Course: Renewable Energy Sources

Module-4: Biomass Energy

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Biomass Energy

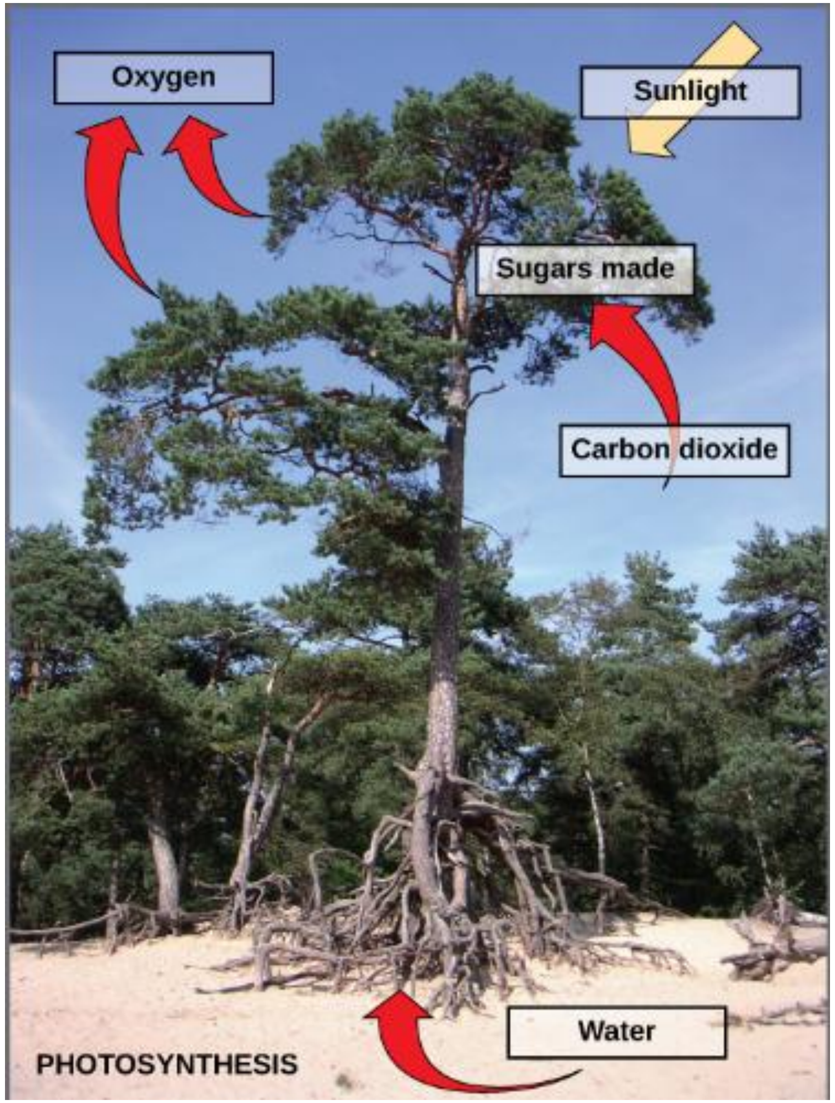
- Solar energy by means of photosynthesis stores energy in trees and plants that can be converted into liquid fuels suitable for internal combustion engines.
- Similarly, ethanol could be produced from cellulose on large scale.
- There is no doubt that rising energy costs will lead to more concentrated research of such biological system; such that, energy gains made via plant photosynthesis using intensive systems are subsequently more than that lost in the conversion of biomass energy content into storable high energy fuels (i.e., ethanol or methane).
- The growth of sugarcane and its fermentation to ethanol may be considered to be the most favourable for the marginal net energy production process, which is suitable for Indian climatic conditions.
- Biomass is used for heating, electric power generation, and combined heat and power.

- Several methods are used for the conversion of biomass into useful energy, such as electricity generation by direct burning of biomass, synthesis gas production by gasification, and methane gas production by anaerobic digestion.
- Sun is the primary source of all kinds of available raw energy resources including biomass.
- The sunlight energy is transferred to biosphere by the photosynthesis process that occurs in plants, algae, and some types of bacteria.
- Plant matter created by the process of photosynthesis is called biomass. Photosynthesis is a natural radiation.

- In its simplest form, the final reaction of this process can be represented as follows:

Photosynthesis Equation						
Carbon dioxide	+	Water	SUNLIGHT →	Sugar	+	Oxygen
$6CO_2$		$6H_2O$		$C_6H_{12}O_6$		$6O_2$

- It is seen that in the process, water and carbon dioxide are converted into organic material.
- The term biomass refers to those organic matters that are stored in plant and trees in the form of carbohydrate (sugar).
- It is then transferred through food chains in humans, animals, and other living creatures and their wastes.



- The term biomass includes all plant life: trees, agricultural plants, bush, grass and algae, and their residues after processing.
- Biomass may be obtained from forests woods, agricultural lands and even waste lands.
- It may be obtained in a planned or unplanned manner.
- The term is also generally understood to include animal and human waste.
- Biomass has the advantage of controllability and availability when compared to many other renewable energy options.
- There are a variety of ways of obtaining energy from biomass.
- These may be broadly classified as direct methods and indirect methods.

Direct Methods

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

1. Forest wood and wastes
2. Agricultural crops and residues
3. Residential food wastes
4. Industrial wastes
5. Human and animal wastes
6. Energy crops

Raw biomass has a low energy density based on their physical forms and moisture contents and their direct use are burning them to produce heat for cooking.

Indirect Methods

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

The efficient conversion processes are as follows:

1. Thermo-electrical conversion:

- The direct combustion of biomass material in the boiler produces steam that is used either to drive a turbine coupled with an electrical generator to produce electricity or to provide heat for residential and industrial system.
- However, the boiler equipment are very expensive and energy recovery is low.
- Fortunately, improved pollution controls and combustion engineering have advanced to the point that any emissions from burning biomass in industrial facilities are generally less when compared to the emissions produced when using fossil fuels (coal, natural gas, and oil).

2. Biomass conversion to fuel:

- Under present conditions, economic factors seem to provide the strongest argument of considering biomass conversion to fuel such as fermentation and gasification.
- In many situations, where the price of petroleum fuels is high or where supplies are unreliable, the biomass gasification can provide an economically viable system, provided the suitable biomass feedstock is easily available.

Biomass conversion processes can be classified under two main types:

(a) Thermo-chemical conversion includes processes such as destructive distillation, pyrolysis, and gasification.

(b) Biological conversion includes processes such as fermentation and anaerobic digestion.

- Gasification produces a synthesis gas with usable energy content by heating the biomass with less oxygen than needed for complete combustion.
- Pyrolysis yields bio-oil by rapidly heating the biomass in the absence of oxygen.
- Anaerobic digestion produces a renewable natural gas (methane gas) when organic matter is decomposed by bacteria in the absence of oxygen.
- As a result, it is often advantageous to convert this waste into more readily usable fuel form.

Biomass gasification

- Biomass gasification 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.
- Gasification, which is incomplete combustion of carbonaceous fuels, can be represented with the following sub-stoichiometric equation.

Biomass + air → carbon monoxide (CO) + carbon dioxide (CO_2) + methane (CH_4) + hydrogen (H_2) + nitrogen (N_2) + water vapour.

- Gasification produces a synthesis gas with usable energy content is produced by gasification in which biomass is heated with less oxygen than that needed for complete combustion.
- As a result, a gaseous mixture of carbon monoxide (CO), carbon dioxide (CO_2), Methane (CH_4), hydrogen (H_2), and nitrogen (N_2) called ***producer gas is obtained***.

Producer gas can be used

1. To run internal combustion engines (both compression and spark ignition)
2. As substitute for furnace oil in direct heat applications and
3. To produce, in an economically viable way, methanol

Gasification processes involved with biomass are as follows:

Drying of fuels:

It is the process of drying biomass before it is fed into gasifier.

Pyrolysis:

It is a process of breaking down biomass into charcoal by applying heat to biomass in the absence of oxygen.

Combustion:

All the heat required for different processes of gasification are made available from combustions.

Cracking:

In this process, breaking down of large complex molecules (such as tar) takes place when heated into lighter gases.

Reduction:

Oxygen atoms are removed in this process from the combustion products (hydrocarbon) molecules and returning them to combustible form again.

GASIFIER AND THEIR CLASSIFICATIONS

- Biomass gasifier may be considered as a chemical reactor in which biomass goes through several complex physical and chemical processes and producer or syngas is produced and recovered.

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 (steam, air, or oxygen) as the fuel is converted to fuel gas.
- They are relatively simple to operate and have reduced erosion.
- Since there is an interaction of air or oxygen and biomass in the gasifier, they are classified according to the way air or oxygen is introduced in it.

There are three types of gasifier as shown in Figure 4.1.

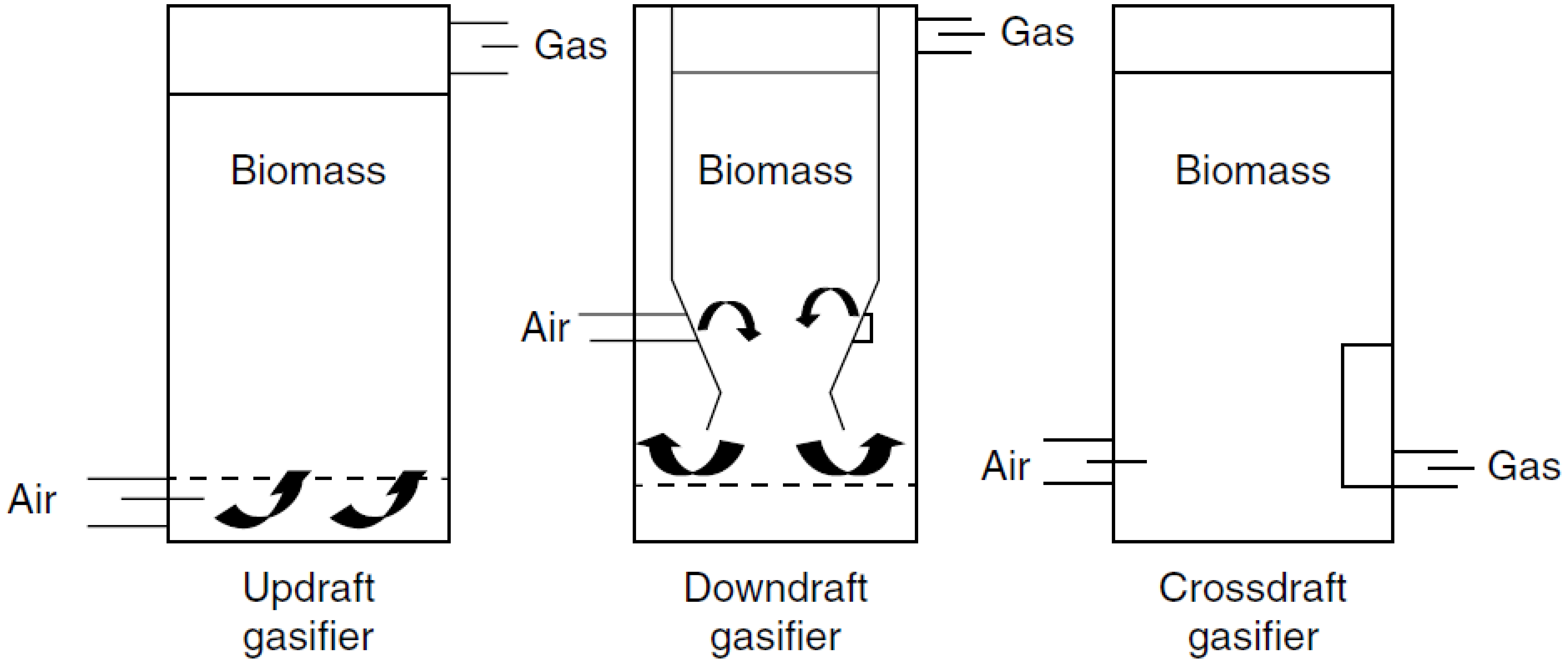
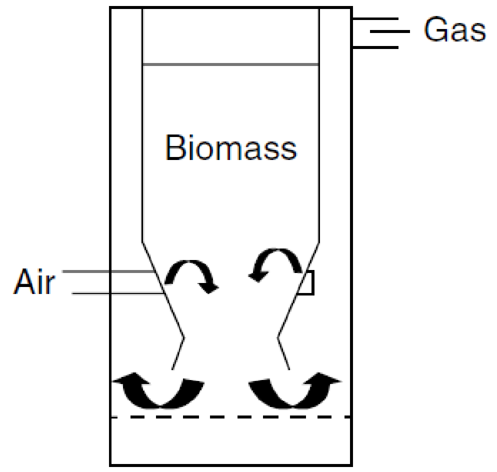


