UNIT-3

BIOGAS

Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Since biogas is a mixture of methane (also known as marsh gas or natural gas, CH_4) and carbon dioxide (CO_2) it is a renewable fuel produced from waste treatment. Anaerobic digestion is basically a simple process carried out in a number of steps by many different bacteria that can use almost any organic material as a substrate - it occurs in digestive systems, marshes, rubbish dumps, septic tanks and the Arctic Tundra. Humans tend to make the process as complicated as possible by trying to improve on nature in complex machines, but a simple approach is still possible. As methane is very hard to compress I see its best use as for stationary fuel, rather than mobile fuel. It takes a lot of energy to compress the gas (this energy is usually just wasted), plus you have the hazard of high pressure. Variable volume storage (flexible bag or floating drum are the two main variants) is much easier and cheaper to arrange than high-pressure cylinders, regulators and compressors.

Types of biogas: Basically two types

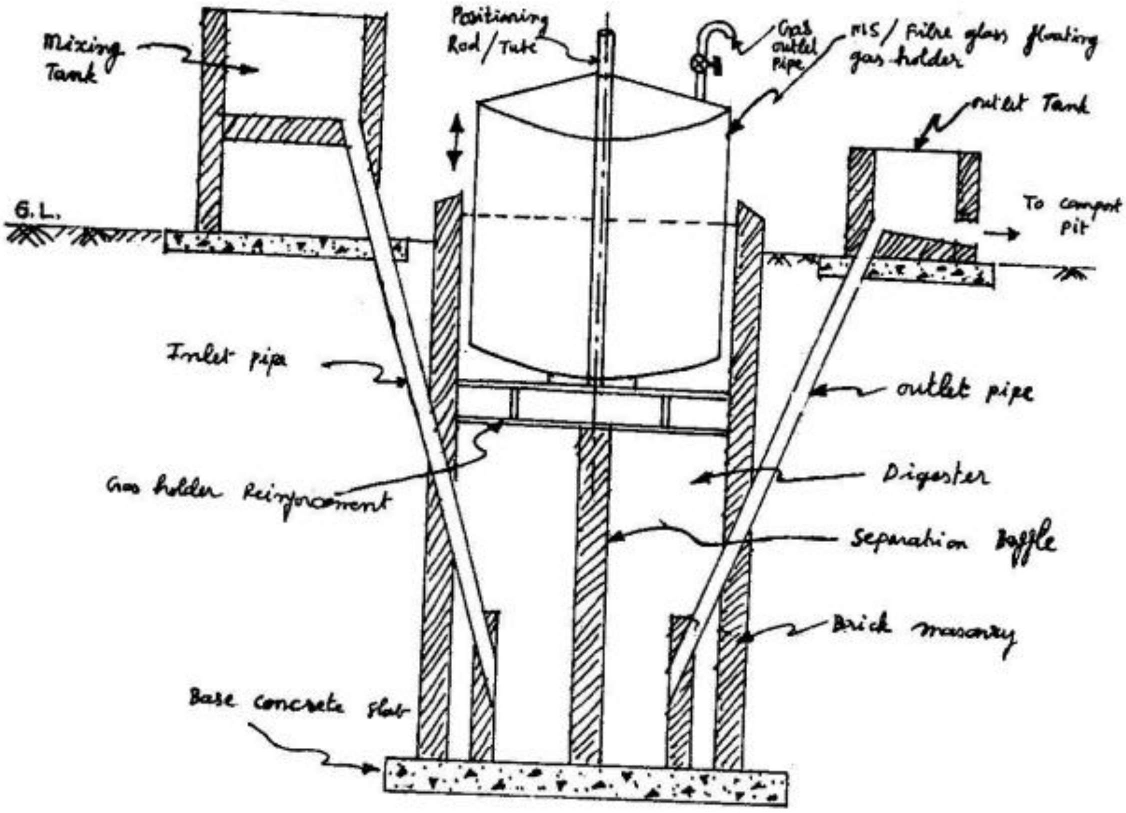
1. **Floating dome type**

   Example: KVIC-type (KVIC- Khadi village Industries commission)

   KVIC type biogas plant This mainly consists of a digester or pit for fermentation and a floating drum for the collection of gas. Digester is 3.5-6.5 m in depth and 1.2 to 1.6 m in diameter. There is a partition wall in the center, which divides the digester vertically and submerges in the slurry when it is full. The digester is connected to the inlet and outlet by two pipes. Through the inlet, the dung is mixed with water (4:5) and loaded into the digester. The fermented material will flow out through outlet pipe. The outlet is generally connected to a compost pit. The gas generation takes place slowly and in two stages. In the first stage, the complex, organic substances contained in the waste are acted upon by a certain kind of bacteria, called acid formers and broken up into small-chain simple acids. In the second stage, these acids are acted upon by another kind of bacteria, called methane formers and produce methane and carbon dioxide.

