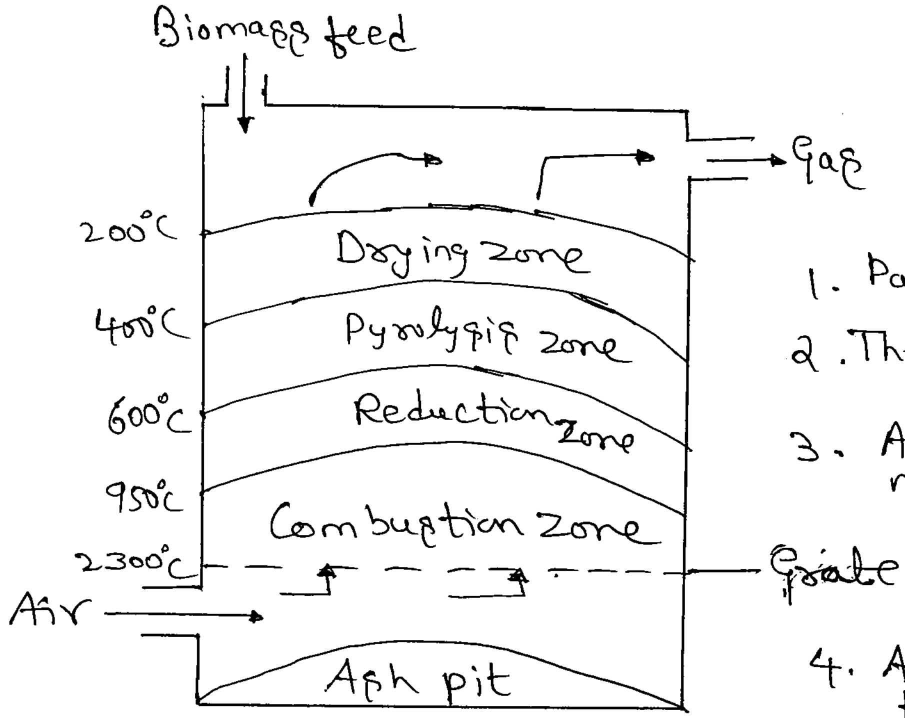


Fig 1. Updraft gasifier.

Applications

1. Packaged boilers
2. Thermal fluid heaters
3. Aluminium melting / annealing furnaces
4. All kinds of dryer roaster

* The reactive agent is injected at the bottom of the reactor and ascends to the top, while the fuel is introduced at the top & descends to the bottom.
* The combustion reactions occur near the grate at the bottom that are followed by reduction reactions somewhat higher up in the gassifier.
* In the upper part of the gasifier, heating & pyrolysis of the feedstock occur as a result of heat transfer by forced convection & radiation from the lower zone
* Updraft gasifiers are widely used to gasify biomass resources & generally use steam as the reactive agent, but slagging can be severe if high ash fuels are used.
* These gasifiers are best suited for applications where moderate amounts of dust in the fuel gas are acceptable & high flame temperature is required.

2. **DOWNDRAFT GASIFIER:** In this gasifiers, the primary gassification air is introduced at or above the oxidation zone in the gasifier & the producer gas is removed at the bottom of the apparatus, so that fuel & gas move in the same direction, as shown in Figure 2.

* Applications

1. Batch type baking oven
2. Boilers
3. Thermal fluid heaters
4. Dryers & curing.
5. Continuous baking oven.
6. I C engines
7. Direct fired rotary kilns
8. Annealing furnaces

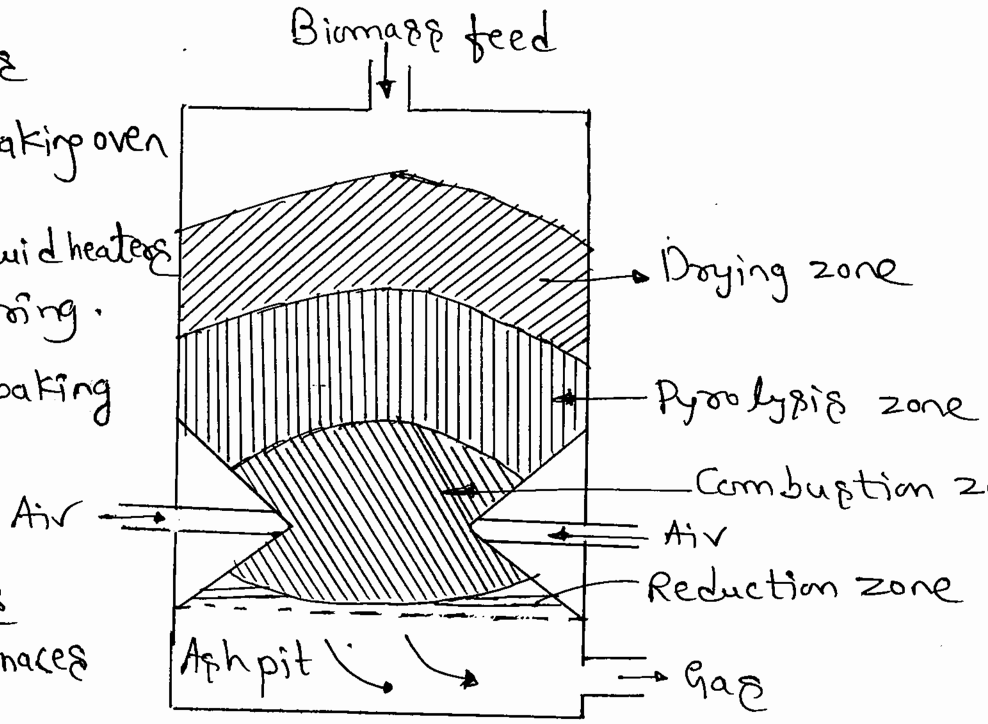


Figure 2. Downdraft gasifier.

* The biomass feed is admitted at the top similar to the updraft gasifier. As the feed progresses down through the gasifier, it dries & its volatiles are pyrolysed.
* Gasification air is injected into the throat through openings in the throat wall.
* Due to the high temperatures existing at the throat section, tars and oils could be cracked, which tend to form in producer gas, particularly when the biomass is wetter than about 20% moisture content.
* The producer gas, leaves at the bottom of the gasifier.
* The start-up time of about 5-10 min is necessary to ignite & bring plant to working temperature with good gas quality is shorter than updraft gas producer.

3. CROSS-DRAFT GASIFIER:

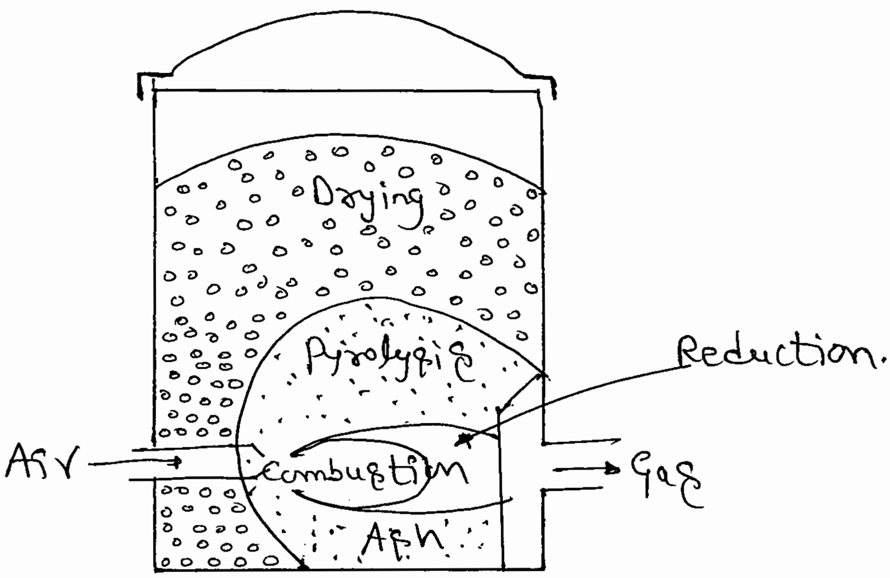


Figure 3. Cross-Draft gasifier.