Figure 4.1 Types of fixed bed gasifiers

(a) Downdraft gasifiers:

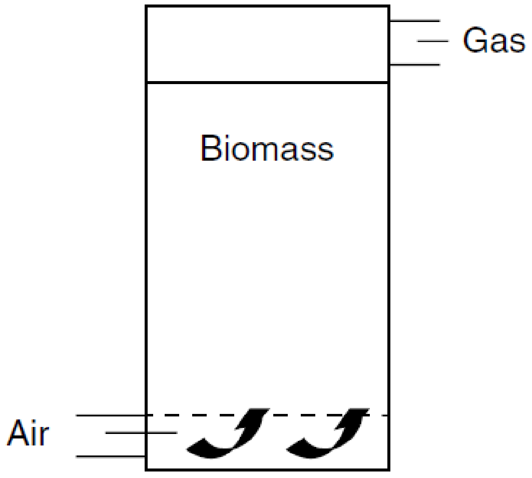
- In the downdraft gasifier, the air is passed from the layers in the downdraft direction.
- Single throat gasifiers are mainly used for stationary applications, whereas double throat gasifier is used for varying loads as well as automotive purposes.



Downdraft gasifier

(b) Updraft gasifiers:

- Updraft gasifier has air passing through the biomass from bottom and the combustible gases come out from the top of the gasifier.

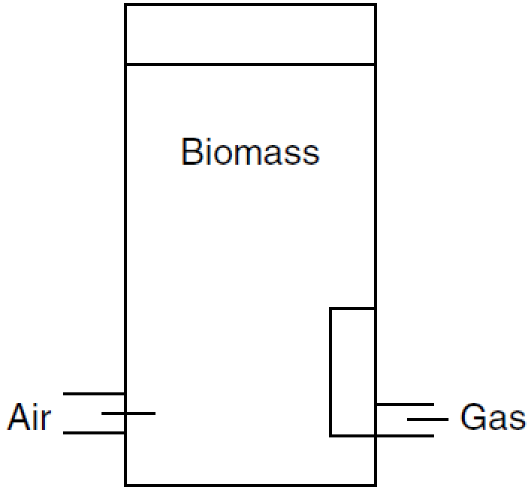


Updraft gasifier

(c) Cross draft gasifiers:

- It is a very simple gasifier and is highly suitable for small outputs.

With slight variation, almost all the gasifiers fall in the above mentioned categories.



Crossdraft gasifier

2. Fluidized bed gasifier:

- In fluidized bed gasifier, an inert material (such as sand, ash, or char) is utilized to make bed and that acts as a heat transfer medium.

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 and other volatiles are driven off.
- The products depend upon temperature, pressure, residence time, and heat losses.

3. Combustion(oxidation) zone:

- In this zone, carbon from the fuel combust and forms carbon dioxide with the oxygen in the air by the reaction:

$$C + O_2 \rightarrow CO_2 + \text{Heat}$$

- Because of the heat emitted during the reaction, the temperature rises until a balance between heat supply and heat loss occurs.

4. Reduction zone:

- The hot gas passes through the reduction zone after the combustion zone.
- As there is no free oxygen in this zone that causes inflammable carbon dioxide gas to react with the carbon in the fuel and forms flammable carbon monoxide gas.

$$C + CO_2 + heat \rightarrow 2CO$$

UPDRAFT GASIFIERS

- The oldest and simplest type of gasifier is the counter current or updraft gasifier shown schematically in Figure 4.2.
- The air intake is at the bottom and gas leaves at the top (the counter current flow).
- The reactive agent is injected at the bottom of the reactor and ascends to the top, while the fuel is introduced at the top and 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 gasifier.

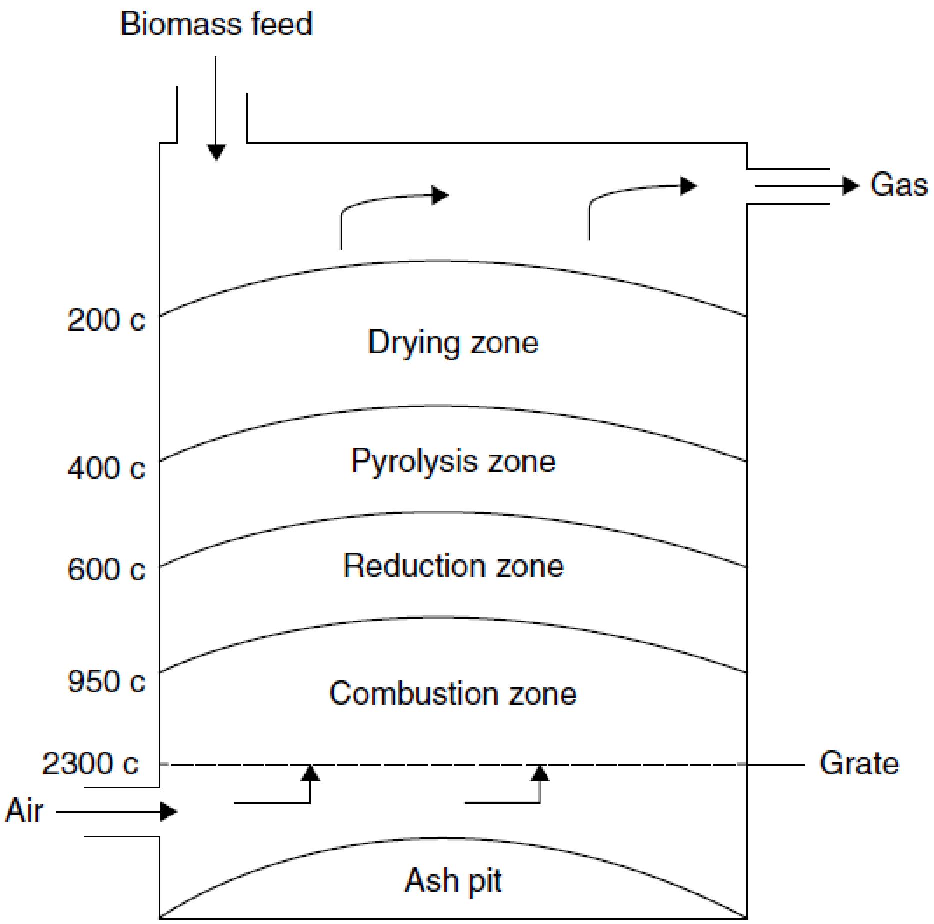
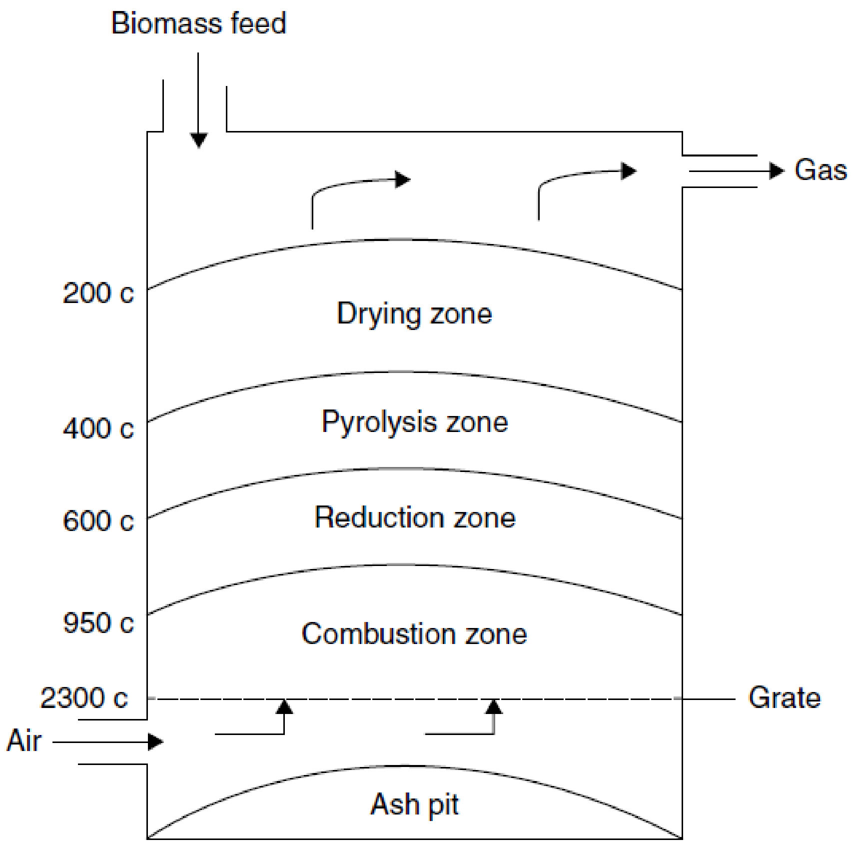


Figure 4.2 Updraft gasifier

- In the upper part of the gasifier, heating and pyrolysis of the feedstock occur as a result of heat transfer by forced convection and radiation from the lower zones.
- Gases, tar, and other volatile compounds are dispersed at the top of the reactor, while ash is removed at the bottom.
- The syngas typically contains high levels of tar, which must be removed or further converted to syngas for use in applications other than direct heating.
- These gasifiers are best suited for applications where moderate amounts of dust in the fuel gas are acceptable and a high flame temperature is required.



