Module-4

Biomass Energy: Biomass Production, Energy Plantation, Biomass Gasification, Theory of Gasification, Gasifier and Their Classifications, Chemistry of Reaction Process in Gasification, Updraft, Downdraft and Cross-draft Gasifiers, Fluidized Bed Gasification, Use of Biomass Gasifier, Gasifier Biomass Feed Characteristics, Applications of Biomass Gasifier, Cooling and Cleaning of Gasifiers.

Biogas Energy: Introduction, Biogas and its Composition, Anaerobic Digestion, Biogas Production, Benefits of Biogas, Factors Affecting the Selection of a Particular Model of a Biogas Plant, Biogas Plant Feeds and their Characteristics.

Tidal Energy: Introduction, Tidal Energy Resource, Tidal Energy Availability, Tidal Power Generation in India, Leading Country in Tidal Power Plant Installation, Energy Availability in Tides, Tidal Power Basin, Turbines for Tidal Power, Advantages and Disadvantages of Tidal Power, Problems Faced in Exploiting Tidal Energy.

The material from this is prepared only for educational use from various text books and material from internet.

Questions from VTU model papers and few important questions

Bio Mass and Bio Gas

1. What are the different types of biomass feedstocks used for energy generation, and how do they differ in their composition and availability
2. How does the process of photosynthesis in plants and other organisms contribute to the generation of biomass, and how can this biomass be converted into renewable energy through various conversion technologies? With a neat schematic diagram, explain fixed -dome type of biogas plant?
3. Explain with figures up-draft and down- draft gasifier? What are the uses of gasifiers.
4. What is biogas, explain with a block diagram and the main stages of Anaerobic digestion.
5. Explain different types of biofuels.
6. Explain the process of photosynthesis?
7. What are the main advantages and disadvantages of biomass energy
8. Explain the fixed dome type of bio gas plant
9. Explain the various stages of cooling and cleaning of gasifier gas?
10. Explain the working of fluidized bed gasifier with a neat sketch
11. Classify the gasifiers on the basis of oxygen/ air flow, explain the working of cross-draft gasifier

Tidal Energy

1. Discuss the problems faced in exploiting tidal energy
2. With a neat diagram, explain double basin tidal power plant.
3. Explain the ‘single-basin’ and ‘two-basin’ systems of tidal power harnessing. Further, discuss their advantages and limitations
4. Derive the expression for power developed due to tides.
5. List the advantages and disadvantages of tidal power generation.
6. explain the utility of tidal waves as a source of energy

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. 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. However, following issues may be thoroughly investigated for implementing biomass production scheme:

1. The types of vegetation best suited for an intensive energy plantation and bio generation selection criteria.
2. The type and availability of land for growing energy crops and plant material productions.
3. Harvesting for conceptual plantation.
4. Techno-economic comparison of firing crops directly for electric power generation with conversion to clean fuel gas (methane or low BTU gas) either at the farm site or at the selected market.

BIOMASS PRODUCTION

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:

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

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, arid 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.

1 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

Properly managed forests will always have more trees, and agricultural and energy crops management will always have crops; further, the residual biological matter are taken from those 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. The twin problems of traditional biomass use for cooking and heating are the energy inefficiency and excessive pollution.
Inefficient way of direct cooking applications, inconvenient and inefficient methods of raw biomass transportation and storage and high environmental pollution problems made them unsuitable for efficient and effective use. This necessitated some kind of pre-processing and conversion technology for enhancing the usefulness of biomass.

2 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 is 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 like producer gas. Hence, it is the attractiveness of gasification. The efficiency of a direct combustion or biomass gasification system is influenced by a number of factors such as including biomass moisture content, combustion air distribution and amounts (excess air), operating temperature and pressure, and flue gas (exhaust) temperature.

ENERGY PLANTATION
An interesting approach for the large-scale planned use of wood is the ‘energy plantation’ approach. In this scheme, selected species of trees are planted and harvested over regular intervals of time in a phased manner so that wood is continuously available for cooking or allied purposes.
Energy plantations include, amongst others, pine, cottonwood, hybrid poplar, sweetgum, and eucalyptus. Much of the emphasis has been on hardwood plantations due to their ability to coppice, continued genetic improvement programs as well as the opportunity to combine fast growth and wood. Some important trees grown in India for this purpose are eucalyptus, babool, and casuarinas.
A rich experience of commercial energy plantations management system in varied climatic conditions has emerged during the past 4–5 decades. Improvements in soil preparation, planting, cultivation methods, species matching, biogenetics and pest, disease and fire control have led to enhanced yields.

It has been suggested that electrical power be produced by the energy plantation approach, the wood grown in this manner being used as a fuel for the boilers of a conventional power plant. The technology of biomass-based electric power plants is well established in the USA and Europe and there are over 500 such plants use wood, wood waste, and various types of agricultural waste. When a photosynthetic conversion efficiency of around 1% is assumed, it is estimated that a 1,000 MW power plant may require an area of about 1,000 km2 for the energy plantation. Although this is a large area, it should not be difficult to provide in most countries since the land required need not displace agricultural land. However, care has been taken so that there is no danger of monoculture weakening the ecological system.

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 (CO2), methane (CH4), hydrogen (H2), and nitrogen (N2) 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

Methanol is an extremely attractive chemical that is useful both as fuel for heat engines as well as chemical feedstock for industries. Since any biomass material can undergo gasification, this process is much more attractive than ethanol production or biogas where only selected biomass materials can produce the fuel.