* Figure 3 is a schematic representation of cross-draft gasifier. unlike downdraft & updraft gasifiers, the ash bin, fire & reduction zone in cross-draft gasifiers are separated.
* These design characteristics limit the type of fuel for operation to low ash fuels such as wood, coke & charcoal.
* The relatively high temperature in cross-draft gas producer has an obvious effect on gas composition such as high carbon monoxide, low hydrogen & methane content when dry fuel like charcoal is used.
* Cross-draft gasifier operates well on dry air blast & dry fuel.
* Typically, the gasifier is a vertical cylindrical vessel of varying cross section.
* the biomass is fed in at the top at regular intervals of time & is converted through a series of processes into producer gas & ash, as it moves down slowly through various zones of the gasifier.

VIII) FLUIDIZED BED GASIFICATION:-

% VVImp.

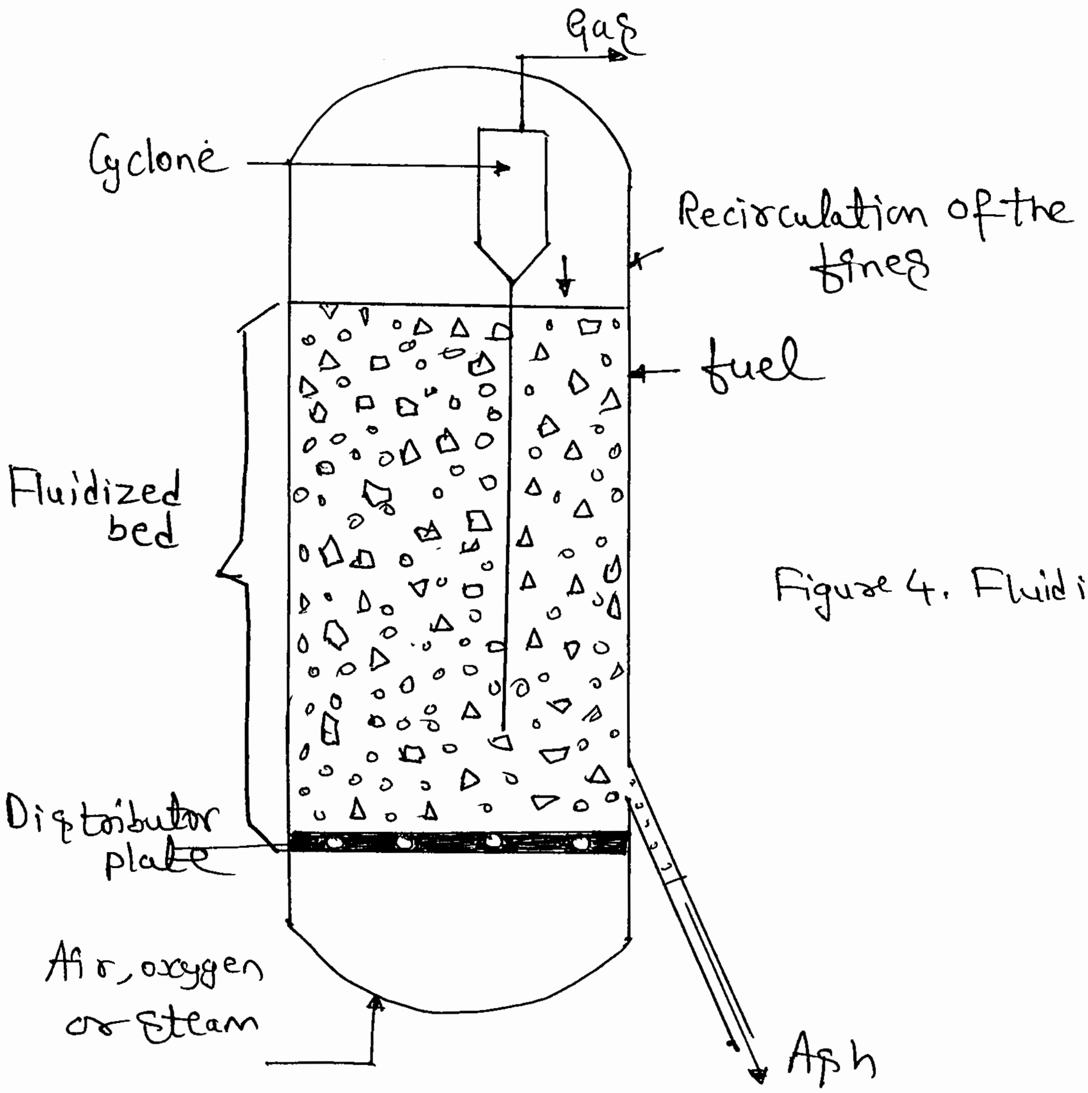


Figure 4. Fluidized bed gasifier.

* It has been successfully used to convert prepared wastes into a clean fuel gas that can be used to fire various types of industrial equipment.
* This gasifier is improved version of fixed bed gasifiers.
* The bed made of inert material initially & it is heated & the fuel is introduced when the temperature has reached the appropriate level.
* The bed material transfers heat to the fuel and blows the reactive agent through a distributor plate at a controlled rate.
* Fluidized bed gasifiers have no distinct reaction zones, but drying, pyrolysis & gassification

occur simultaneously.

* The fuel particles are introduced at the bottom of the reactor, very quickly mixed with the bed material and almost instaneously heated up to the bed temperature.

Advantages:-

1. Reduced cost of boiler or dryer or kiln operation by using wood / bark wastes rather than gas or oil.
2. Reduced cost for additional steaming capacity when compared to new wood or bark fired boilers
3. Reduced dependency on external fuel sources for propane, natural gas & oil.

Benefits:-

1. High overall efficiency
2. Fuel flexibility
3. Highly reliable
4. Low purchase & installation costs
5. Flexible operations
6. Low emissions.

IX Gassifier Biomass Feed Characteristics. ✗ ✗ vvImp.

Following biomass feed characteristics or parameters dictate the quality & classification of gasifiers.

1. Energy content & Bulk Density of Fuel:- The higher the energy content & bulk density of fuel the similar is the gasifier volume.
2. Moisture content :- Moisture content is very trivial components of biomass fuels & it is determined by the type of fuel, its origin & treatment. It is desirable to use fuel with Low moisture content to minimize heat loss due to its evaporation

3. Dust Content: All gasifier fuels produce undesirable dust that can clog the internal combustion engine & hence it has to be removed. The higher the dust produced, more is the load put on filters necessitating their frequent flushing & increased maintainence.

4. Tar content: Tar is one of the most unpleasant constituents of the gas as it tends to deposit in the carburettor & intake values causing sticking & troublesome operations.
Tar can be reduced by filters & coolers

5. Ash & Slagging characteristics:
"The mineral content in the fuel that remains in oxidized form after complete combustion is usually called ash."
Ash basically interferes with the gassification process in two ways
(i) It fuses together to form slag & this clinker stops or inhibits the downward flow of biomass feed.
(ii) Even if it does not fuse together, it shelters the points in fuel where ignition is initiated, & thus lowers the fuel's reaction response.
However, slagging can be overcome by two types of operation of gasifier.
(i) Low temperature operation that keeps the temperature well below the flow temperature of the ash.
(ii) Low temperature operation that keeps the temperature above the melting point of ash.