Typical applications where the updraft gasifiers have been successfully used are as follows:

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

DOWNDRAFT GASIFIER

- In this gasifiers, the primary gasification air is introduced at or above the oxidation zone in the gasifier and the producer gas is removed at the bottom of the apparatus, so that fuel and gas move in the same direction, as schematically shown in Figure 4.3.
- The biomass feed (such as wood waste) and its gasification air both flow in the same downward direction through the gasifiers' fuel bed.
- The biomass feed is admitted at the top similar to the updraft gasifier.
- As the feed progresses down through the gasifier, it dries and its volatiles are pyrolyzed.

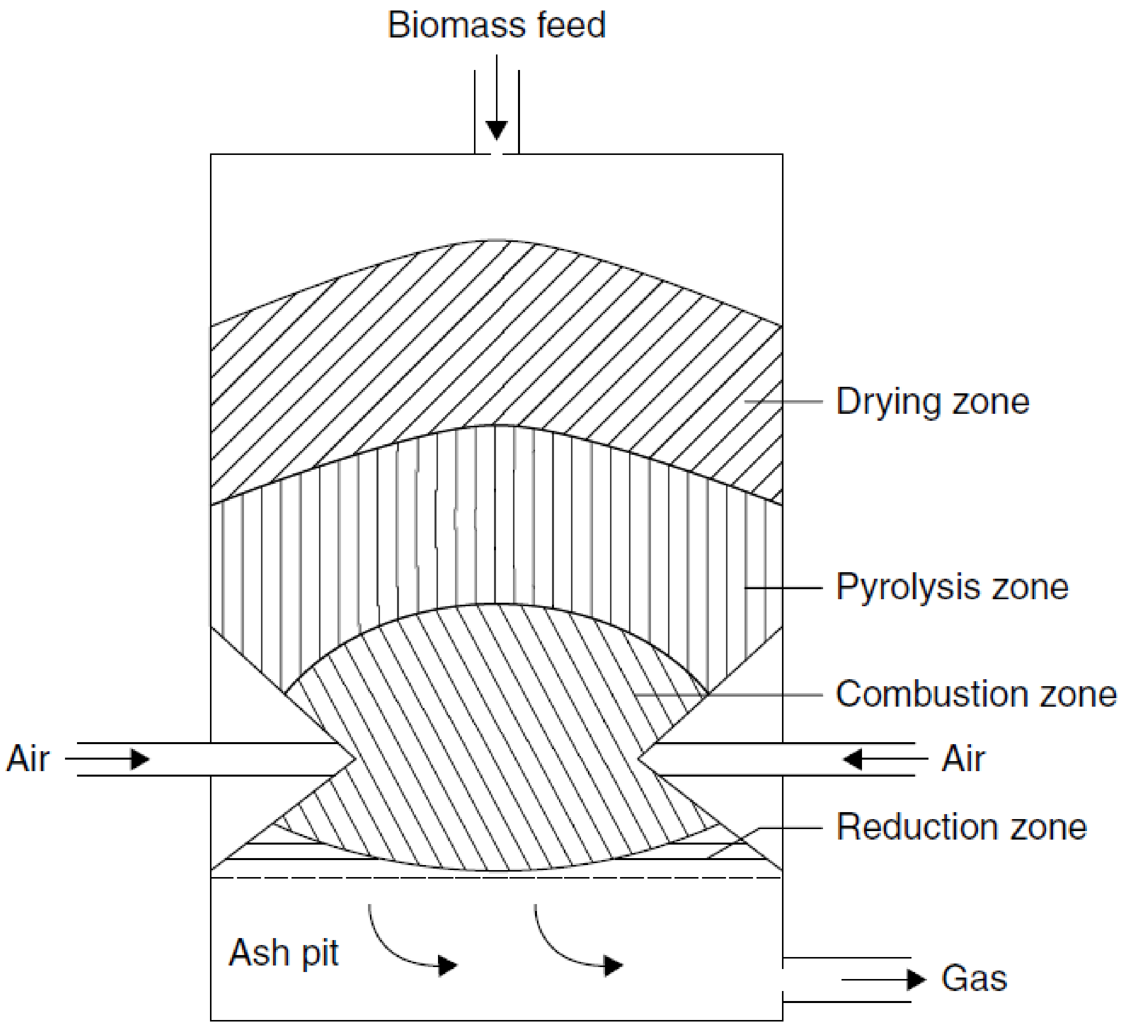


Figure 4.3 Downdraft gasifier

- The char is directed into a reduced diameter cylindrical throat section at the bottom of the gasifier.
- 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.
- The producer gas leaves at the bottom of the gasifier.

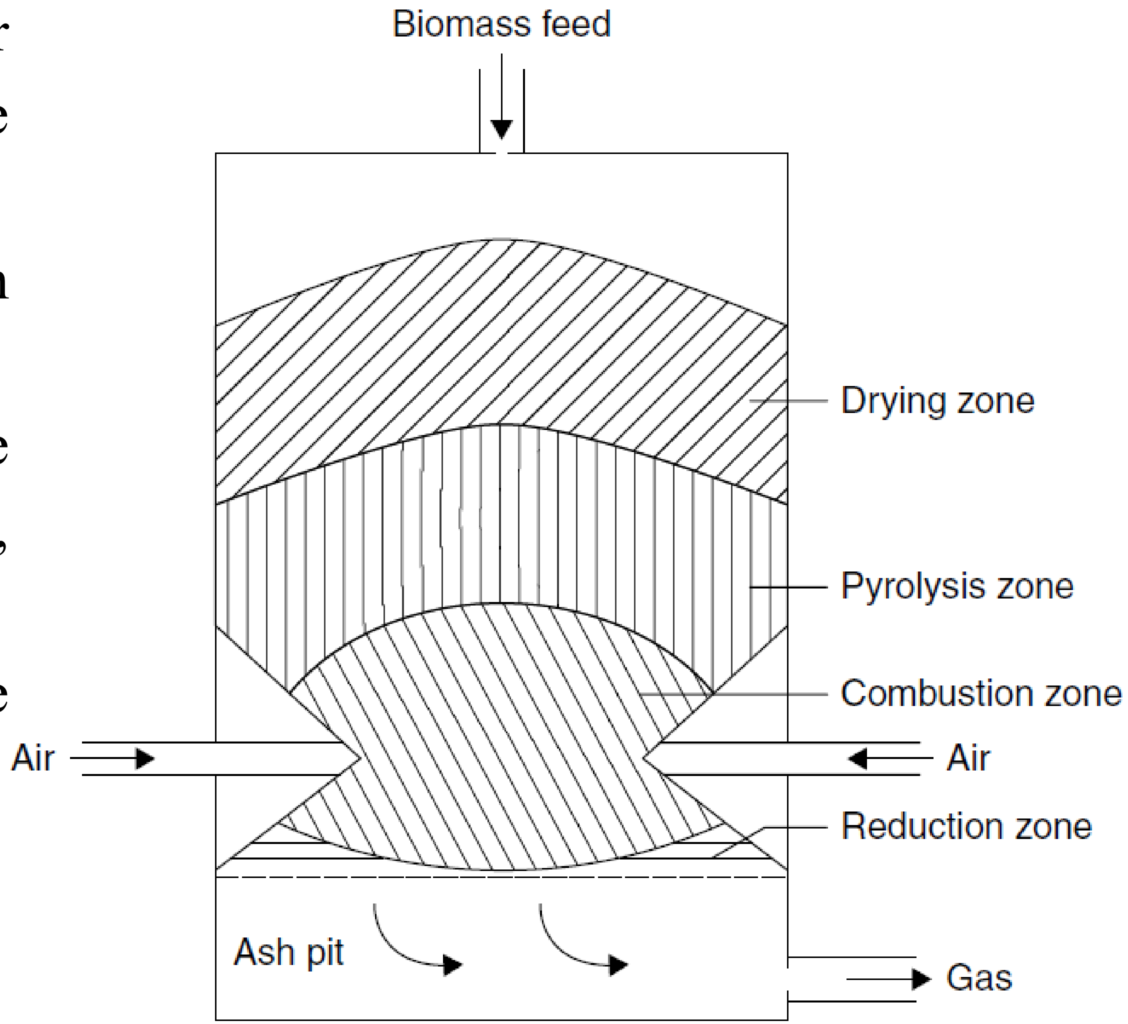


Figure 4.3 Downdraft gasifier

Downdraft gasifiers are widely used in the following applications:

1. Continuous baking ovens (bread, biscuits, and paint)
2. Batch type baking oven (rotary oven for bread)
3. Dryers and curing (tea, coffee, mosquito coil, and paper drying)
4. Boilers
5. Thermal fluid heaters
6. Annealing furnaces
7. Direct fired rotary kilns
8. Internal combustion engines

CROSS-DRAFT GASIFIER

- Figure 4.4 is a schematic representation of cross-draft gasifier.
- Unlike downdraft and updraft gasifiers, the ash bin, fire, and 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, charcoal, and coke.
- The relatively high temperature in cross-draft gas producer has an obvious effect on gas composition such as high carbon monoxide, and low hydrogen and methane content when dry fuel like charcoal is used.
- Cross-draft gasifier operates well on dry air blast and dry fuel.

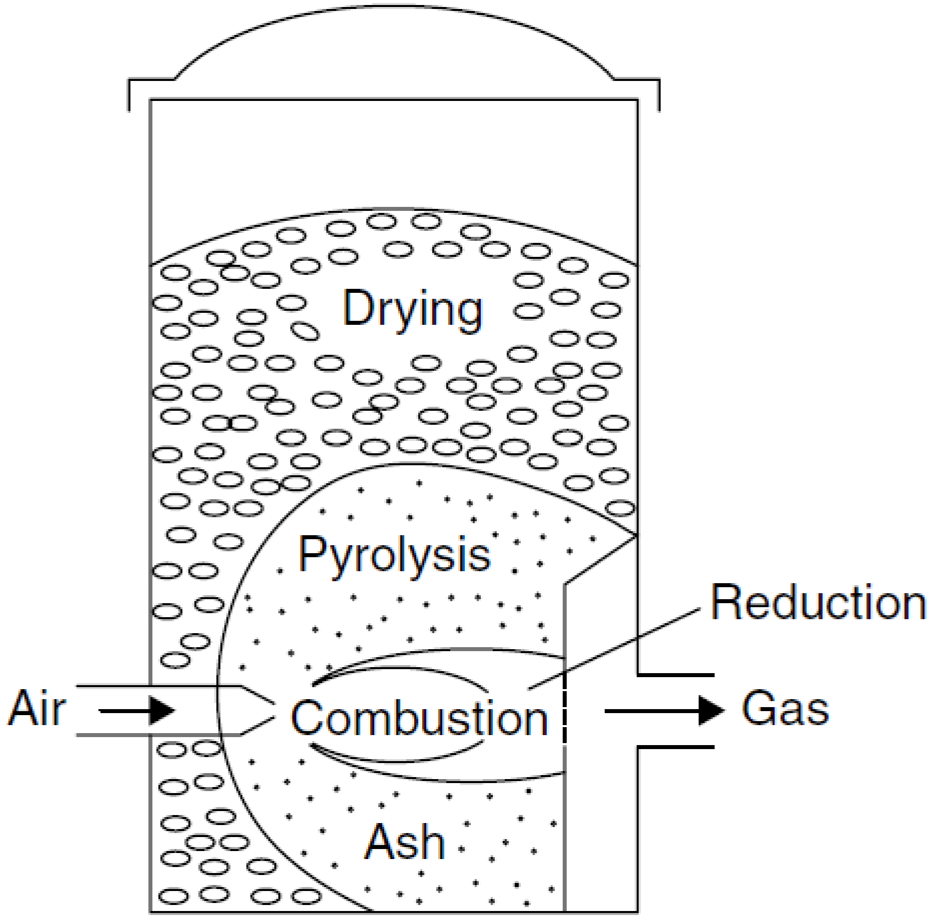


Figure 4.4 Cross-draft Gasifier

- 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 and is converted through a series of processes into producer gas and ash, as it moves down slowly through various zones of the gasifier.