Gasification processes involved with biomass are as follows:

1. Drying of fuels: It is the process of drying biomass before it is fed into gasifier.
2. Pyrolysis: It is a process of breaking down biomass into charcoal by applying heat to biomass in the absence of oxygen.
3. Combustion: All the heat required for different processes of gasification are made available from combustions.
4. Cracking: In this process, breaking down of large complex molecules (such as tar) takes place when heated into lighter gases.
5. Reduction: Oxygen atoms are removed in this process from the combustion products (hydrocarbon) molecules and returning them to combustible form again.

THEORY OF GASIFICATION

Gasification may be considered as a special case of pyrolysis where destructive decomposition of biomass (wood wastes) by heat is converted into charcoal, oils, tars, and combustible gas. It is referred to as the partial combustion of solid fuel (biomass) and takes place at temperatures of about 1,000°C. The reactor used for gasification is called a gasifier.

The complete combustion of biomass produces biomass gasses that generally contain nitrogen, water vapour, carbon dioxide, and surplus of oxygen. However, in gasification (with incomplete combustion), as shown in Figure 4.1, product gas contains gases such as carbon mono oxide (CO), hydrogen (H2), and traces of methane and non-useful products such as tar and dust. The production of these gases is obtained by the reaction of water vapour and carbon dioxide through a glowing layer of charcoal. Thus, the key to gasifier design is to create conditions such that

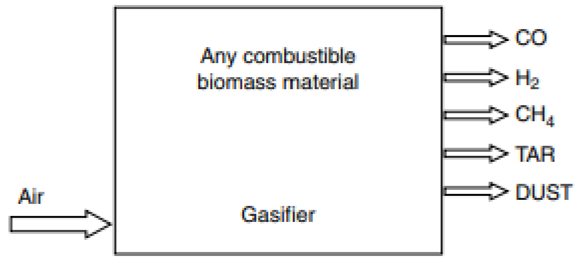

Figure 4.1 Products of gasifiers

1. Biomass is reduced to charcoal
2. Charcoal is converted at suitable temperature to produce CO and H2

Typically, the volumetric composition of biomass-based producer gas is as follows:
CO : 20%–22%,
H_2 : 15%–18%,
CH_4 : 2%–4%,
CO_2 : 9%–11% and
N_2 : 50%–54%.

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 4.2.

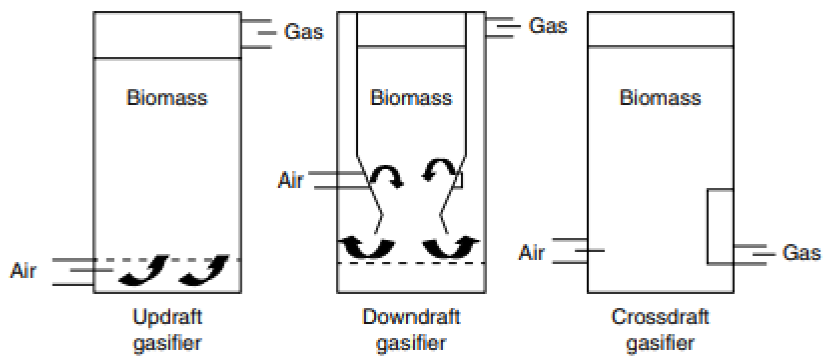

Figure 4.2 Types of fixed bed gasifiers

(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.

(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.

(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 abovementioned categories.

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. However, following general remarks can be made about them.

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

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

(c) The real pyrolysis, which takes place between 280°C and 500°C, produces large quantities of tar and gases containing carbon dioxide. Besides light tars, some methyl alcohol is also formed.

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

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 occur.

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. This reaction is endothermic (demands heat) and occurs at temperature exceeding about 1,000°C. Carbon monoxide is the most important flammable elements in the produced gas obtained from the reduction reaction as

$$C + CO_2 + \text{heat} \rightarrow 2CO \quad (4.1)$$

Another important endothermic reaction in the reduction zone is the water–gas shift reaction. It is the reaction of water vapour and carbon to give carbon monoxide and hydrogen.

$$C + H_2O + \text{Heat} \rightarrow CO + H_2 \quad (4.2)$$

Both gasses are flammable, and the heating value of the gas is increased. If there is still surplus of water in the reduction zone, then carbon monoxide may react with water vapour and form carbon dioxide and hydrogen. This reaction is exothermic (emits heat) and decreases the heating value of the produced gas. The reaction is

$$CO + H_2O - \text{Heat} \rightarrow CO_2 + H_2 \quad (4.3)$$

Equations (4.1) and (4.2) are main reduction reactions and being endothermic have the capability of reducing gas temperature. Consequently, the temperatures in the reduction zone are normally 800°C–1,000°C. The lower the reduction zone temperature (~700°C–800°C), lower is the calorific value of gas.

The gas also contains measurable amounts of particulate material and tar. The heating value of the gas ranges from 4,000 to 5,000 kJ/m^3, which is a relatively low value when compared to the heating value of other gaseous fuels like natural gas.

The conversion efficiency of a gasifier is defined as the ratio of the heat content in the producer gas to the heat content in the biomass supplied and is usually around 75%.