Charcoal is tar free & has relatively low ash content property.

X Application of Biomass Gasifier: ※ ※ vv Imp

The main application of biomass gasifier products are as follows;

1. **Motive power:-** Gasi products are used to provide shaft power to industrial & agricultural equipment & machinery such as
   (a) Diesel engine operation on dual or 100% modes.
   (b) Water pumps
   (c) Tractors, harvesters
   (d) Running of high efficiency stirling engines.

2. **Direct heat applications:** Gassifies heat has direct heat application such as
   (a) Drying of agricultural crop & food products such as large cardamom, ginger, rubber & tea at low temperature range of about 85°C-125°C.
   (b) Baking of tiles & potteries in the moderate temperature range of about 800°C-900°C.
   (c) For melting metals & alloys in non-ferrous in the temperature range of 700°C-1000°C.

3. **Electrical power generation:-** Electric power generation from few kilowatts to hundreds for local consumption or for grid power is being installed based on gasifier products.

4. **Chemical production:-** production of chemicals such as methanol & formic acid from producer gas.

5. dyeing, turmeric boiling, cooking, silk reeling jiggery making. ⇒ other Direct heat applications.

XI Cooling & cleaning of gasifiers:

For efficient and effective use of gas for numerous applications, it should be cleaned of tar and dust, free from moisture content & cooled.

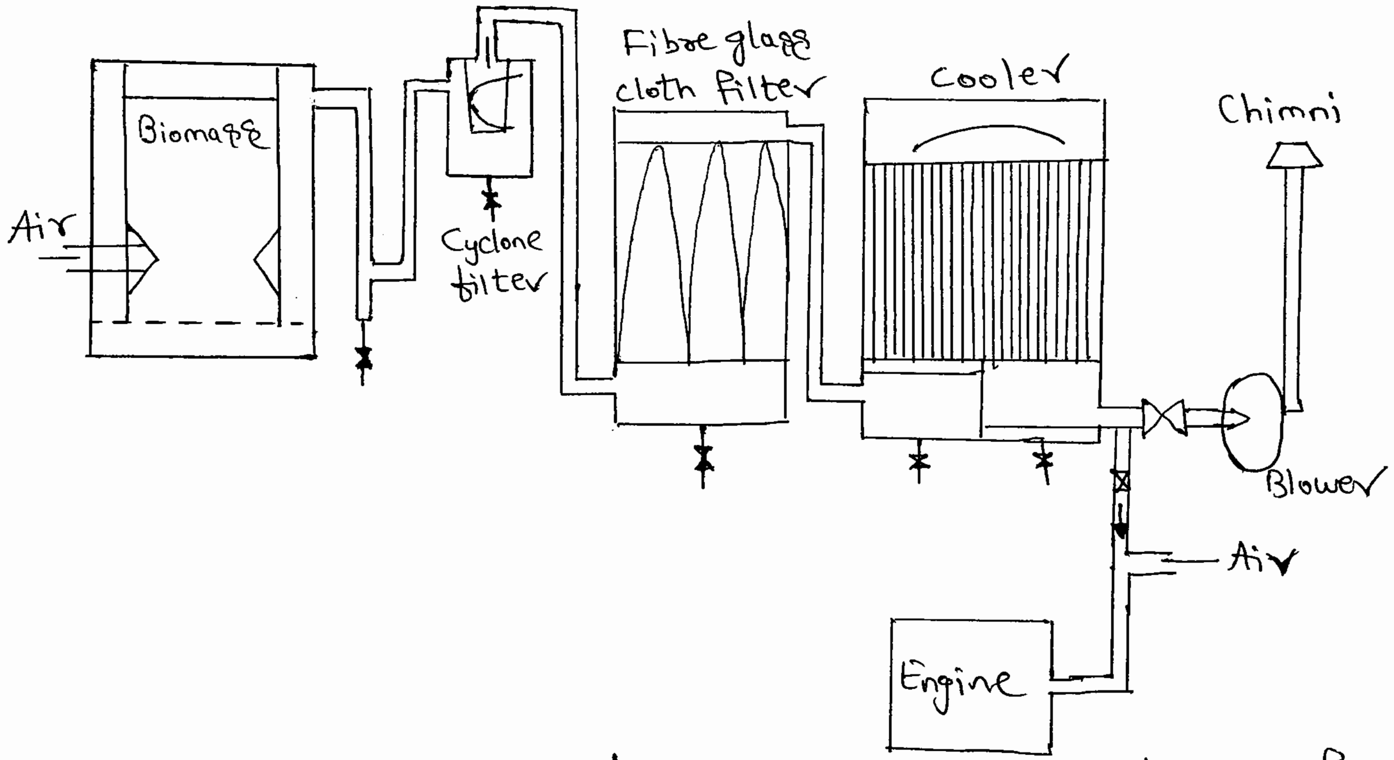


Figure 5 Schematic diagram of cooling & cleaning of gas producer plant.

* Cooling & 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°C & 500°C.
* 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.
* Normally there are three types of filters used for cleaning of gas

(a) Cyclone filters: They are designed according to the rate of gas production & its dust content. It is excellent cleaning device

(b) Wet scrubber: Even after cyclone filtering, the gas still contains fine dust, particles & tar. The scrubber also acts like a cooler.

(c) Cloth / cork filter:- It is a fine filter. Any condensation of water on it stops the gas flow because of an increase in pressure drop across it. No condensation takes place in filter.

(b) Biogas Energy:-

I Biogas & its composition:-

* Biogas is a clean, non-polluting and low-cost fuel
* It contains about 50%-70% methane, which is inflammable.
* A methane gas molecule has one atom of carbon & four atoms of hydrogen (CH_4) & is the main constituent of popularly known as Biogas.
* A colourless, odourless, inflammable gas also been referred to as sewerage gas, clear gas, marsh gas, refuse-derived fuel (RDF), sludge gas, gobar gas & bio energy
* Composition of Biogas

SL No.	Substances	Symbol	%
1	Methane	CH_4	50-70
2.	Carbon dioxide	CO_2	30-40
3.	Hydrogen	H_2	5-10
4.	Nitrogen	N_2	1-2
5	Water vapour	H_2O	0.2-0.3
6.	Hydrogen Sulphide	H_2S	Minute traces

* A 1,000 cubic feet of processed biogas is equivalent to about
  (1) 600 cubic feet of natural gas
  (2) 4.6 gallons of diesel oil
  (3) 5.2 gallons of gasoline
  (4) 6.4 gallons of butane.

* It is also estimated that for a simple family size of five persons & four cows & buffaloes animal dung will produce about 175 cubic feet of biogas per day which will be sufficient for family requirements of cooking & lighting.

II ANAEROBIC DIGESTION: ** V Imp.

* Anaerobic digestion of methane gas production is a series of processes in which microorganism break down bio degrable material in the absence of oxygen which completes through following steps.

  (i) In the first step, the organic matter is decomposed to break down the organic material into usable-sized molecules such as sugar.

  (ii) Conversion of decomposed matter into organic acids is the second step

  (iii) Finally, organic acids are converted to biogas (methane gas).

* The biological & chemical stages of anaerobic digestion are shown in Figure 1. These are divided into the following four main stages.