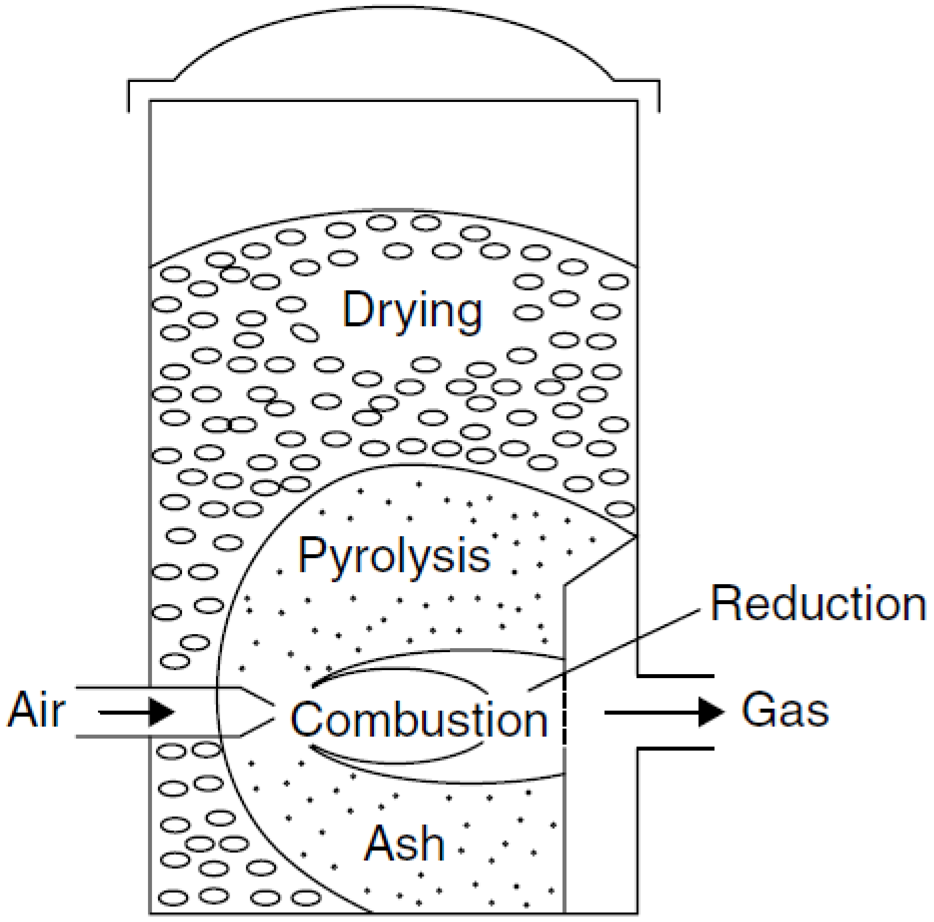


Figure 4.4 Cross-draft Gasifier

Fluidized Bed Gasification

- Fluidized bed gasification has been successfully used to convert prepared wastes (i.e., wood wastes, bark, agricultural wastes, and RDF (Refused Derived Fuel) into a clean fuel gas that can be used to fire various types of industrial equipment.
- The fluidized bed gasifier is illustrated schematically in Figure 4.5.
- This gasifier is an improved version of fixed bed gasifiers.
- The bed made of an inert material (such as sand, ash, or char) initially and it is heated and the fuel is introduced when the temperature has reached the appropriate level.

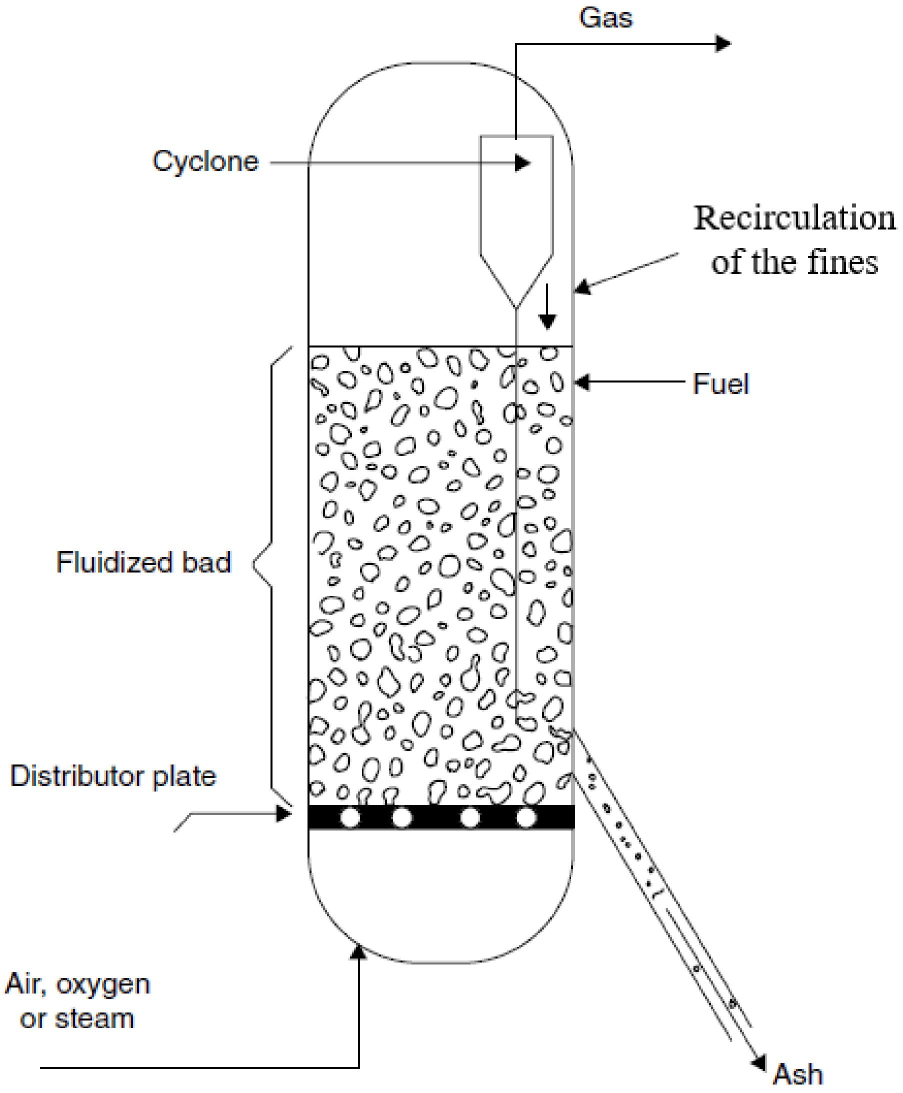


Figure 4.5 Fluidized Bed Gasifier

- 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 (as in the case of fixed bed gasifiers) and drying, pyrolysis and gasification occur simultaneously.
- The fuel particles are introduced at the bottom of the reactor, very quickly mixed with the bed material and almost instantaneously heated up to the bed temperature.
- As a result of this treatment, the fuel is pyrolyzed very fast, resulting in a component mix with a relatively large amount of gaseous materials.

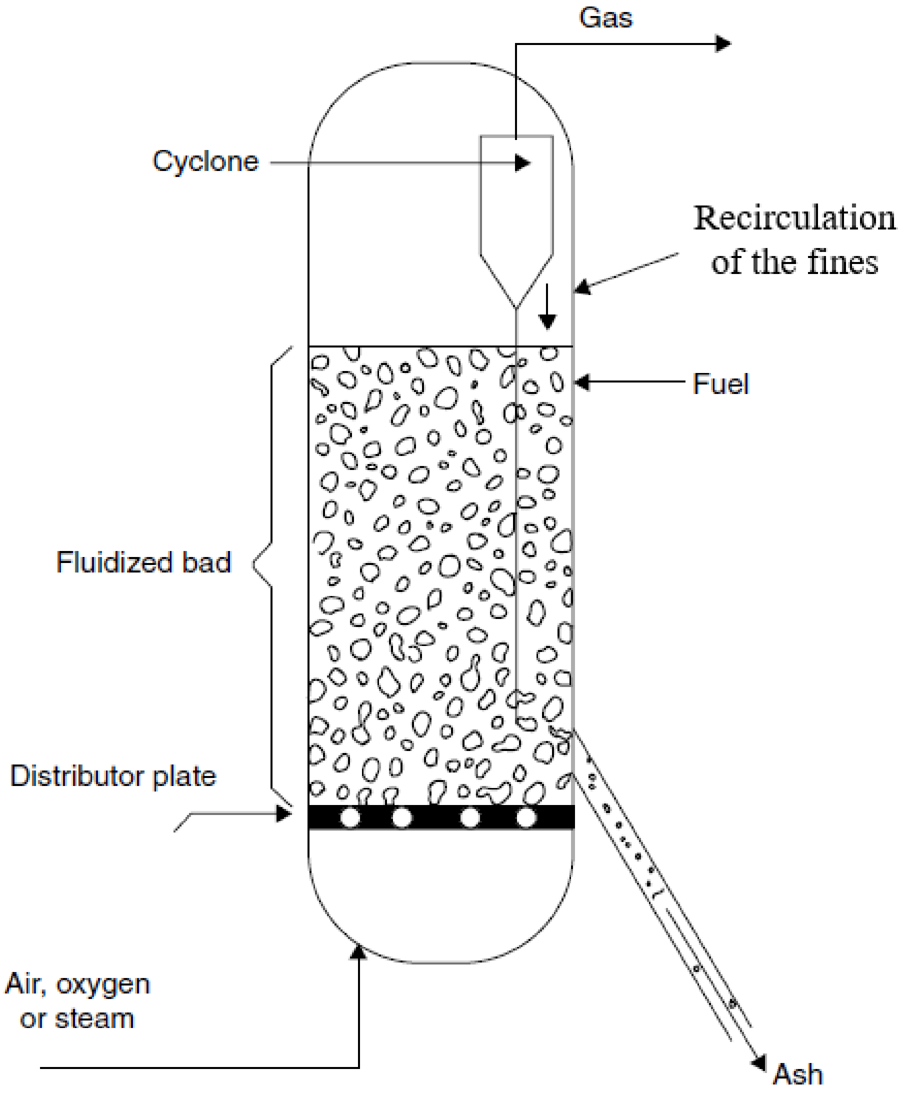


Figure 4.5 Fluidized Bed Gasifier

APPLICATIONS OF BIOMASS GASIFIERS

The main applications of biomass gasifier products are as follows:

1. Motive power:

Gasifier products are used to provide shaft power to industrial and agricultural equipment and machinery such as

(a) Diesel engine operation on dual or 100% modes.