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

UPDRAFT GASIFIERS

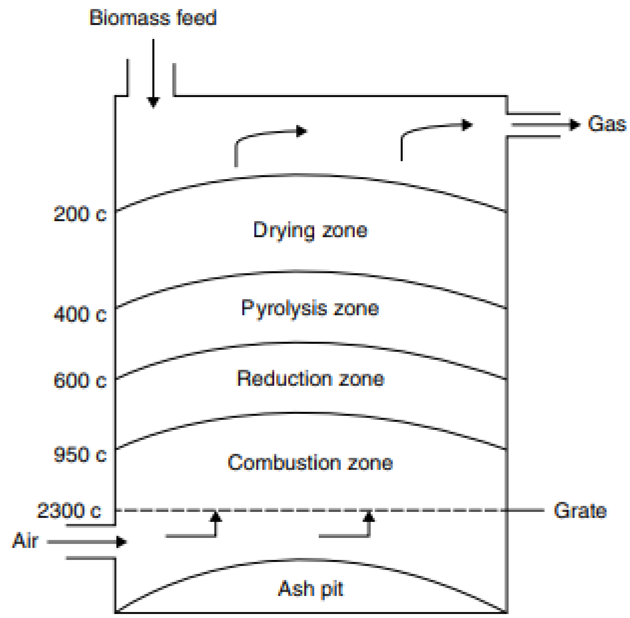

Figure 4.3 Updraft gasifier

The oldest and simplest type of gasifier is the countercurrent or updraft gasifier shown schematically in Figure 4.3. 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.

In the upper part of the gasifier, heating and pyrolysis of the feedstock occur because 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.

Updraft gasifiers are widely used to gasify biomass resources and generally use steam as the reactive agent, but slagging can be severe if high ash fuels are used. They are unsuitable for use with fluffy, low-density fuels.

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 gasifier, 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 4.4. The biomass feed (such as wood waste) and its gasification air both flow in the same downward direction through the gasifiers' fuel bed.

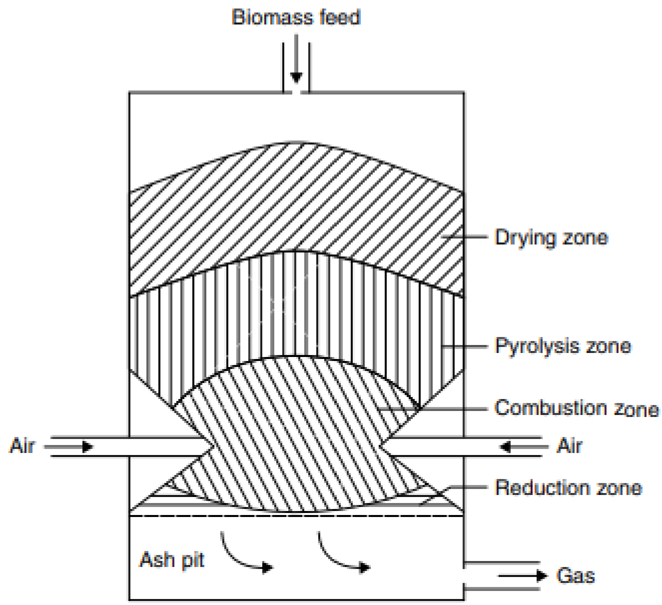

Figure 4.4 Downdraft gasifier

The biomass feed is admitted at the top similar to the updraft gasifier. As the feed progresses down through the gasifier, it dries and its volatiles are pyrolysed. 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, particularly when the biomass is wetter than about 20% moisture content (wet basis). The producer gas leaves at the bottom of the gasifier. The start-up time of about 5–10 min is necessary to ignite and bring plant to working temperature with good gas quality is shorter than updraft gas producer.

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 4.5 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.

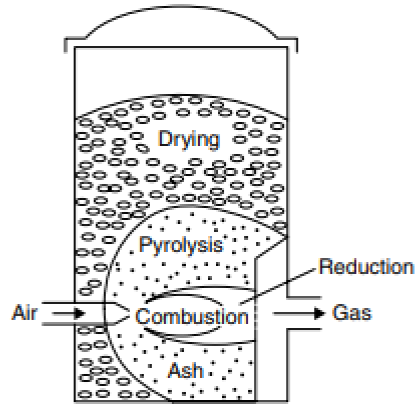

Figure 4.5 Cross-draft gasifier

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.

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.

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. Past applications have included gasification of wastes to provide gas for dryers previously fired on natural gas.

The fluidized bed gasifier is illustrated schematically in Figure 4.6. 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. 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 pyrolysed very fast, resulting in a component mix with a relatively large amount of gaseous materials. Further gasification and tar-conversion reactions occur in the gas phase. For biomass feeds which have high ash content and the ash has low melting point, fluidized bed combustion seems to gasify them.