   Gas holder

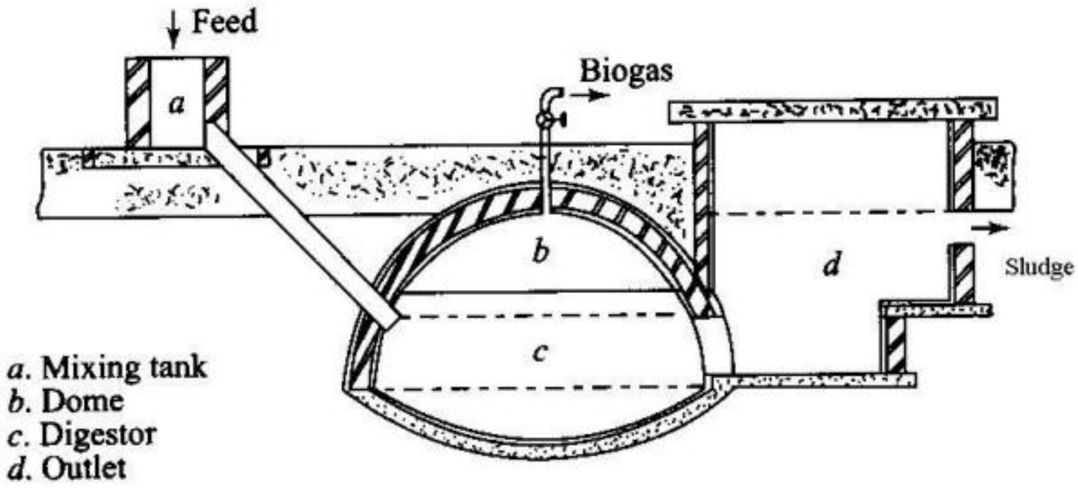
   The gas holder is a drum constructed of mild steel sheets. This is cylindrical in shape with concave. The top is supported radically with angular iron. The holder fits into the digester like a stopper. It sinks into the slurry due to its own weight and rests upon the ring constructed for this purpose. When gas is generated the holder rises and floats freely on the surface of slurry. A central guide pipe is provided to prevent the holder from tilting. The holder also acts as a seal for the gas. The gas pressure varies between 7 and 9 cm of water column. Under shallow water table conditions, the adopted diameter of digester is more and depth is reduced. The cost of drum is about 40% of total cost of plant. It requires periodical maintenance. The unit cost of KVIC model with a capacity of 2 m3/day costs approximately Rs.14, 000 - 00. Fig. 1. Schematic diagram of a KVIC biogas plant.



Schematic diagram of a KVIC biogas plant

2. **Fixed dome type.**
   Example: Deenbandhu model
   Deenbandhu biogas plant :
   Deenbandhu model was developed in 1984, by Action for Food Production (AFPRO), a voluntary organization based in New Delhi. Schematic diagram of a Deenabandhu biogas plant entire biogas programme of India as it reduced the cost of the plant half of that of KVIC model and brought biogas technology within the reach of even the poorer sections of the population. The cost reduction has been achieved by minimizing the surface area through joining the segments of two spheres of different diameters at their bases. The cost of a Deenbandhu plant having a capacity of 2 m3/day is about Rs.8000-00. The Deenbandhu biogas plant has a hemispherical fixed-dome type of gas holder, unlike the floating dome of of the KVIC-design is shown. The dome is made from pre-fabricated ferrocement or reinforced concrete and attached to the digester, which has a curved bottom. The slurry is fed from a mixing tank through an inlet pipe connected to the digester. After fermentation, the biogas collects in the space under the dome. It is taken out for use through a pipe connected to the top of the dome, while the sludge, which is a by-product, comes out through an

opening in the side of the digester. About 90 percent of the biogas plants in India are of the Deenbandhu type.