(b) Water pumps

(c) Tractors, harvesters, etc.

2. Direct heat applications:

Gasifiers heat has direct heat applications such as

(a) Drying of agricultural crop and food products such as large cardamom, ginger, rubber, and tea at low temperature range of about 85°C–125°C.

(b) Baking of tiles and potteries in the moderate temperature range of about 800°C–900°C.

3. *Electrical power generation*:

- Electric power generation from few kilowatts to hundreds of kilowatts either for local consumption or for grid power is being installed based on gasifier products.
- Small-scale electricity generation systems also provide an attractive alternative to electric supply company.

4. *Chemical production*:

- Production of chemicals such as methanol and formic acid from producer gas.

Biogas Energy

- Biogas is a mixture of different gases, such as methane, carbon dioxide, hydrogen, etc., produced by the biological breakdown of organic matter in the absence of oxygen.
- It is a renewable energy source, and in many cases, it exerts a very small carbon footprint.
- Biogas can be produced by either anaerobic digestion with anaerobic bacteria, which digest material inside a closed system, or fermentation of biodegradable materials.
- Anaerobic digestion is a process that breaks down organic matter into simpler chemical components in the absence of oxygen.
- This process has proved to be very effective to treat organic wastes for minimizing environmental pollution.

The common organic wastes are listed as follows:

1. Sewage sludge
2. Organic farm wastes
3. Municipal solid wastes
4. Organic industrial and commercial wastes
5. Forests and agricultural wastes
   - The digestion process itself takes place in digester, which is classified in terms of temperature, water content of feedstock and the number of stages (single or multi-stage).
   - The by-products of anaerobic digestion, namely biogas and digestate.

BIOGAS AND 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 and four atoms of hydrogen (CH_4) and is the main constituent of popularly known 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 (cow dung gas), and bio energy.
- It produces about 9,000 kcal of heat energy per cubic metres of gas burnt and specifically used for cooking, heating, and lighting.
- The composition of biogas, which mainly composed of 50% to 70% methane (CH_4), 30% to 40% carbon dioxide (CO_2), and traces of other gases.

- Biogas is lighter than air by about 20% and has an ignition temperature in the range of 650°C to 750°C burns with clear blue flame similar to that of liquefied petroleum gas (LPG) and burns with 60% efficiency in a conventional biogas stove.

ANAEROBIC DIGESTION

- It is a biological process that produces a gas (commonly known as biogas) in the absence of oxygen and has major components of methane (CH4) and carbon dioxide (CO2).
- Anaerobic digestion of methane gas production is a series of processes in which microorganism break down biodegradable material in the absence of oxygen which completes through following steps:

1. In the first step, the organic matter (e.g. plants residues, human and animal wastes and residues) is decomposed (hydrolysis) to break down the organic material into usable-sized molecules such as sugar.
2. Conversion of decomposed matter into organic acids is the second step.
3. Finally, organic acids are converted to biogas (methane gas).

Process Stages of Anaerobic Digestion

The biological and chemical stages of anaerobic digestion are shown in Figure 4.6. These are divided into the following four main stages:

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

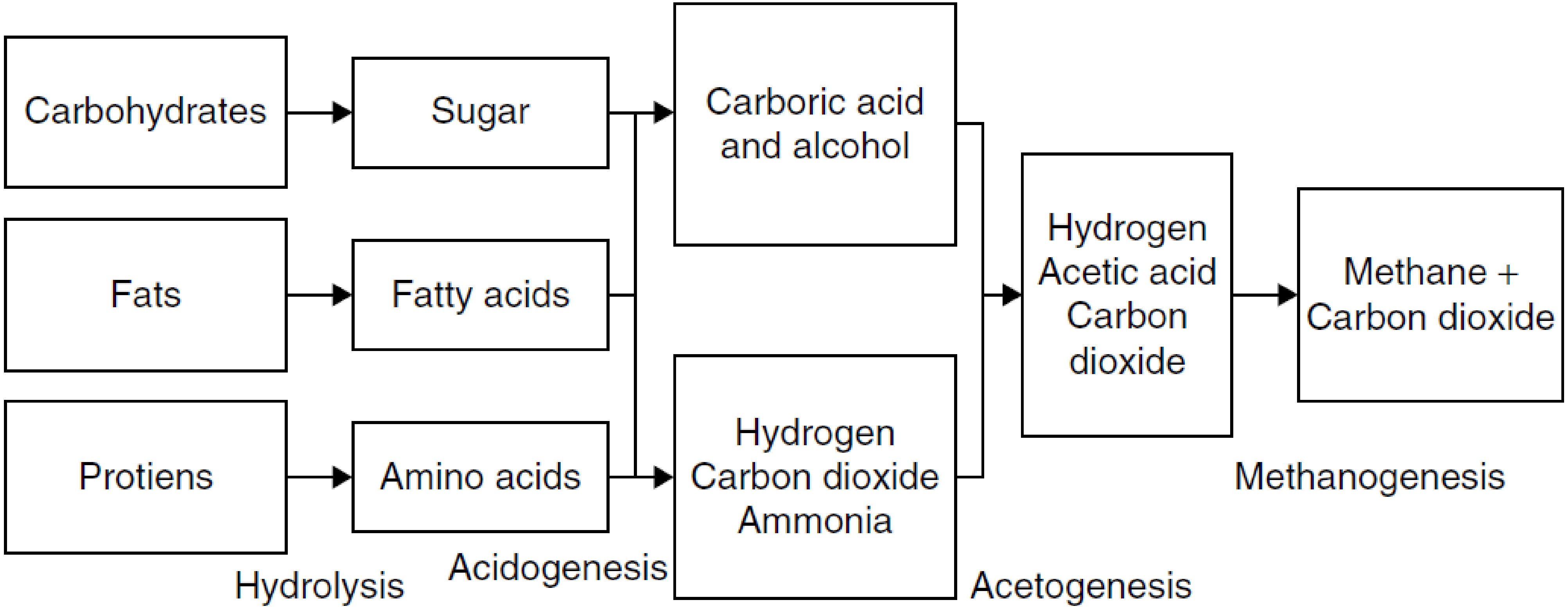


Figure 4.6 Process of Anaerobic Digestion

The four main stages are explained as follows.

Hydrolysis

- The process of breaking large biomass organic chains into their smaller constituent parts such as sugar, fatty acids, and amino acids and dissolving the smaller molecules into solution is called **hydrolysis**.
- This process assists bacteria in anaerobic digesters to access the energy potential of the material.
- Hydrolysis of these high-molecular-weight polymeric components of biomass completes the first step in anaerobic digestion.

Acidogenesis

- Acidogenesis is the biological process in which the remaining components are broken down by acidogenetic (fermentative) bacteria.
- It creates voltaic fatty acids together with ammonia, carbon dioxide, and hydrogen sulphide, and other by-products.

Acetogenesis

- In this stage of anaerobic digestion, simple molecules created through the acidogenesis phase are further digested to produce more acetic acid, carbon dioxide, and hydrogen.

Methanogenesis

- Finally, the process of biogas production is completed by methanogenesis.
- In this stage of anaerobic digestion, the methanogens use intermediate products of the preceding stages and convert them into methane, carbon dioxide, and water which makes the majority of the biogas emitted from the system.
- Methanogenesis is sensitive to both high and low pH values.
- A simplified generic chemical equation for the overall processes is as follows:

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$$

The remaining indigestible material cannot be used by microbes and any dead bacterial remains constitute the digestate.

Construction Parts of Biogas Plants

- Figure 4.7 shows various parts of typical biogas plant.
- It is a brick and cement structure having the following five sections:
  1. Mixing tank
  2. Digester tank
  3. Dome or gas holder
  4. Inlet chamber
  5. Outlet chamber

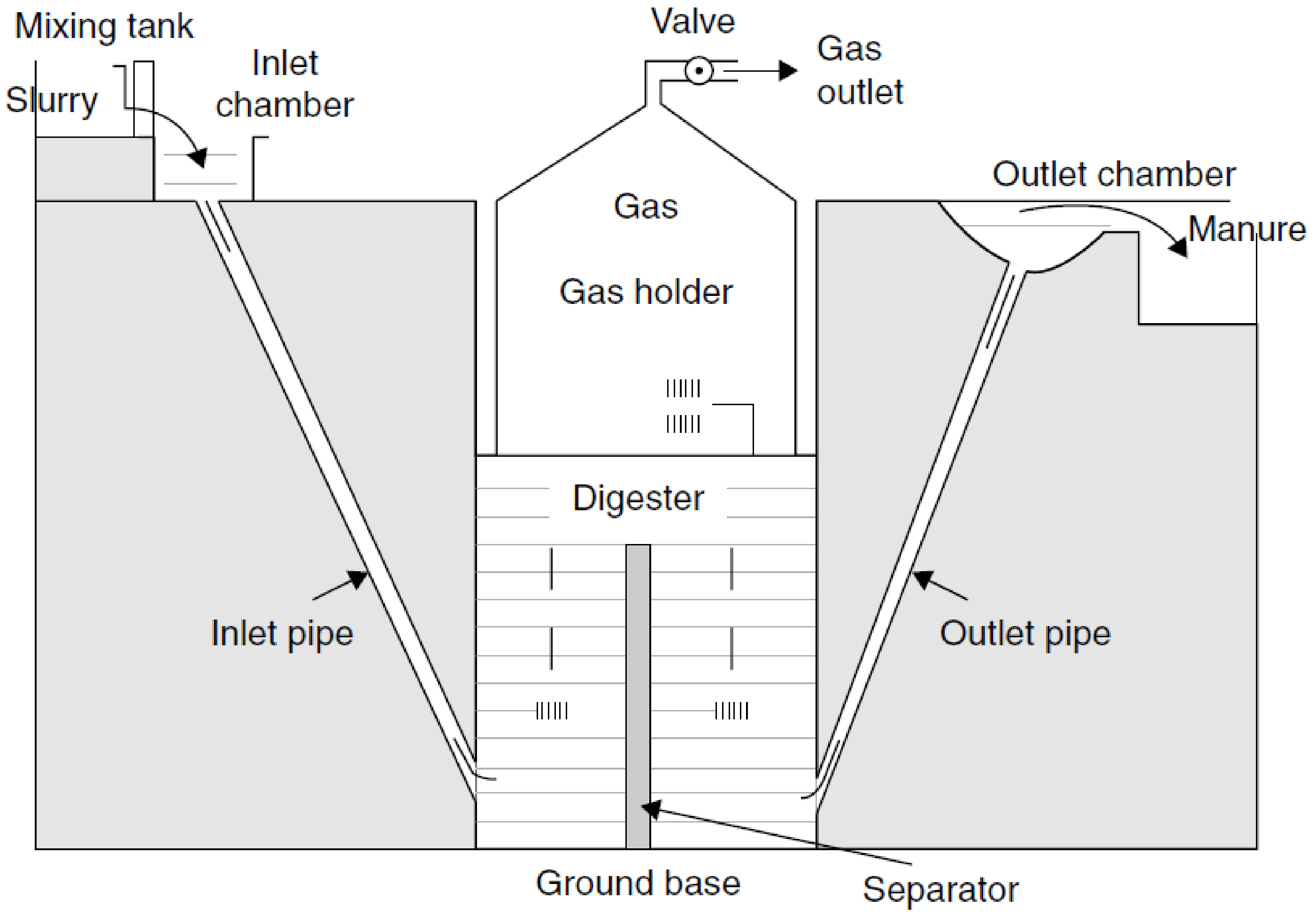
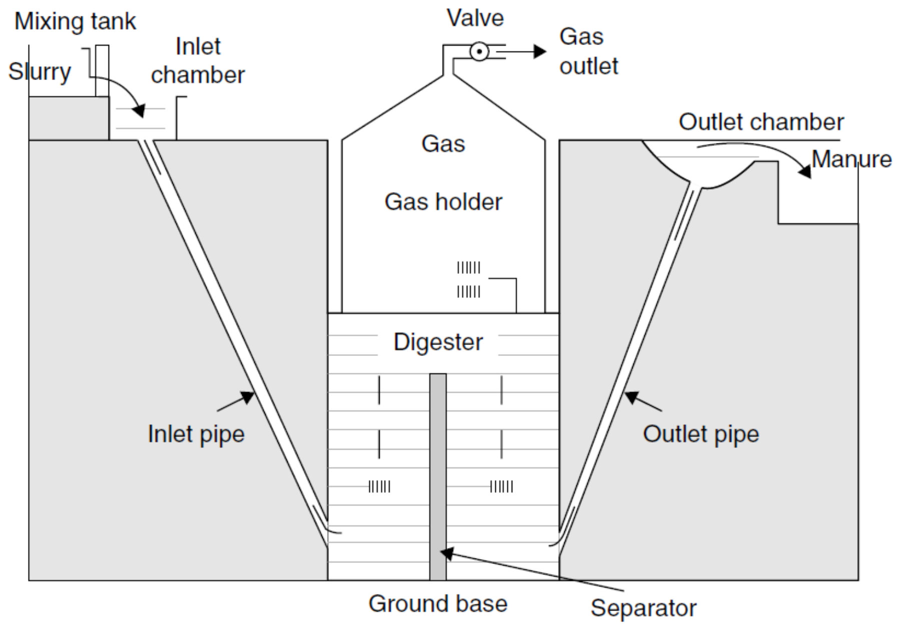