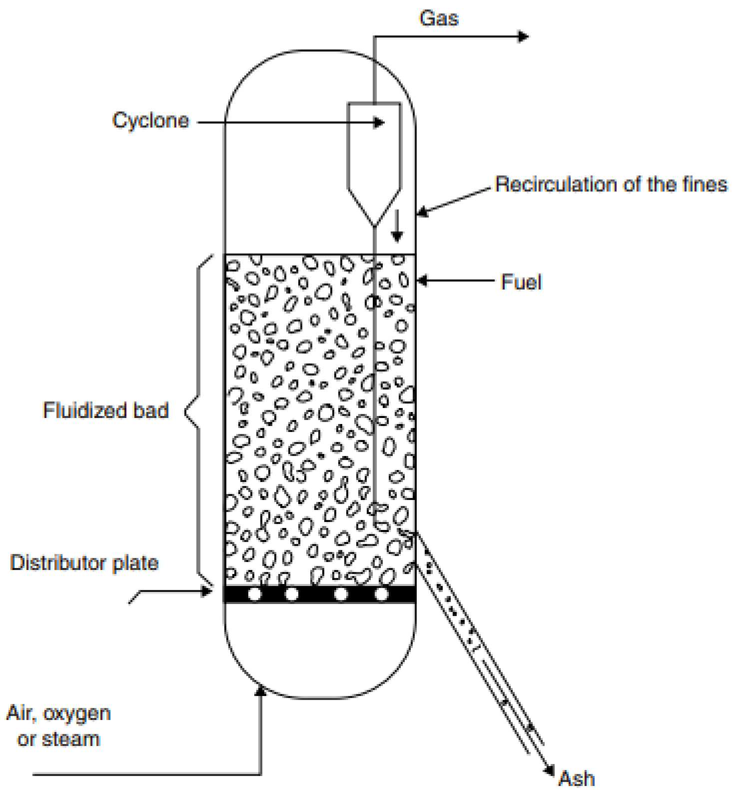

Figure 4.6 fluidized bed gasifier

USE OF BIOMASS GASIFIER

The output of a biomass gasifier can be used for a variety of direct thermal applications such as cooking, drying, heating water, and generating steam. It can also be used as a fuel for internal combustion engines to obtain mechanical shaft power or electrical power.

If used as a fuel for internal combustion engines, it has to be cleaned first for complete removal of particulate material and tar. A cleaning system consisting of cyclone, a scrubber, and a filter is used for the purpose. If the engine is a spark-ignition engine, it can operate with producer gas alone. The gas is sucked from the gasifier and cleaner unit by the engine suction along with a proportionate amount of air. It is then compression-ignition engine, as it operates in the 'dual-fuel' mode. Here, the engine sucks in a mixture that is compressed and a small amount of diesel sprayed in. Combustion initiates with the diesel droplets and then spreads to the mixture of the gaseous fuel and air. The phrase 'dual-fuel' implies that both diesel and producer gas are simultaneously used.

India is one of the leading countries in the world in the field of biomass gasification. Biomass gasifier systems are available in a wide range of capacities and standard facilities for testing and evaluating gasifiers have been set up. For thermal applications, systems with outputs ranging from 60,000 to 5×10^6 kJ/h are available, while for electrical power generation, systems with outputs ranging from 3 to 500 kW are also available.

The largest biomass gasification system produces 5×10^6 kJ/h (1,450 kW) output in the thermal mode and 500 kW in the electric power generation mode. It uses biomass in the form of wood blocks (25 to 100 mm long and up to 70 mm in diameter) at the rate of 500 kg/h and produces 1,250 m3/h of gas. The internal combustion engine is a compression ignition engine operating in the dual-fuel mode. It uses only 25% of the diesel normally required by the engine if operating with diesel alone.

GASIFIER BIOMASS FEED CHARACTERISTICS

Most of gasifier manufacturers claim that a gasifier is available and can gasify any biomass feed. However, there is no such thing as a universal gasifier. A gasifier is in real sense very much biomass feed specific and it is tailored accordingly.

Following biomass feed characteristics or parameters dictate the quality and classification of gasifiers:

1. Energy content of the fuel
2. Bulk density
3. Moisture content
4. Dust content
5. Tar content
6. Ash and slogging characteristic

1 Energy Content and Bulk Density of Fuel

The higher the energy content and bulk density of fuel, the similar is the gasifier volume; as for one biomass fuel charge, power can be obtained for longer time duration.

2 Moisture Content

Moisture content is very trivial components of biomass fuels and it is determined by the type of fuel, its origin, and treatment. It is desirable to use fuel with low moisture content to minimize heat loss due to its evaporation.

Besides impairing the gasifier heat budget, high moisture content also puts load on cooling and filtering equipment by increasing the pressure drop across these units because of condensing liquid. Thus, in order to reduce the moisture content of fuel, some pre-treatment of fuel is required. Generally, desirable moisture content for fuel should be less than 20%.

3 Dust Content

All gasifier fuels produce undesirable dust that can clog the internal combustion engine and hence it has to be removed. The gasifier design should be such that it should not produce dust beyond specified limits.

The higher the dust produced, more is the load put on filters necessitating their frequent flushing and increased maintenance.

4 Tar Content

Tar is one of the most unpleasant constituents of the gas as it tends to deposit in the carburettor and intake valves causing sticking and troublesome operations. It is a product of highly irreversible process taking place in the pyrolysis zone. There are approximately 200 chemical constituents that have been identified in tar so far.

Very little research work has been done in the area of removing or burning tar in the gasifier so that relatively tar free gas comes out. Thus, the major effort has been devoted to cleaning this tar by filters and coolers.

5 Ash and Slagging Characteristics

The mineral content in the fuel that remains in oxidized form after complete combustion is usually called ash. The ash content of a fuel and the ash composition has a major impact on troublefree operation of gasifier. Ash basically interferes with the gasification process in two ways:

1. It fuses together to form slag and this clinker stops or inhibits the downward flow of biomass feed.
2. Even if it does not fuse together, it shelters the points in fuel where ignition is initiated, and thus lowers the fuel’s reaction response.