1. Hydrolysis
2. Acedogenesis
3. Acetogenesis
4. Methanogenesis.

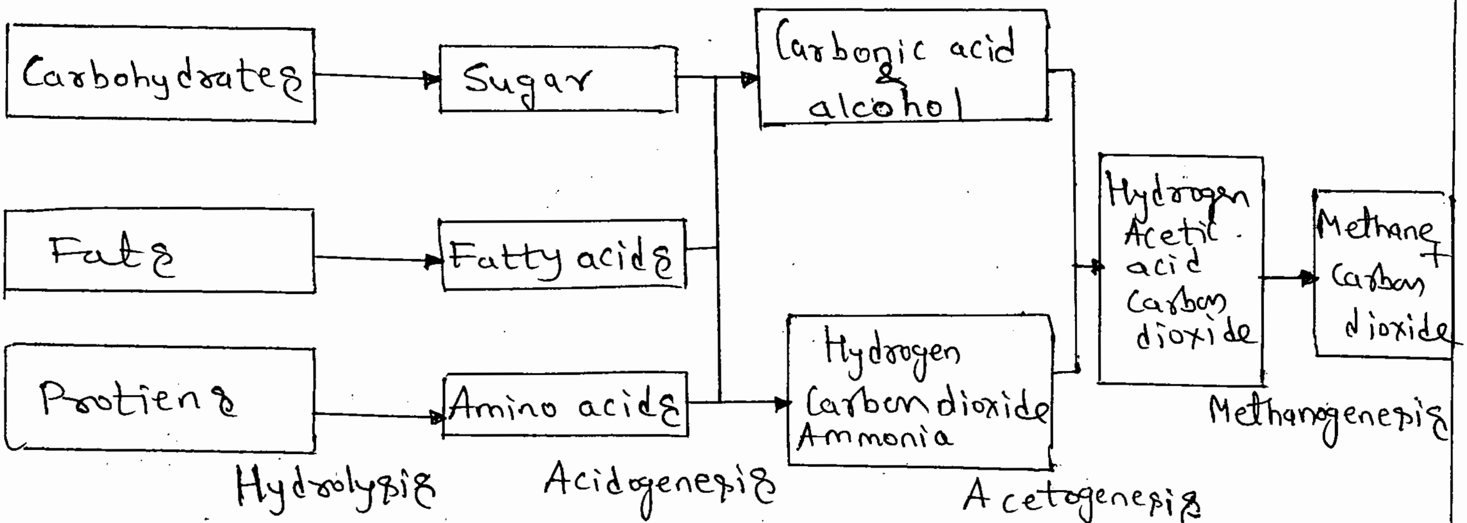


Figure 1. process of anaerobic Digestion.

1. <u>Hydrolysis</u>:- The process of breaking large biomass organic chains into their smaller constituent parts such as sugar, fatty acids & amino acids & dissolving the smaller molecules into solution is called Hydrolysis.

2. <u>Acidogenesis</u>:- It is the biological process in which the remaining components are broken down by acidogenetic bacteria. It creates voltaic fatty acids together with ammonia, carbon dioxide & hydrogen sulphide & other byproducts.

3. <u>Acetogenesis</u>:- In this stage of anaerobic digestion, simple molecules created through the acidogenesis phase are further digested to produce more acitic acid, carbon dioxide & hydrogen.

4. <u>Methanogenesis</u>:- The process of biogas production is completed by methanogenesis. In this stage the methanogens use intermediate products of the preceding stages & convert them into methane, carbon dioxide & water which makes the majority of the biogas emitted from the system.

overall process equation, $C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$ //.

III BIOGAS PRODUCTION

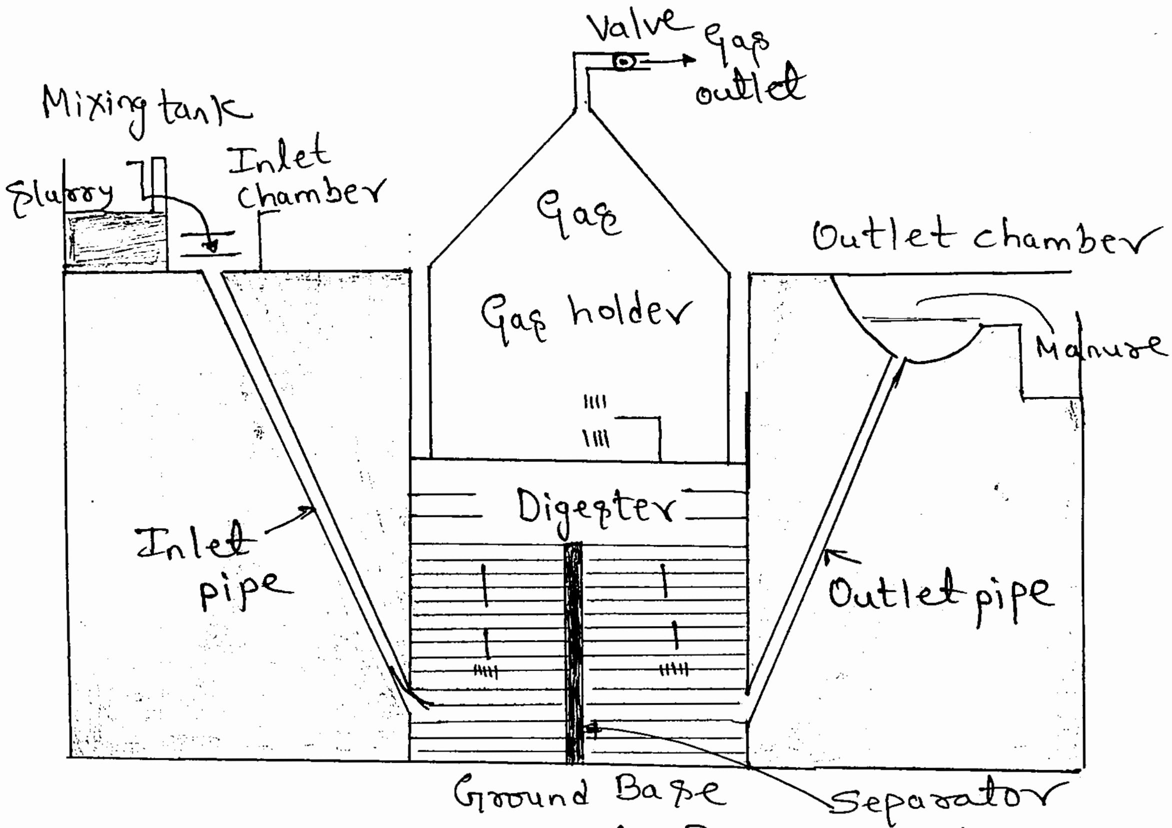


Figure 2. Typical Biogas plants.

Figure 2 shows various parts of typical biogas plant.

* It is a brick & cement structure having the following five sections.
  1. Mixing tank 2. Digester tank 3. Dome or gas holder
  4. Inlet chamber 5. Outlet chamber.

* Mixing tank :- It is the first part of biogas plants located above the ground level in which the water & cow dung are mixed together in equal proportions (1:1) to form the slurry that is fed into the inlet chamber.

* Digester tank :- It is deep underground well-like structure & divided into two chambers by a partition wall in between. The Digester is also called as fermentation tank.

  It is cylindrical in shape & made up of bricks, sand & cement built underground over the solid foundation.

It has two pipes

1. Inlet pipe opening into the inlet chamber for inputting the slurry in digester tank.
2. Outlet pipe opening into the overflow tank for the removal of spent slurry from the digester tank.