Figure 4.7 A typical Biogas Plants

Mixing Tank

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



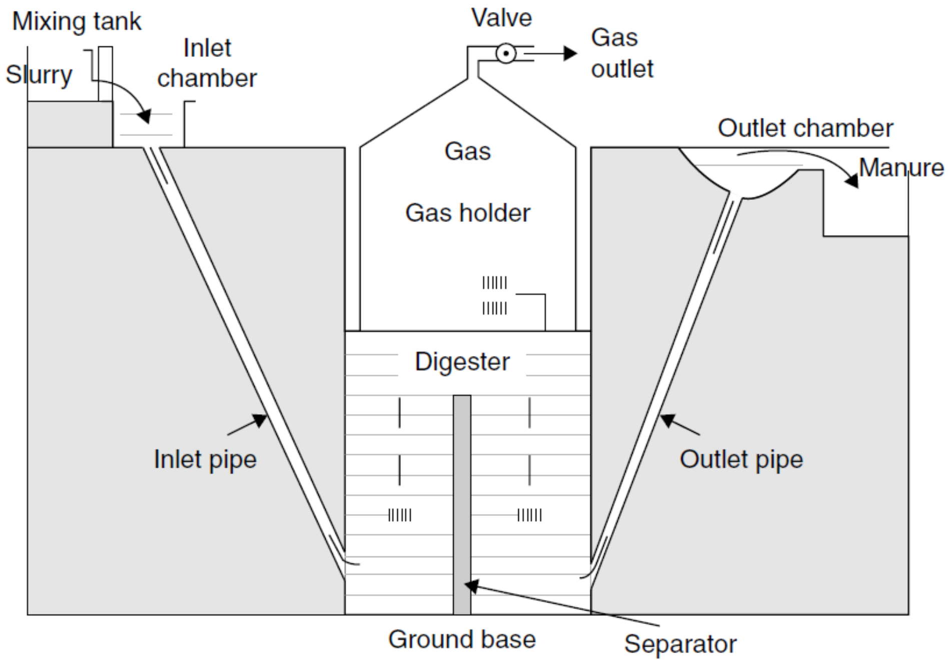
Digester Tank

- It is a deep underground well-like structure and is divided into two chambers by a partition wall in between.
- It is the most important part of the cow dung biogas plants where all the important chemical processes or fermentation of cow dung and production of biogas takes place.
- The digester is also called as **fermentation tank**.
- It is cylindrical in shape and made up of bricks, sand, and cement built underground over the solid foundation.
- Two openings are provided on the opposite sides and at the specified height of digester for inflow of fresh cow dung slurry and outflow of used slurry as manure.

The two long cement pipes are used as follows:

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

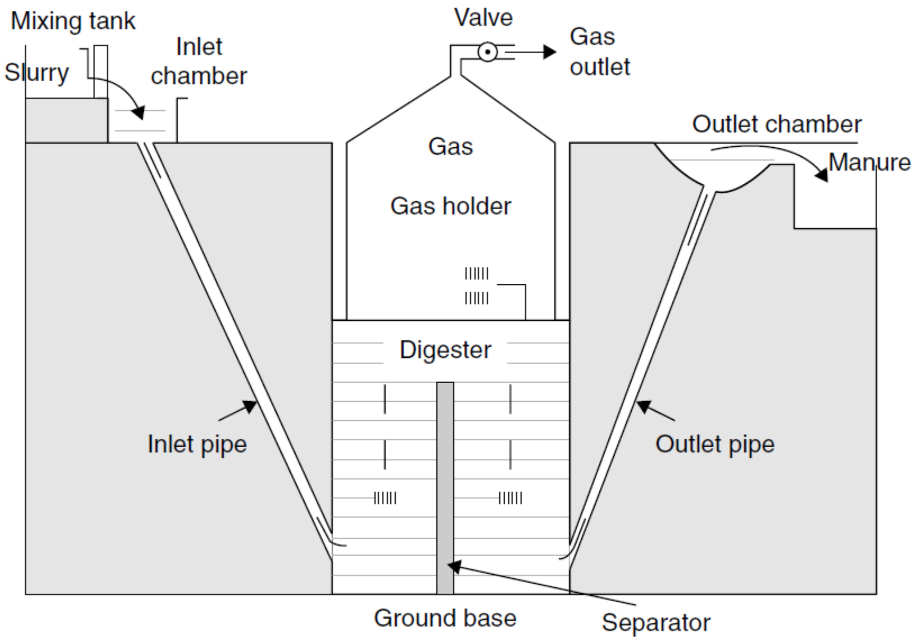
- A separator is also placed in the middle of digester tank to improve effective fermentations of feedstock.



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 gas collected in the dome exerts pressure on the slurry in the digester.
- The dome or gas holder is made either fixed dome or floating dome type.

- Cement and bricks are used in the construction of fixed dome, and it is constructed using approximately at the ground surface.
- Floating dome type is an inverted steel drum resting on the digester above the ground surface.
- The drum floats over the digester and moves up and down with biogas pressure.

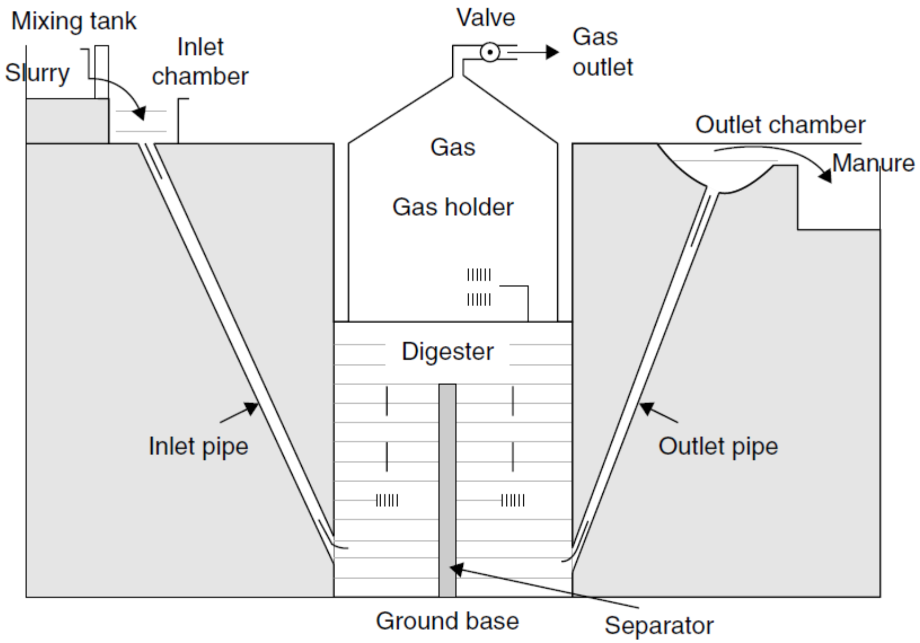


Inlet Chamber

- The cow dung slurry is supplied to the digester of the biogas plant via inlet chamber, which is made at the ground level so that the slurry can be poured easily.
- It has bell mouth sort of shape and is made up of bricks, cement, and sand.
- The outlet wall of the inlet chamber is made inclined so that the slurry easily flows into the digester.

Outlet Chamber

- The digested slurry from the biogas plants is removed through the outlet chamber.
- The opening of the outlet chamber is also at the ground level.
- The slurry from the outlet chamber flows to the pit made especially for this purpose.



Gas Outlet Pipe and Valve

- The gas holder has an outlet at the top which could be connected to gas stoves for cooking or gas-lighting equipments or any other purpose.
- Flow of the gas from the dome via gas pipe can be controlled by valve.
- The gas taken from the pipe can be transferred to the point of use.

Foundation

- The foundation forms the base of the digester where the most important processes of biogas plant occur.
- It is made up of cement, concrete, and bricks strong enough so that it should be able to provide stable foundation for the digester walls and be able to sustain the full load of slurry filled in it.
- The foundation should be waterproof so that there is no percolation and leakage of water.

Types of Biogas Plants

- Fixed dome and floating dome construction are the two types of biogas plants.
- Based on these types, several biogas plant models are developed.

Fixed Dome Type

Schematic of a fixed dome biogas plant is given in Figure 4.8. It consists of following parts.

***Mixing tank*:**

- In mixing tank, the water and cattle dung are mixed together thoroughly in the ratio of 1:1 to form the slurry.