Schematic diagram of a Deenabandhu biogas plant

Advantages of Biogas plants

- The initial investment is low for the construction of biogas plant.
- The technology is very suitable for rural areas.
- Biogas is locally generated and can be easily distributed for domestic use.
- Biogas reduces the rural poor from dependence on traditional fuel sources, which lead to deforestation.
- The use of biogas in village helps in improving the sanitary condition and checks environmental pollution.
- The by-products like nitrogen rich manure can be used with advantage.
- Biogas reduces the drudgery of women and lowers incidence of eye and lung diseases.

Raw materials for biogas generation Biogas is produced mainly from

- Cow dung
- Sewage
- Crop residues
- Vegetable wastes
- Water hyacinth
- Poultry droppings
- Pig manure

Digestion is biological process that occurs in the absence of oxygen and in the presence of anaerobic organisms at temperatures (35-70ºc) and atmospheric pressure. The container in which, this process takes place is known as digester.

Anaerobic digestion:

The treatment of any slurry or sludge containing a large amount of organic matter utilizing bacteria and other organisms under anaerobic condition is commonly referred as anaerobic digestion or digestion. Anaerobic digestion consists of the following three stages. The three stages are (i) the enzymatic hydrolysis, (ii) acid formation and (iii) methane formation.

Enzymatic hydrolysis

In this stage, a group of facultative microorganisms acts upon the organic matter and convert insoluble, complex, high molecular compounds of biomass into simple, soluble, low molecular compounds. The organic substances such as polysaccharide, protein and lipid are converted into mono-saccharide, peptide, amino acids, and fatty acids. Then they are further converted into acetate, propionate and butyrate.

Acid formation

The micro organisms of facultative and anaerobic group collectively called as acid formers, hydrolyze and ferment the productions of first phase i.e., water soluble substances into volatile acid. The major component of the volatile acid is the acetic acid. In addition to acetate or hydrogen and carbon dioxide, some other acids like butyric acid and propionic acid are also produced.

Methane formation

Finally, acetate or hydrogen plus carbon dioxide are converted into gas mixture of methane (CH4) and CO2 by the bacteria, which are strictly anaerobes. These bacteria are called methane fermentators. For efficient digestion, these acid formers and methane fermentators must remain in a state of dynamic equilibrium. The remaining indigestible matter is referred as "slurry".

The following are some approximate rules used for sizing biogas plants or for estimating their performance:

1. One kg of dry cattle dung produces approximately 1 m3 of biogas.
2. One kg of fresh cattle dung contains 8% dry biodegradable mass.
3. One kg of fresh cattle dung has a volume of about 0.9 liters.
4. One kg of fresh cattle dung requires an equal volume of water for preparing slurry.
5. Typical retention time of slurry in a biogas plant is 40 days.

The efficiency of biogas generation depends upon the following factors:

a. Acid formers and methane fomenters must remain in a state of dynamic equilibrium, which can be achieved by proper design of digester.

b. Anaerobic fermentation of raw cow dung can takes place at any temperature between 8 and 55°C. The value of 35°C is taken as optimum. The rate of biogas formation is very slow at 8°C. For anaerobic digestion, temperature variation should not be more than 2 to 3°C. Methane bacteria work best in the temperature range of 35 and 38°C.

c. A pH value between 6.8 and 7.8 must be maintained for best fermentation and normal gas production. The pH above 8.5 should not be used as it is difficult for the bacteria to survive above this pH.

d. A specific ratio of carbon to nitrogen (C/N ration) must be maintained between 25:1 and 30:1 depending upon the raw material used. The ratio of 30:1 is taken as optimum.
e. The water content should be around 90% of the weight of the total contents. Anaerobic fermentation of cow dung proceeds well if the slurry contains 8 to 9% solid organic matter.
f. The slurry should be agitated to improve the gas yield.
g. Loading rate should be optimum. If digester is loaded with too much raw material, acids will accumulate and fermentation will be affected.

Is Biomass Really Renewable?

Biomass, a renewable energy source derived from organic matter such as wood, crop waste, or garbage, makes up 4.8 percent of total U.S. energy consumption and about 12 percent of all U.S. renewable energy. Wood is the largest biomass energy source. In the U.S., there are currently 227 biomass plants operating. In the U.K., 35 are operating, 15 are under construction and 17 have been proposed. But just how renewable is biomass energy?