Ash and tar removal are the two most important processes in gasification system for its smooth running. However, slagging can be overcome by two types of operation of gasifier:

1. Low temperature operation that keeps the temperature well below the flow temperature of the ash.
2. High temperature operation that keeps the temperature above the melting point of ash.

The first method is usually accomplished by steam or water injection, while the latter method requires provisions for tapping the molten slag out of the oxidation zone. Each method has its advantages and disadvantages and depends on specific fuel and gasifier design.

Keeping in mind the abovementioned characteristics of fuel, only two fuels have been thoroughly tested and proven to be reliable. They are charcoal and wood.

As charcoal is tar free and has relatively low ash content property, it was the preferred fuel during World War II and still remains so. However, there is a major disadvantage of charcoal in terms of energy. Charcoal is mostly produced from wood and in the conversion of wood to charcoal, about 50% of original energy is lost.

6 Biomass Feed (Fuel)

The major biomass sources presently used are as follows:

1. Sugarcane and corn, wheat, sugar beet, sweet sorghum, and cassava to produce bioethanol.
2. Rapeseed, sunflower seeds, soybean, canola, peanuts, jatropha, coconut, and palm oil for biodiesel production.
3. Wide range of cellulosic materials (such as grassy crops, woody plants, by-products from the forestry and agricultural sector including wood residues, stems, and stalks and municipal wastes constitute the so-called second generation of feedstock).
4. Wastes and residues constitute a large source of biomass. These include solid and liquid municipal wastes, manure, lumber and pulp mill wastes, and forest and agricultural residues.

Low water content (dried) biomass feedstock is burnt to generate heat and electricity. Wood wastes in the paper and pulp industries and bagasse from the sugarcane industry are used in ethanol fermentation.

A variety of raw materials that include agricultural wastes, municipal solid wastes, market garbage, and waste, water from food and fermentation industries (all organic materials containing carbohydrates, lipids, and proteins) are feedstock for anaerobic digester for methane production.

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.
(d) Running of high efficiency Stirling engines.

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.
(c) For melting metals and alloys in non-ferrous in the temperature range of 700°C–1,000°C.
(d) As boiler fuels provide steam or hot water for process industries such as silk reeling, dyeing, turmeric boiling, cooking, jiggery making, etc.

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.

COOLING AND CLEANING OF GAS

For efficient and effective use of gas for numerous applications, it should be cleaned of tar and dust, free from moisture content and cooled. Therefore, cooling and cleaning of the gas is one of the most important processes in the whole gasification system. The failure or the success of producer gas units depends completely on their ability to provide a clean and cool gas to the engines or for burners.

The temperature of gas coming out of generator is normally between 300°C and 500°C. The energy density of gas can be increased to a large extent by cooling it. 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. Some heat exchangers provide partial scrubbing of gas for the removal of moisture and tar contents. Thus, ideally, the gas going to an internal combustion engine should be cooled to nearly ambient temperature and shall be free from tar and moisture contents.

Normally, there are three types of filters used for cleaning of gas, as shown in Figure 4.7, which is schematically a downdraft gasification system with cleaning and cooling train.

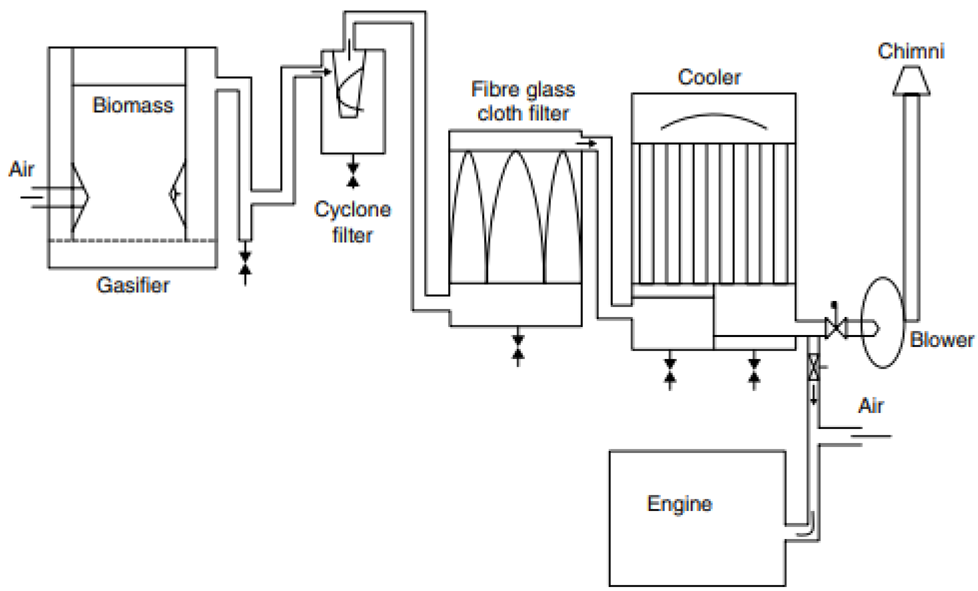

Figure 4.7 Schematic diagram of producer gas plant

Biogas Energy:

INTRODUCTION

In an anaerobic digestion process, organic matters are broken down into simpler chemical components in the absence of oxygen, and this process has proved to be very useful for organic wastes treatment in order to minimize environmental pollution. In this process, breaking down of organic matters takes place in anaerobic digesters that are classified based on feedstock, water content, temperature, and number of stages.