***Inlet chamber*:**

- The mixing tank opens underground into a sloping inlet chamber.

***Digester*:**

- Digester is a huge tank with a dome type ceiling.

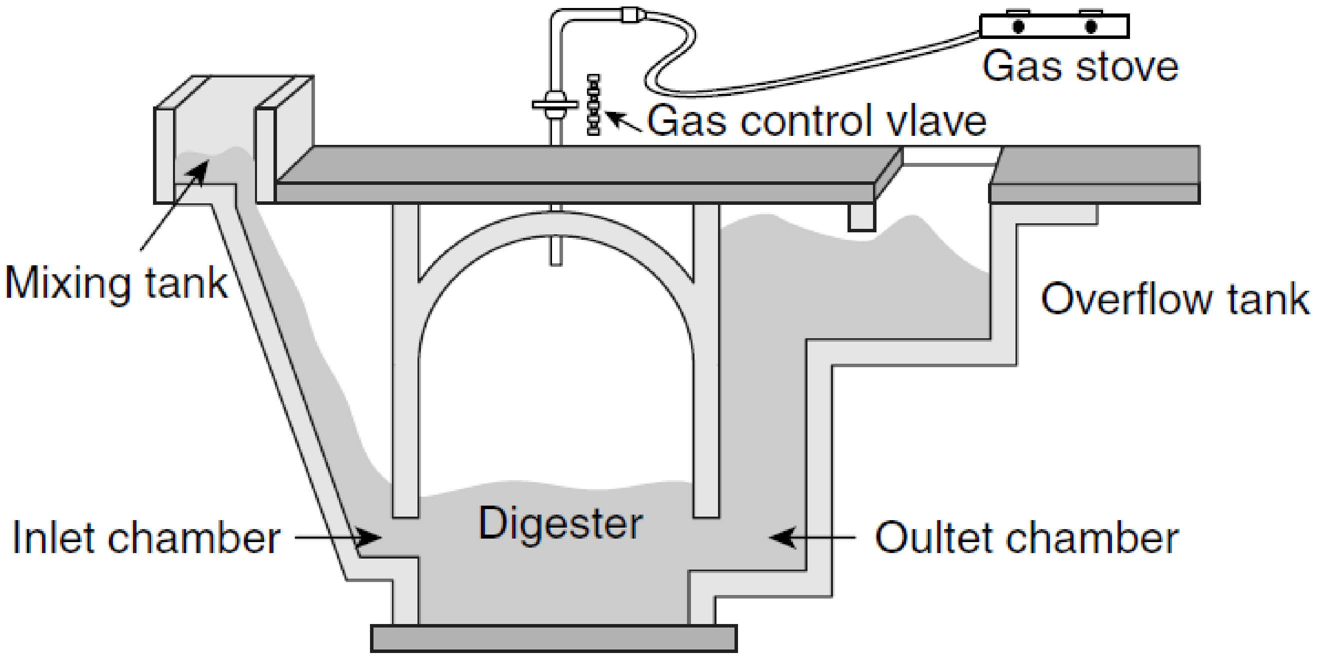


Figure 4.8 Fixed dome type Biogas Plant

- The ceiling of the digester has an outlet with a valve for the supply of biogas.
- The inlet chamber opens from below into the digester tank.
- The digester opens from below into an outlet chamber which is opened from the top into a small overflow tank.

Working Principle

- The various forms of organic biodegradable biomass are collected and mixed with equal amount of water properly in the mixing tank to form slurry.
- The slurry is fed into the digester tank through inlet chamber and pipe, and 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, and 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 and plants.
- Gas control valve at the top of dome is opened partially or fully to supply required gas for particular applications.

Advantages of fixed dome-type biogas plant are as follows:

1. The costs of a fixed dome biogas plant are relatively low as compared to floating dome type.
2. It is simple in construction as no movable dome exists.
3. It is made up of concrete, bricks, and cements and long life of the plant (20 years or more) can be expected.
4. Underground and almost ground surface dome construction saves space and protect from physical damage to the plant.
5. The anaerobic digestion processes in the digester are little influenced by temperature fluctuation in day and night.

Disadvantages of biogas plant are as follows:

1. Porosity and cracks in plant walls is the major drawbacks.
2. Maintenance is rather difficult.

Floating Type

- The floating gas holder type of biogas plant is shown in Figure 4.9.
- The construction and working principle of this biogas plants is similar to fixed dome type except that gas holder tank is made up of steel and placed on the top of digester circular tank and is movable up and down also shown in Figure 4.7.

Floating dome-type biogas plant has the following advantages:

1. Very efficient
2. Simple maintenance scheduling possible

Floating dome-type biogas plant has the following disadvantages:

1. Expensive
2. Steel drum may rust
3. Requires regular maintenance

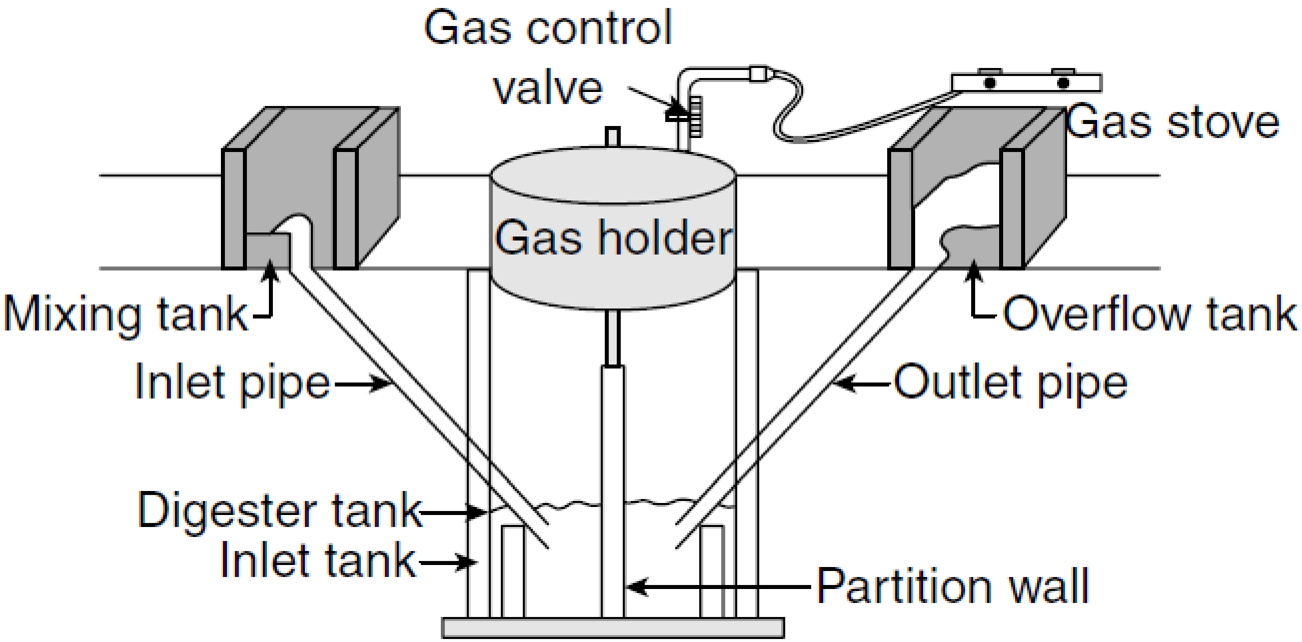


Figure 4.9 Floating dome-type biogas plant

Benefits of Biogas

A biogas energy system has whole range of benefits for the users, the society, and the environment.

It includes the following:

Production of energy (heat, light, and electricity):

- The calorific value of biogas is about 6 kWh/m3, which is equivalent to about half a litre of diesel oil.
- The net calorific value depends on the efficiency of the burners or appliances.
- It replaces the conventional and traditional cooking and heating fuels and therefore permits the conservations of energy and fuels.
- The small- and medium-sized units (up to 6 m3) are generally used for providing gas for cooking and lighting purposes.
- Large units (or communal units) produce this gas in large quantities and can be used to power engines and generators for mechanical work or power generation.

Transformation of organic wastes into high-quality organic fertilizer:

- The biogas plant is considered as a perfect fertilizer-making machine.
- There is no better way to digest or compost manure and other organic material than in a biogas plant.
- Output from the digester (digested manure) is actually a high-quality organic fertilizer.
- It has been analysed that the fertilizer, which comes from a biogas plant, contains three times more nitrogen than the best compost made through open air digestion.
- This nitrogen is already present in the manure. The nitrogen is preserved when waste is digested in an enclosed biogas plant, whereas the same nitrogen evaporates away as ammonia during open air composting.
- The biogas plant does not make extra nitrogen, it does not create nitrogen, and it merely preserves the nitrogen that is already there.

Health benefits of biogas and the improvement of hygienic conditions (reduction of pathogens, worm eggs, and flies):

- Significant health benefits are achieved by the use of pure biogas.
- It has been found that non-biogas users have more respiratory diseases than those who use biogas plants.
- Respiratory illness, eye infection, asthma, and lung problems have largely decreased in the family having installing a biogas plant for heating, cooking, and other work.
- The improvement in hygienic cooking on biogas also has economic benefits.

Reduction of workload, mainly for women, in firewood collection and cooking:

- Time and human labour energy is greatly reduced in searching, collecting, and carrying the firewood home from long distance places and cleaning of cooking equipments and utensils.
- Biogas plants also improve health conditions in the homes. Home remains free from smokes and dust, and more hygienic conditions are maintained, and the space required for keeping firewood materials is also minimized.

Environmental advantages through protection of forests, soil, water, and air:

- A biogas plant directly saves the use of forest wood and forest residues and helps in deforestation.
- The widespread production and utilization of biogas is expected to make a substantial contribution to soil protection.

Global environmental benefits of biogas technology:

- Biogas is a renewable source of energy which has important climatic effects.
- As the demand for fossil fuel required for heating and cooking is reduced by the use of bio gas, emissions of carbon dioxide are also largely reduced.
- Also, capturing-uncontrolled methane emission significantly reduces the global warming.

Factors Affecting The Selection of a Particular Model of a Biogas Plant

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

***Cost*:**

- The principal and maintenance costs of biogas plants should be as low as possible (in terms of the production cost per unit volume of biogas) both to the user and to the society.

***Simplicity in design*:**

- The design should be simple not only for construction purposes but also for operation and maintenance.
- This is an important consideration especially in countries where the rate of literacy is low and the availability of skilled human resource is scarce.

***Durability*:**

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

Suitability for use with available raw inputs:

- The design should be compatible with the type of inputs that would be used.
- If plant materials such as rice straw, maize straw, or similar agricultural wastes are to be used, then the batch feeding design or discontinuous system should be used instead of a design for continuous or semi-continuous feeding.

Inputs and outputs use frequency:

- Frequency of utilization of biogas and feedstock inputting in biogas plants, influence the selection of a particular design, and the size of various components of biogas plants.

Advantages

It includes the following:

1. Clean fuel of high calorific value and has a convenient ignition temperature.
2. No residue, smoke, and dust produced.
3. Non-polluting, Significant health benefits are achieved by the use of clean biogas.
4. Economical benefits of biogas and high-quality manure.
5. Provides nutrient rich manure for plants.