A separator is placed in the middle of digester tank to improve effective fermentations of feedstock.

* Dome or Gas Holder:- The hemispherical top portion of the digester is called dome. It has fixed height in which all the gas generated within the digester is collected. The dome or gas holder is made either fixed dome or floating dome type.

* The cow dung slurry is supplied to the digester of the biogas plant via inlet chamber.
* The digested slurry from the biogas plants is removed through the outlet chamber

Working of Biogas plant:-

1. Cattle dung and water are mixed together throughly in equal proportion to form the slurry in the mixing tank. Then, this slurry is poured into the digester via inlet chamber up to the cylindrical portion level of the digester.
2. The fermentation of slurry starts in the digester tank, and after completion of different anaerobic digestion processes, biogas is formed.
3. The gas continuously produced in digester tank is accumulated at the top of the digester in the dome or gas holder.
4. If the gas valve is still kept closed the biogas will further get accumulated in the dome & develop high pressure enough in the gas to start escaping

through the inlet and outlet chambers to the atmosphere.

5. An increase in the volume of slurry in the inlet & outlet chambers helps to calculate the amount of biogas generated within the digester.
6. Gas pipe valve can be opened partly or fully to provide biogas for different applications.
7. When the gas is being taken out from the gas outlet at the top of the dome, the slurry from the outlet chamber is removed & equivalent amount of fresh slurry is inducted into the digester to continue the process of fermentation & the formation of the biogas.

Types of Biogas plants: ~~vv Imp~~ ※ ※

1. Fixed Dome Type.

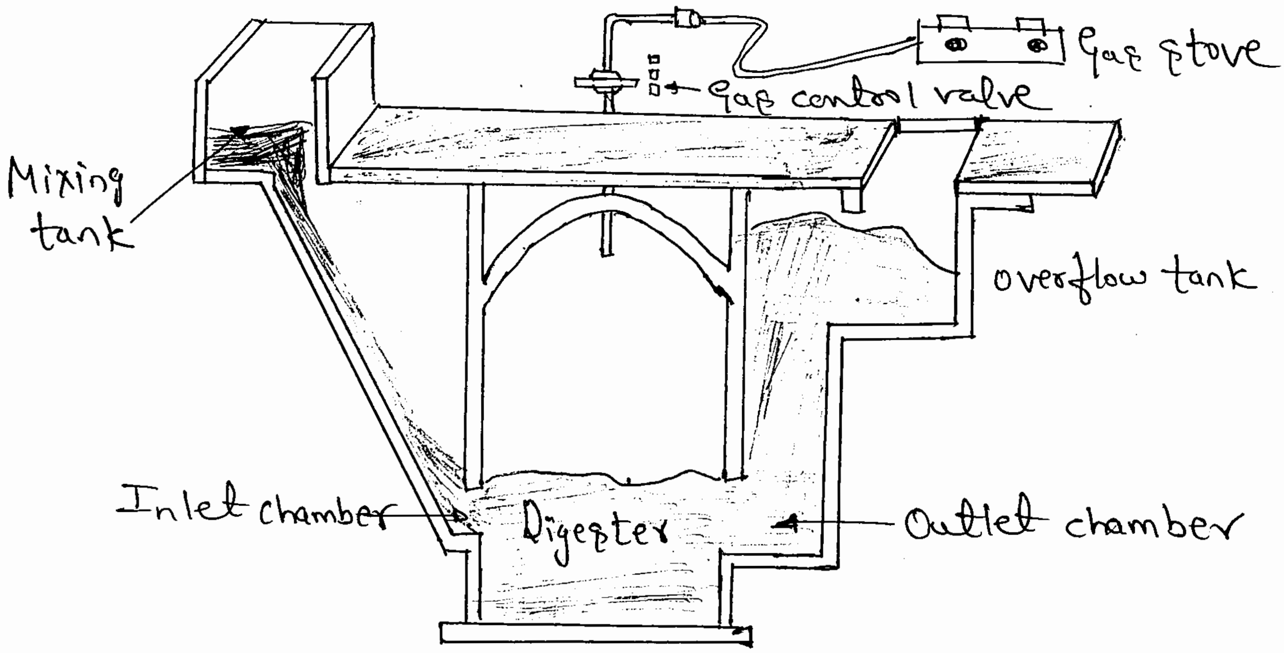


Figure 3. Fixed Dome type Biogas plant.

* It consists of following parts
  1. Mixing tank: In mixing tank, the water & cattle dung are mixed together throughly in the ratio 1:1 to form the slurry.

2. **Inlet Chamber:** The mixing tank opens underground into a sloping inlet chamber.
3. **Digester:** Digester is a huge tank with a dome type ceiling.

Working principle; The various forms of organic biodegrable biomass are collected & mixed with equal amount of water properly in the mixing tank which form slurry. The slurry is fed into the digester tank through inlet chamber and pipe & the digester is partially filled by about half of its height. The feeding of slurry is then discontinued for about 60 days when anaerobic bacteria present in the slurry decomposes or ferments the biomass in the presence of water.

Biogas is then formed and starts accumulating in the upper dome area of the biogas plants & the pressure is exerted on the spent slurry to force it flow into the outlet chamber.

Finally, the spent slurry overflows into the overflow tank from where it is manually removed and used as manure for agricultural crops & plants.

Gas control valve at the top of dome is opened partially or fully to supply required gas for particular applications.

Advantages: (i) The cost is relatively low
(ii) Simple in construction as no movable dome
(iii) Long life of plant
(iv) Saves space
(v) Little influenced by temperature fluctuation in day & night

Disadvantages (i) Porosity & cracks in plant walls
(ii) Maintenance is rather difficult.