The common organic wastes feed for anaerobic digesters include human and animal excreta, forests and agricultural wastes, sewage sludge, organic farm wastes, municipal solid wastes, organic industrial and commercial wastes.
Biogas and manure are the by-products of anaerobic digestion that provides energy and organic fertilizers for improving comforts and income. Anaerobic digestion is also used for waste management in industrial and domestic sectors.

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 (CH4) 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 is shown in Table 10.1, which mainly composed of 50% to 70% methane (CH4), 30% to 40% carbon dioxide (CO2), 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. Its calorific value is 20 MJ/m3.
Its equivalence with other energy and fuels are as follows:
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 and four cows and buffaloes, animal dung (leaving the use of human excreta for social problems) will produce about 175 cubic feet of biogas per day which will be sufficient for family requirements of cooking and lighting. In addition, rural housewives using the biofuel are spared the irritating smoke coming out of traditional cooking on raw biomass material and reduced labour required for cleaning the cooking equipments and utensils. The digested material, which comes out of the plant, is enriched manure.

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).
1 Process Stages of Anaerobic Digestion
The biological and chemical stages of anaerobic digestion are shown in Figure 4.8. These are divided into the following four main stages:
1. Hydrolysis

2. Acedogenesis
3. Acetogenesis
4. Methanogenesis

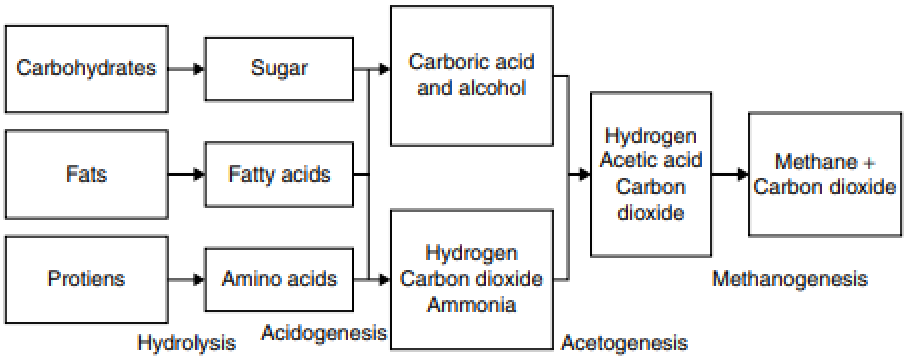

Figure 4.8 Process of anaerobic digestion

The four main stages are explained as follows.

1 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.

Hydrogen and acetate products of first stage are directly used by methanogens. Other molecules with a chain length larger than that of acetate (e.g. volatile fatty acids) must first be catabolized into compounds and then used by methanogens.

2 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.

3 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.

4 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 most 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 outlined earlier is as follows:

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4 \quad (4.4)$$

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

BIOGAS PRODUCTION

Biogas originates from bacteria in the process of biodegradation of organic material under anaerobic (in the absence of oxygen) conditions.

Anaerobic processes either occur naturally or created in a controlled environment, namely a biogas plant in which organic wastes are put in an airtight container called digester to perform anaerobic digestion process.

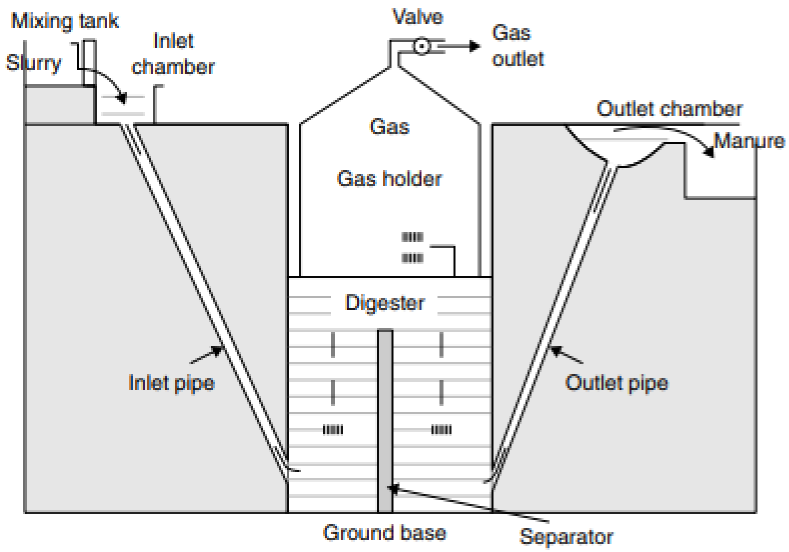

Figure 4.9 A fixed dome type biogas plant

Working of Biogas Plant

The working principle of biogas plant can be explained in Figure 4.9. The various steps of working principle of biogas plants are as follows:

1. Cattle dung and water are mixed thoroughly in equal proportion (in the ratio of 1:1) 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.

Normally, the outlet gas valve remains closed, and hence, the accumulated biogas in the dome exerts pressure on the slurry which starts moving in the inlet and outlet chamber due to which the level of slurry drops in digester and increases in the outlet chamber. This process continues till the slurry reaches to highest possible level in the inlet and outlet chamber because of increased gas pressure.

4. If the gas valve is still kept closed the biogas will further get accumulated in the dome and develop high pressure enough in the gas to start escaping through the inlet and outlet chambers to the atmosphere. The biogas creates bubbles in the slurry in inlet and outlet chambers during its escape, and froth is also formed.
5. An increase in the volume of slurry in the inlet and 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.

Under this situation, slurry level in the digester increases while the level in inlet and outlet chambers reduces.