Limitations

The limitations are as follows:

1. Initial cost of installation of the plant is high.
2. Inadequacy of organic raw materials and its continuity of supply.
3. Social acceptability.
4. Maintenance and repair of bio gas plants.

Uses

1. It is used as a domestic fuel.
2. It is used as a fuel for motive power.
3. It is used for electricity generation.

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.
- 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.
- 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.

General Information

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:

***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 5m.

***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.

***Ocean thermal energy*:**

- 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.

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).

Energy Availability in Tides

Potential energy and kinetic energy are the two energy components of energy of the tide waves. The potential energy is the work done in lifting the mass of water above the ocean surface.

This energy can be calculated as

$$E = \rho g A \int z\, dz = 0.5\, \rho g A h^2$$

where E = the energy; g = acceleration of gravity; ρ = the seawater density (which equals its mass per unit volume); A = sea area under consideration; z = vertical coordinate of the ocean surface; and h = the tide amplitude.

Taking an average of the product of $(\rho g) = 10.15\ \text{kN/m}^3$ for seawater, energy for a tidal cycle per m^2 of ocean surface can be approximated as:

$$E = 1.4\, h^2 \quad \text{(Watt-hour)}$$

$$= 5.04\, h^2 \quad \text{(kJ)}$$

Since extracting all the available stream power could be environmentally damaging, it is necessary to use a factor that expresses the usable power percentage with apparently no damaging consequences. It is called α (significant extraction factor) that may vary from 0.2 to 0.6.

The kinetic energy (KE) of the water mass (m) is its capacity to do work by virtue of its velocity (V). It is defined by

$$\text{KE} = 0.5mV^2$$

The total energy of tide waves equals the sum of its potential and kinetic energy components.

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.
- The dam includes a sluice that is opened to allow the tide to flow into the basin during tide rise periods and the sluice is then closed.
- When the sea level drops, traditional hydropower technologies (water is allowed to run through hydro turbines) are used to generate electricity from the elevated water in the basin.
- From Equation $P = 0.226AH^2\ (\mathrm{W})$
- We can observe that the tidal power varies as the square of the head and since the head varies with the tidal range, the power available at different sites shows very wide variation.
- In order to overcome this wide variation in availability of tidal power, various tidal basin systems have, therefore, been developed.

Single-basin System

- This is the simplest way of power generation and the simplest scheme for developing tidal power is the single-basin arrangement as shown in Figure 4.10.
- 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.

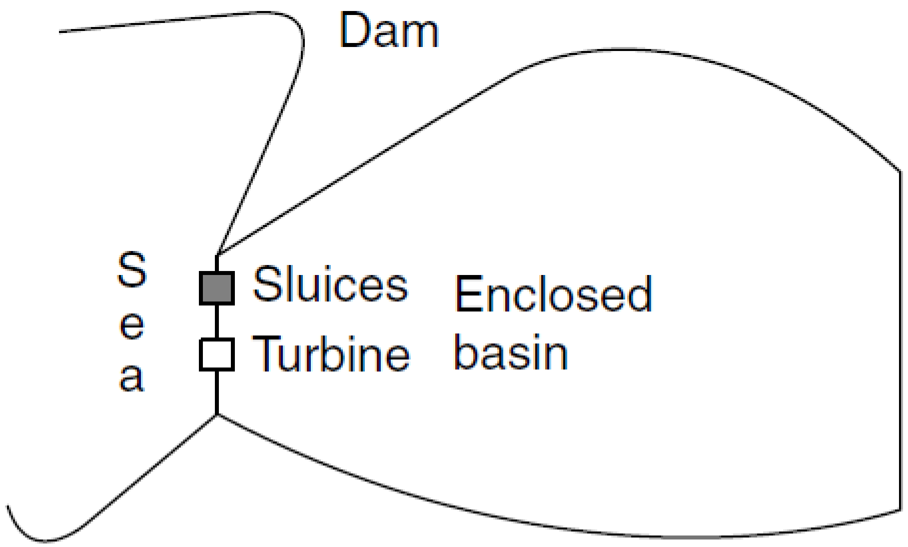


Figure 4.10 Single-basin system

The single-basin system has two configurations, namely:

***1. One-way single-basin system*:**

- The basin is filled by seawater passing through the sluice gate during the high tide period.
- When the water level in the basin is higher than the sea level at low tide period, then power is generated by emptying the basin water through turbine generators.

- This type of systems can allow power generation only for about 5 h and is followed by the refilling of the basin.
- 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, and then, at low tide, moving back to the sea.
- This process requires bigger and more expensive turbine.

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

Two-basin Systems

- An improvement over the single-basin system is the two-basin system.
- In this system, a constant and continuous output is maintained by suitable adjustment of the turbine valves 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 and neap tides.
- Therefore, this system provides a partial solution to the problem of getting a steady output of power from a tidal scheme.
- This disadvantage can be overcome by the joint operation of tidal power and pumped storage plant.
- During the period, when the tidal power plant is producing more energy than required, the pumped storage plant utilizes the surplus power for pumping water to the upper reservoir.

- When the output of the tidal power plant is low, the pumped storage plant generates electric power and feeds it to the system.
- This arrangement, even though technically feasible, is much more expensive, as it calls for high installed capacity for meeting a particular load.
- This basic principle of joint operation of tidal power with steam plant is also possible when it is connected to a grid.
- In this case, whenever tidal power is available, the output of the steam plant will be reduced by that extent that leads to saving in fuel and reduced wear and tear of steam plant.

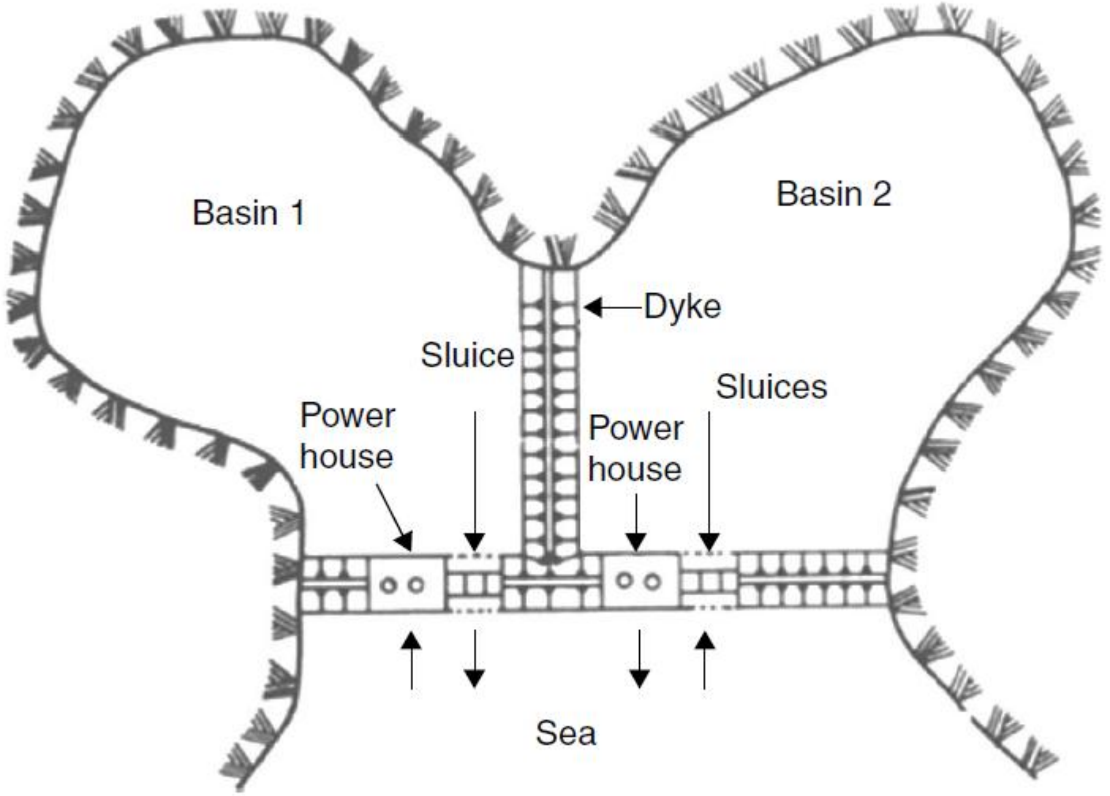


Figure 4.11 Two-basin system

- This operation requires the capacity of steam power plant to be equal to that of tidal power plant and makes the overall cost of power obtained from such a combined scheme very high.
- In the system shown in Figure 4.11, the two basins close to each other, operate alternatively.
- One basin generates power when the tide is rising (basin getting filled up) and the other basin generates power while the tide is falling (basin getting emptied).
- The two basins may have a common power house or may have separate power house for each basin.
- In both the cases, the power can be generated continuously.
- The system could be thought of as a combination of two single-basin systems, in which one is generating power during tiding cycle, and the other is generating power during emptying.

Advantages and Disadvantages of Tidal Power

The following are the advantages of tidal power:

- About two-third of earth's surface is covered by water, there is scope to generate tidal energy on large scale.
- Techniques to predict the rise and fall of tides as they follow cyclic fashion and prediction of energy availability is well established.
- The energy density of tidal energy is relatively higher than other renewable energy sources.
- Tidal energy is a clean source of energy and does not require much land or other resources as in harnessing energy from other sources.
- It is an inexhaustible source of energy.
- It is an environment friendly energy and does not produce greenhouse effects.
- Efficiency of tidal power generation is far greater when compared to coal, solar, or wind energy. Its efficiency is around 80%.

- Despite the fact that capital investment of construction of tidal power is high, running and maintenance costs are relatively low.
- The life of tidal energy power plant is very long.

The following are the disadvantages of tidal power:

- Capital investment for construction of tidal power plant is high.
- Only a very few ideal locations for construction of plant are available and they too are localized to coastal regions.
- Unpredictable intensity of sea waves can cause damage to power generating units.
- Aquatic life is influenced adversely and can disrupt the migration of fish.
- The energy generated is not much as high and low tides occur only twice a day and continuous energy production is not possible.
- The actual generation is for a short period of time. The tides only happen twice a day so electricity can be produced only for that time, approximately for 12 h and 25 min.

- This technology is still not cost effective and more technological advancements are required to make it commercially viable.

Problems Faced in Exploiting Tidal Energy

- Usually the places where tidal energy is produced are far away from the places where it is consumed. **This transmission is expensive and difficult.**
- **Intermittent supply:** Cost and environmental problems, particularly barrage systems are less attractive than some other forms of renewable energy.
- **Cost:** The disadvantages of using tidal and wave energy must be considered before jumping to conclusion that this renewable, clean resource is the answer to all our problems. The main detriment is the cost of those plants.
- **Altering the ecosystem at the bay:** Damages such as reduced flushing, winter icing, and erosion can change the vegetation of the area and disrupt the balance. Similar to other ocean energies, tidal energy has several prerequisites that make it only available in a small number of regions.

THANK YOU