2. Floating Type Biogas plant.

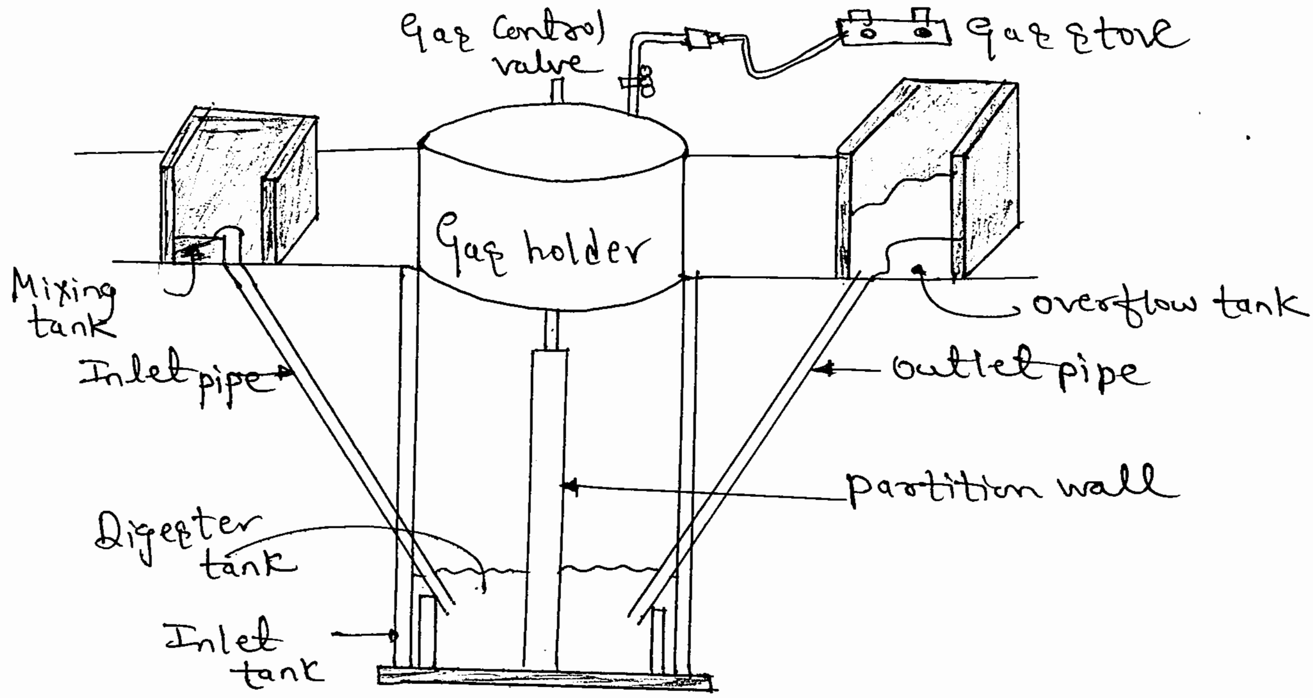


Figure 4. Floating dome-type biogas plant.

The construction & working principle of this biogas plants is similar to fixed dome type except that gas holder tank is made up of steel & placed on the top of digester circular tank and is movable up & down.

Advantages : (i) Very efficient
(ii) Simple maintenance scheduling possible

Disadvantages : (i) Expensive
(ii) Steel drum may rust
(iii) Requires regular maintenance

Types

Fixed Dome type	Floating Drum type
1. Chinese fixed dome type	1. KVIC model
2. Janata model	2. Pragati model
3. Deenbandhu model	3. Ganesh model
4. CAMARTEC model.	4. Arati Biogas model
	5. BORDA model.

extra

IV Benefits of Biogas, Advantages, Limitations.

※ ※ vv Imp.

Benifits:

(i) production of energy (heat, light & electricity)
(ii) Transformation of organic waste into high quality organic fertilizer.
(iii) Health benefits of biogas & the improvement of hygienic conditions (reduction of pathogens, worm eggs & flies).
(iv) Reduction of workload, mainly for women, in firewood collection & cooking.
(v) Environmental advantages through protection of forests, soil, water & air.
(vi) Global environmental benefits of biogas technology.

Advantages:

(i) Clean fuel of high calorific value & has a convenient ignition temperature.
(ii) No residue, smoke & dust produced
(iii) Non-polluting, significant health benefits are achieved by the use of clean biogass.
(iv) Economical benefits of biogas & high quality manure
(v) Provides nutrient rich (N & P) manure for

Limitations:

(i) Initial cost of installation of the plant is high
(ii) Inadequacy of organic raw materials & its continuity of supply
(iii) Social acceptability
(iv) Maintenance & repair of biogas plants.

V Factors affecting the selection of a particular model of a biogas plant.

※ ※ vvImp

Various factors affecting the selection of a particular model of a biogas plant are as follows

(i) Cost :- The principal & maintenance cost of biogas plants should be as low as possible both to the user & to the society.

(ii) Simplicity in design: The design should be simple not only for construction purposes but also for operation & maintenance.

(iii) Durability: Longer lifespan of biogas plants is essential in situations where people are yet to be motivated for the adoption of this technology & the necessary skill & materials are not readily available, & it is necessary to construct plants that are more durable, although this may require a higher initial investment.

(iv) Suitability for use with available raw inputs: The design should be compatible with the type of inputs that would be used.

(v) Inputs & outputs use frequency: Frequency of utilization of biogas & feedstock inputting in biogas plants, influence the selection of a particular design & size of various components of biogas plants.

VI Biogas plant feeds and their characteristics.

* - The major characteristic is Carbon/Nitrogen (C/N) ratio.

* A C/N ratio ranging from 20 to 30 is considered optimum for anaerobic digestion.
* For organic materials with very high C/N ratio, the nitrogen will be consumed rapidly by methanogens for meeting their protien requirements & left over carbon content of the material will not have any reaction process. This will reduce the biogas production.
* For very low, C/N nitrogen will be liberated & accumulated in the form of ammonia (NH_4) which will increase the pH value of the content in the digester.
* A pH values higher than 8.5 will start showing toxic effect on methanogens population.

(C) Tidal energy.

I. Advantages & Disadvantages of Tidal power.

X X vvImp.

Advantages

i) About two-third of earth's surface is covered by water, there is scope to generate tidal energy on large scale

ii) Techniques to predict the rise & fall of tides as they follow cyclic fashion & prediction of energy availability is well established.

iii) It is an environment friendly energy & does not produce greenhouse effects

iv) It is an inexhaustible source of energy.

v) The life of tidal energy power plant is very long

vi) The energy density is relatively higher.

vii) It is clean source of energy & does not require much land or other resources as in harnessing energy from other sources

viii) Efficiency of tidal power generation is far greater when compared to coal, solar or wind energy. Its efficiency is around 80%

ix) Capital investment of construction of tidal power is high, running & maintenance costs are relatively low.

Disadvantages:-

i) Capital investment for construction of tidal power is high

ii) Only a very few ideal locations for construction of plant are available & they too are localized to coastal regions.

iii) Unpredictable intensity of sea waves can cause damage to power generating units.

iv) Aquatic life is influenced adversely & can disrupt the migration of fish.

v) The energy generated is not much as high & low tides occur only twice a day & continuous energy production is not possible.

vi) The actual generation is for a short period of time.

vii) This technology is still not cost effective & more technological advancements are required to make it commertially viable.

II Problems Faced in exploiting Tidal energy.

i) Usually the places where tidal energy is produced are far away from the places where it is consumed.

ii) Transmission is expensive & difficult.

iii) Intermittent supply: cost & environmental problems particularly barrage systems are less attractive than some other forms of renewable energy.

iv) Cost

v) Altering the ecosystem at the bay.

vi) Limited constructed locations

vii) provides power for around 10h each day.

viii) Expensive to construct

ix) Barrages may also destroy the habitat of the wild life living neat it.

III. TIDAL POWER BASIN:-

The basin system is the most practical method of harnessing tidal energy. It is created by enclosing a portion of sea behind erected dams.

vv Imp.

There are two types

(i) Single basin system:-

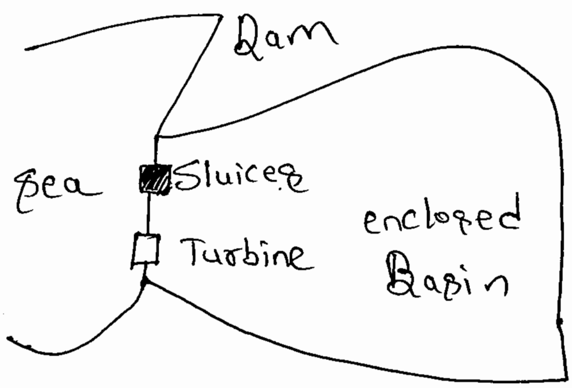


Figure 1. Single-basin system.

* This is the simplest way of power generation & the simplest scheme for developing tidal power is the single-basin arrangement as shown in Figure 1.

* Single water reservoir is closed off by constructing dam or barrage.
* Sluice [gate], large enough to admit the water during tide so that the loss of head is small, is provided in the dam.
* The single-basin system has two configuration namely.

1. One-way single basin system: This type of systems can allow power generation only for about 5h. Power is generated till the level of falling tides coincides with the level of the next rising tide

2. Two-way single basin: This system allows power generation from the water moving from the sea to the basin, & then at low tide, moving back to the sea. This process requires bigger & more expensive turbine.