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 and equivalent amount of fresh slurry is inducted into the digester to continue the process of fermentation and the formation of the biogas. Therefore, more is the biogas required, more continuous will be the fresh slurry of cow dung and water required. The size of the digester tank also decides the amount of the gas that can be generated by the biogas plant.

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

1. Production of energy (heat, light, and electricity): The calorific value of biogas is about 6 kWh/m^3, 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 m^3) 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.

2. 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.

3. Health benefits of biogas and the improvement of hygienic conditions (reduction of pathogens, worm eggs, and flies): Significant health benefits are achieved using 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 installed a biogas plant for heating, cooking, and other work. The improvement in hygienic cooking on biogas also has economic benefits.
The principal disease spreading organisms, such as typhoid, paratyphoid, cholera and dysentery bacteria, hookworm, bilharzias tapeworm, and roundworm, are killed in biogas plants. Cooking on biogas can have effects on nutritional patterns too. It increases cooked food digestibility.

4. 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 equipment 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.

5. 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 and amelioration. First, biogas could increasingly replace firewood as a source of energy. Second, biogas systems yield more and better fertilizer. As a result, more fodder becomes available for domestic animals. This, in turn, can lessen the danger of soil erosion attributable to overgrazing.

6. 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 biogas, 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 as follows:

1. Cost: The principal and maintenance costs of biogas plans should be as low as possible (interms of the production cost per unit volume of biogas) both to the user and to the society
2. 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.
3. 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.
4. 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.
5. 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.

BIOGAS PLANT FEEDS AND THEIR CHARACTERISTICS

Any biodegradable organic material can be used as inputs for processing inside the biodigester. However, for economic and technical reasons, some materials are more preferred as inputs than others. If the inputs are costly or have to be purchased, then the economic benefits of outputs such as gas and slurry will become low.

Economic value of biogas and its slurry and reduced environmental cost of biodegradable wastes disposal in landfill are the two benefits of biogas energy.

One of the main attractions of biogas technology is its ability to generate biogas out of organic wastes that are in abundance and freely available. Cattle dung is most used as an input mainly because of its availability.

In addition to the animal and human wastes, plant materials are also used to produce biogas and biomanure. Since different organic materials have different biochemical characteristics, their potential for gas production also varies.

Basic requirements for gas production or for normal growth of methanogens are achieved by mixing two or more of different organic materials and feeding to the biogas plants can be used together provided that some are met. Some characteristics of these raw organic inputs materials having significant impact on the level of gas production are described below.

1 Carbon/Nitrogen (C/N) Ratio

The relationship between amount of carbon and nitrogen present in organic materials is expressed in terms of the 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 protein requirements and 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 and accumulated in the form of ammonia ($NH4$) 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. Animal waste, particularly cattle dung has an average C/N ratio of about 24. The plant materials, such as straw and sawdust, contain a higher percentage of carbon/nitrogen ratio whereas the human excreta have a C/N ratio as low as 8.

In order to bring the average ratio of the composite input to a desirable level materials with high C/N ratio could be mixed with those of low C/N ratio. In China, it is customary to load rice straw at the bottom of the digester upon which latrine waste is discharged as a means to balance C/N ratio.

Tidal Energy: Introduction

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 way:

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.

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).

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.

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.

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. 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.

LEADING COUNTRY IN TIDAL POWER PLANT INSTALLATION

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

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

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

$E = \rho g A \int z\,dz = 0.5\,\rho g A h^2$ (4.5)

where E = the energy; g = acceleration of gravity; r = 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 (rg) = 10.15 kN/m^3 for seawater, energy for a tidal cycle per m2 of ocean surface can be approximated as:

E = 1.4 h^2 (Watt-hour) (4.6)

or = 5.04 h^2 (kJ) (4.7)

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 a (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

KE = 0.5mV^2 (4.8)

The total energy of tide waves equals the sum of its potential and kinetic energy components. Estimation and understanding of the potential energy availability of the tides are key for designing conventional tidal power plants using water dams for creating artificial upstream water heads. Such power plants exploit the potential energy of vertical rise and fall of the water.

The kinetic energy of the tide has to be known for designing other types of tidal power plants (like Soating), which harness energy from tidal currents or horizontal water. They do not involve the installation of water dams.

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. In order to overcome wide variation in availability of tidal power, various tidal basin systems have, therefore, been developed.

1. 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.

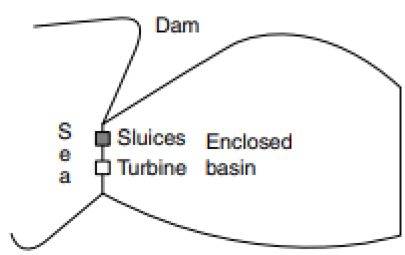

Figure 4.10 Single-basin system

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.

2 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.

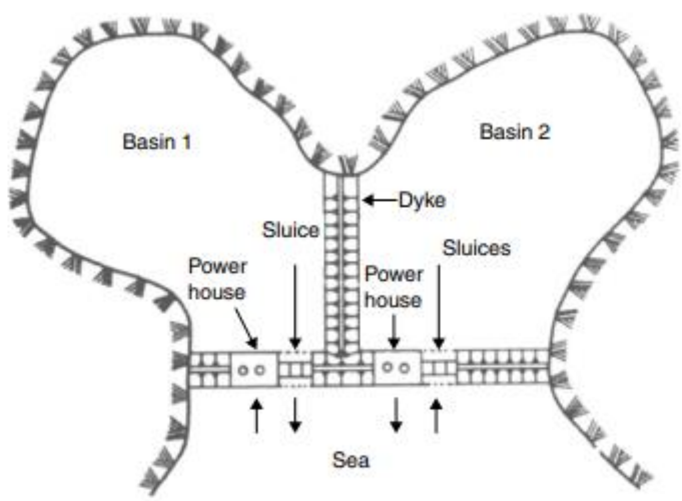

Figure 4.11 Two-basin system

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. 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.