* Single basin system has the drawbacks of intermittent power supply & harnessing of only about 50% of available tidal energy.

(ii) Two-basin system:-

* An improvement over the single-basin system is the two-basin system.
* In two-basin system, a constant & continuous output is maintained by suitable adjustment of the turbine values to suit the head under which these turbines are operating.
* A two-basin system regulates power output of an individual tide, but it cannot take care of the great difference in outputs between spring

& neap tides.

* Therefore, this system provides a partial solution to the problem of getting a steady output of power from a tidal scheme.

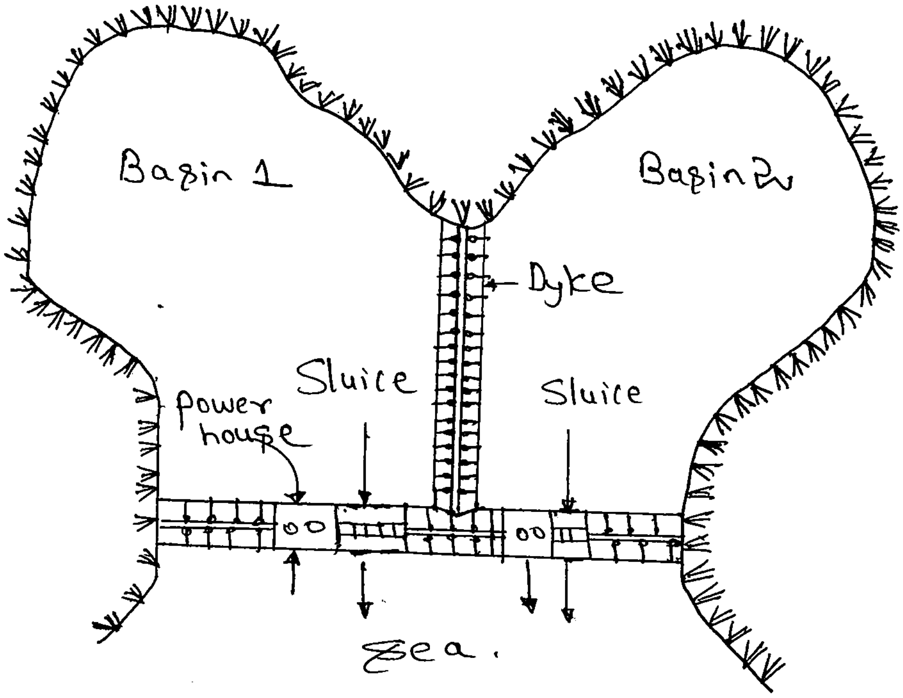


Figure 2: Two basin system.

* This arrangement, even though technically feasible, is much more expensive, as it calls for high installed capacity for meeting a particular load.

* The Figure 2 shown, the two basins close to each other, operate alternatively.
* One basin generates power when the tide is rising and other basin generates power while the tide is falling.
* The two basins may have a common power house or may have separate power house for each basin.
* In both cases power is generated continuously.
* It is a combination of 2 single basin system:, in which

one is generating power during tiding cycle & other is generating power during emptying.

IV Turbines for Tidal power ** vv Imp.

Tidal power plants operate using a rapidly varying head of water, & therefore, their turbines must have high efficiency at varying load.

1. Kaplan type of water turbine operates quite favourably under these conditions
2. propeller type of turbine is also suitable because the angle of the blades can be altered to obtain maximum efficiency while water is falling.
3. Bulb-type turbine, it acts with equal efficiency both as a pump & as a turbine.

Bulb-type turbines:-

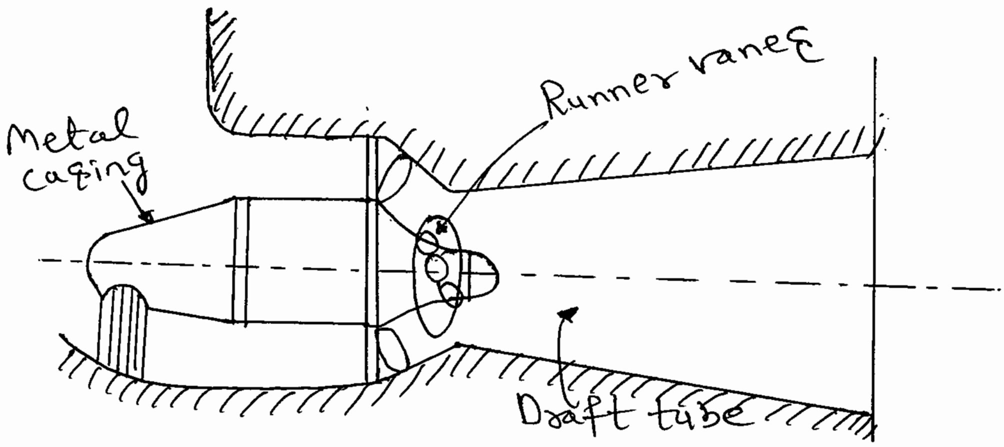


Figure 3. Bulb-type turbine.

* It consists of a steel shell completely enclosing the generator that is coupled to the turbine runner.
* The turbine in mounted in a tube within the structure of the barrage & the whole machine

being submerged at all times.

* Bulb turbines incorporated the generator-motor unit in the flow passage of the water. These turbine are used at the La Rance power station in France.
* The main draw back is that water flows around the turbine, making maintenance difficult.

V Energy availability in Tides

potential & kinetic energy are the two energy components of tide waves.

* potential energy, E_1

$$E = \rho g A \int z \, dz$$

$$\boxed{E_1 = 0.5 \rho g A h^2}$$

E = energy
g = accelaration of gravity
ρ = seawater density
A = sea area under construction.
Z = vertical coordinate of ocean surface
h = tide Amplitude

$$\rho g = 10.15 \ kN/m^3$$

$$\therefore \boxed{\begin{aligned} E_1 &= 1.4 h^2 \text{ wath-hour} \\ E_1 &= 5.04 h^2 \ kJ \end{aligned}}$$

* kinetic energy E_2

$$\boxed{E_2 = 0.5 m V^2}$$

m = mass
V = velocity.

* Tidal power is given as

$$\boxed{P = \frac{\rho g A H^2}{2T}}$$

T = Tidal period (s)
H = tidal ranges (m)

Assume $\rho = 1.04 \times 10^3 \ kg/m^3$ & $T = 6h$

then $\boxed{P = 0.226 A H^2}$ watts

* Tidal power is given as

$$\boxed{P = 0.5 \rho A \eta_T V^3}$$

A = caputure Area
η_T = combined efficiency form water to electric wire.

Chapter 11

Tidal Energy

Tides are periodic rises and falls of large bodies of water. Gravity is one major force that creates tides. In 1687, Sir Isaac Newton explained that ocean tides result from the gravitational attraction of the sun and moon on the oceans of the earth. Spring tides are especially strong tides that occur when the earth, the sun, and the moon are in a line. The gravitational forces of the moon and the sun both contribute to the tides. Spring tides occur during the full moon and the new moon. Neap tides are especially weak tides. They occur when the gravitational forces of the moon and the sun are perpendicular to one another with respect to the earth. Neap tides occur during quarter moons. Tidal energy is a form of hydropower that converts the energy of the tides into electricity or other useful forms of power. The tide is created by the gravitational effect of the sun and the moon on the earth causing cyclical movement of the seas. Therefore, tidal energy is an entirely predictable form of renewable energy. Until recently, the common plant for tidal power facilities involved erecting a tidal dam, or barrage, with a sluice across a narrow bay or estuary. As the tide flows in or out, creating uneven water levels on either side of the barrage, the sluice is opened and water flows through low-head hydro turbines to generate electricity. For a tidal barrage to be feasible, the difference between high and low tides must be at least 5 m.

KEY CONCEPTS

- Tidal energy resource
- Tidal energy availability world wide and in india
- Energy availability in tides and calculation of tidal power
- Tidal power basin
- Turbines for tidal power
- Problems faced in exploiting tidal energy

11.1 GENERAL

Energy naturally present in ocean water bodies or in their movement can be used for the generation of electricity. This is achieved broadly in the following ways:

1. *Tidal energy*: During the rising period of tides, water is stored in a water reservoir constructed behind dams on shore. The potential energy of stored water body is used to generate electrical energy similar to that in a conventional hydropower plant. For the tidal energy method to work effectively, the tidal difference (difference in the height of the high and low tides) should be at least 4m. We discuss tidal energy in this chapter.
2. *Wave energy*: Using the kinetic (dynamic) energy of the ocean, waves is utilized to rotate an underwater power turbine and generate electricity thereon as an underwater wind farm. This will be discussed in Chapter 12.
3. *Ocean thermal energy*: Chapter 13 focusses on the temperature difference between warm ocean surface water and deep sea cold water is used to generate electricity. This is similar to geothermal power generation where heat trapped in the earth surface is converted into electrical energy.

11.2 TIDAL ENERGY RESOURCE

Tides are the waves caused due to the gravitational pull of the moon and also the sun (although its pull is very low). The rise of seawater is called high tide and fall in seawater is called low tide and this process of rising and receding of water waves happen twice a day and cause enormous movement of water.

Thus, enormous rising and falling movement of water is called tidal energy, which is a large source of energy and can be harnessed in many coastal areas of the world. Tidal dams are built near shores for this purpose in which water flows during high tide and water flows out of dam during low tides. Thus, the head created results in turning the turbine coupled to electrical generator.

Tidal energy has been developed on a commercial scale among the various forms of energy contained in the oceans. When the moon, the earth, and the sun are positioned close to a straight line, the highest tides called spring tides occur. When the earth, moon, and sun are at right angles to each other (moon quadrature), the lowest tides called neap tides occur.

The water mass moved by the moon's gravitational pull when moon is very close to ocean and results in dramatic rises of the water level (tide cycle). The tide starts receding as the moon continues its travel further over the land, away from the ocean, reducing its gravitational influence on the ocean waters (ebb cycle).

11.3 TIDAL ENERGY AVAILABILITY

Gravitational forces between the moon, the sun, and the earth cause the rhythmic rise and fall of ocean waters throughout the world. Those result in tide waves. The moon exerts more than twice as great a force on the tides as the sun due to its much closer position to the earth. As a result, the tide closely follows the moon during its rotation around the earth, creating diurnal tide and ebb cycles at any particular ocean surface. The amplitude or height of the tide wave is very small in the open ocean where it measures several centimetres in the centre of the wave distributed over hundreds of kilometres. However, the tide can increase dramatically when it reaches continental shelves, bringing huge masses of water into narrow bays, and river estuaries along a coastline. For instance, the tides in the Bay of Fundy in Canada are the greatest in the world, with amplitude between 16 and 17 m near shore. High tides close to these figures can be observed at many other sites worldwide, such as the Bristol Channel in England, the Kimberly coast of Australia, and the Okhotsk Sea of Russia. Table 11.1 gives ranges of amplitude for some locations with large tides.

Table 11.1 Highest Tides (Tide Ranges) of the Global Ocean

Country	Site	Highest Tide Range (m)
Canada	Bay of Fundy	16.2
EnglandZ	Severn Estuary	14.5
France	Port of Granville	14.7
France	La Rance	13.5
Argentina	Puerto Rio Gallegos	13.3
Russia	Bay of Mezen (White Sea)	10.0
Russia	Penzhinskayaguba	13.4
India	The Gulf of Cambay, Gujarat	11
India	Gulf of Kutch, Gujarat	8
India	The Ganges Delta in the Sundarban, West Bengal	5

Source: NOAA Federal

Tidal energy projects are extremely site specific. The quality of the topography of the basin also needs to facilitate civil construction of the power plant. It is a clean mechanism and does not involve the use of fossil fuels. However, environmental concerns exist mainly to do with high silt formation at the shore (due to preventing tides from reaching the shore and washing away silt) and disruption to marine life near the tidal basin. Wave energy projects have lesser ecological impact than tidal wave energy projects.

In terms of reliability, tidal energy projects are believed to be more predictable than those harnessing solar or wind energy, since occurrences of tides are fully predictable. Table 11.2 provides glimpses of few potential sites for tidal power generation.

Table 11.2 A Few Potential Sites for Tidal Power Generation

Country	Site	Average Tide Height (m)	Basin Area (m^2)	Estimated Power Potential (MW)
Argentina	San-Jose	6.0	780	7,000
Australia	Secure	8.4	130	570
Australia	Walcoti	8.4	260	1,750
Korea	Carolina Bay	4.7	90	480
Russia	Mezen	5.66	2,640	15,000
Russia	Tugur	5.38	1,080	6,790
UK	Severn	8.3	490	6,000
UK	Mersey	8.4	60	700
USA	Cook Inlet	4.35	3,100	18,000
USA	Passamaquoddy	5.55	300	400

Source: NOAA Federal

11.4 TIDAL POWER GENERATION IN INDIA

Long coastline with the estuaries and gulfs in India has a strong tidal range and height to move turbines for electrical power generation. Important site location and estimated power potential of a few Indian tidal energy plant is given in Table 11.3.

Table 11.3 Indian Tidal Energy Plant

Site Location	Tide Heights (m)	Estimated Power Potential (MW)
The Gulf of Cambay, Gujarat	11 (6.7 av)	7,000
Gulf of Kutch, Gujarat	8 (5.23 av)	12,000
The Ganges Delta in the Sundarban, West Bengal	5 (2.97)	8,000

Many organizations and government agencies are busy in the construction of tidal power plants on all those location and harnessing tidal energy at full capacity. There is an ample prospect for tidal power development in India. It has been investigated that Gulf of Cambay may prove the biggest tidal energy reservoir for India. Extensive exploration on the western coast in Gulf of Kutch (at Mandva), Gulf of Combay (at Hazira), Maharashtra (at Janjira and Dharmata) and also in Hoogali, Chhatarpur, and Puri on Eastern coast may be worth attempting.

Nevertheless, the possibility of developing tidal power scheme in India may be examined in the following all aspects:

1. Economic aspects of tidal power schemes when compared to the conventional schemes.
2. Problems associated with the construction and operation of plant.
3. Problems related to the hydraulic balance of the system in order to minimize the fluctuation in the power output.
4. Environmental effects of the schemes.

11.5 LEADING COUNTRY IN TIDAL POWER PLANT INSTALLATION

Worldwide installed capacity of few countries are approximately shown in Table 11.4.

Table 11.4 Installed Tidal Power Capacities of Few Countries

Country	Site Location	Installed Capacity (MW)
France	La Rance	24 bulb-type turbines, each of 10 MW rating. Total = 240 MW
UK	The Severn Barrage	A total of 214 turbines each of 40 MW rating. Total = 8,560 MW
Russia	Kislaya Guba	0.4 MW
Canada	Annapolis	18 MW
China		3.9 MW