TURBINES FOR TIDAL POWER

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

These are as follows:

1. The Kaplan type of water turbine operates quite favourably under these conditions.
2. The 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. A compact reversible horizontal turbine (bulb-type turbine) has been developed by French Engineer and it acts with equal efficiency both as a pump and as a turbine.

Bulb-type turbine

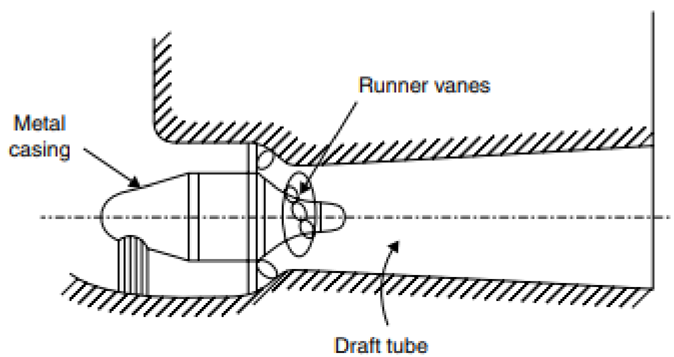

Figure 4.12 Bulb-type turbine

The bulb-type turbine shown in Figure 4.12 consists of a steel shell completely enclosing the generator that is coupled to the turbine runner. The turbine is mounted in a tube within the structure of the barrage, and the whole machine being submerged at all times. When the power demand on the system is low during the rising tides, the unit operates as a pump to transfer water from sea to the basin. When the load on this system is high, the unit will work as a generator, and deliver the stored energy that is a valuable additional input to the system.

Bulb turbines incorporated the generator–motor unit in the flow passage of the water. The main drawback is that water flows around the turbine, making maintenance difficult.

ADVANTAGES AND DISADVANTAGES OF TIDAL POWER

The following are the advantages of tidal power:

1. About two-third of earth’s surface is covered by water, there is scope to generate tidal energy on large scale.
2. Techniques to predict the rise and fall of tides as they follow cyclic fashion and prediction of energy availability is well established.
3. The energy density of tidal energy is relatively higher than other renewable energy sources.
4. Tidal energy is a clean source of energy and does not require much land or other resources as in harnessing energy from other sources.
5. It is an inexhaustible source of energy.

6. It is an environment friendly energy and does not produce greenhouse effects.
7. Efficiency of tidal power generation is far greater when compared to coal, solar, or wind energy. Its efficiency is around 80%.
8. Despite the fact that capital investment of construction of tidal power is high, running and maintenance costs are relatively low.
9. The life of tidal energy power plant is very long.

The following are the disadvantages of tidal power:
1. Capital investment for construction of tidal power plant is high.
2. Only a very few ideal locations for construction of plant are available and they too are localized to coastal regions.
3. Unpredictable intensity of sea waves can cause damage to power generating units.
4. Aquatic life is influenced adversely and can disrupt the migration of fish.
5. The energy generated is not much as high and low tides occur only twice a day and continuous energy production is not possible.
6. 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.
7. This technology is still not cost effective and more technological advancements are required to make it commercially viable

PROBLEMS FACED IN EXPLOITING TIDAL ENERGY
1. Usually the places where tidal energy is produced are far away from the places where it is consumed. This transmission is expensive and difficult.
2. Intermittent supply: Cost and environmental problems, particularly barrage systems are less attractive than some other forms of renewable energy.
3. 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.
4. 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.

For a tidal power plant to produce electricity effectively (about 85% efficiency), it requires a basin or a gulf that has a mean tidal amplitude (the differences between spring and neap tide) of 7 m or more. It is also desirable to have semi-diurnal tides where there are two high and low tides everyday.

A barrage across an estuary is very expensive to build and affects a very wide area—the environment is changed for many miles upstream and downstream. Many birds rely on the tide uncovering the mud fl ats so that they can feed. There are few suitable sites for tidal barrages.
1. Only provides power for around 10 h each day, when the tide is actually moving in or out.
2. Present designs do not produce a lot of electricity, and barrages across river estuaries can change the flow of water, and consequently, the habitat for birds and other wildlife.
3. Expensive to construct.
4. Power is often generated when there is little demand for electricity.
5. Limited construction locations.
6. Barrages may block outlets to open water. Although locks can be in stalled, this is often a slow and expensive process.
7. Barrages affect fish migration and other wildlife; many fish like salmon swim up to the barrages and are killed by the spinning turbines.

8. Fish ladders may be used to allow passage for the fish, but these are never 100% effective.
9. Barrages may also destroy the habitat of the wildlife living near it.
10. Barrages may affect the tidal level—the change in tidal level may affect navigation, recreation, cause flooding of the shoreline, and affect local marine life.
11. Tidal plants are expensive to build.
12. They can only be built on ocean coastlines; this mean that for communities that are far away from the sea, it is useless.