There are several ways to produce energy from biomass, including burning biomass to generate heat or run steam turbines that produce electricity, burning biomass to produce heat in thermal systems (when combined with electricity generation, it's called "combined heat and power"), turning feedstock's into liquid bio fuels, and harvesting gas from landfills or anaerobic digesters. Biomass can consist of wood from forests and logging residues, sawdust from lumber mills, construction or organic municipal waste, energy crops (switch grass), crop residue, and even chicken litter. Since the rapid expansion of biomass energy today relies largely on wood from forests, we'll focus here on energy produced by the combustion of biomass from forest wood and woody residue.

According to the U.S. Forest Service, "Wood is an abundant, sustainable, home-grown cellulosic resource that can significantly contribute to meeting 30 percent of U.S. petroleum consumption from biomass sources by 2030 and help create a more stable energy future, improve environmental quality, and increase economic opportunities."

Biomass advocates maintain that thinning out small-diameter or dead trees from overcrowded forests, and harvesting the byproducts of forest management such as limbs, treetops, needles, leaves, etc. improves the health of the trees that remain in the forest and helps reduce the incidence of wildfires. Biomass creates jobs and supports local economies by providing new markets for farmers and forest owners. It can also lessen our dependence on fossil fuels, and under certain conditions, can reduce greenhouse gas emissions.

What is Biomass Co-firing?

- Biomass co-firing is the practice of substituting a part of the fuel with biomass at coal thermal plants.
- Biomass co-firing stands for adding biomass as a partial substitute fuel in high efficiency coal boilers.

(a) Coal and biomass are combusted together in boilers that have been designed to burn coal. For this purpose, the existing coal power plant has to be partly reconstructed and retrofitted.
(b) Co-firing is an option to convert biomass to electricity, in an efficient and clean way, and to reduce GHG (Green house Gases) emissions of the power plant.

- Biomass co-firing is a globally accepted cost-effective method for decarbonising a coal fleet.
- India is a country where biomass is usually burnt on the field which reflects apathy towards resolving the problem of clean coal using a very simple solution that is readily available.

Significance of Biomass Co-firing:

- Biomass co-firing is an effective way to curb emissions from open burning of crop residue, it also decarbonises the process of electricity generation using coal.
  - Substituting 5-7 % of coal with biomass in coal-based power plants can save 38 million tonnes of carbon dioxide emissions.
- It can help cut emissions from combustion of fossil fuels, address India's burgeoning problem of farm stubble burning to some extent, reduce waste burden while also creating jobs in rural areas.
- India has large biomass availability as well as rapid growth in coal-fired capacity.

ENERGY FROM BIOMASS

Biomass energy is energy generated or produced by living or once –living organisms. The most common biomass materials used for energy are plants, such as corn and soy, above. The energy heat or converted into electricity. People have used biomass energy—energy from living things—since the earliest "cave men" first made wood fires for cooking or keeping warm. biomass is organic, meaning it is made of material that comes from living organisms, such as plants and animals. The most common biomass materials used for energy are plants, wood, and waste. These are called biomass feed stocks. Biomass energy can also be a non-renewable energy source. biomass contains energy first derived from the sun: Plants absorb the sun's energy through photosynthesis, and convert carbon dioxide and water into nutrients (carbohydrates).
The energy from these organisms can be transformed into usable energy through direct and indirect means. Biomass can be burned to create heat (direct), converted into electricity (direct), or processed into bio-fuel (indirect).

Thermal Conversion

Biomass can be burned by thermal conversion and used for energy. Thermal conversion involves heating the biomass feedstock in order to burn, dehydrate, or stabilize it. The most familiar biomass feed-stocks for thermal conversion are raw materials such as municipal solid waste (MSW) and scraps from paper or lumber mills. Different types of energy are created through direct firing, co-firing, pyrolysis, gasification, and anaerobic decomposition. before biomass can be burned, however, it must be dried. This chemical process is called torrefaction. During torrefaction, biomass is heated to about 200° to 320° Celsius (390° to 610° Fahrenheit). The biomass dries out so completely that it loses the ability to absorb moisture, or rot. It loses about 20% of its original mass, but retains 90% of its energy. The lost energy and mass can be used to fuel the torrefaction process. During torrefaction, biomass becomes a dry, blackened material. It is then compressed into briquettes. Biomass briquettes are very hydrophobic, meaning they repel water. This makes it possible to store them in moist areas. The briquettes have high energy density and are easy to burn during direct or co-firing.

Types of Biomass Fuels

There is different type of Biomass.

- Woody Fuels. Wood wastes of all types make excellent biomass fuels and can be used in a wide variety of biomass technologies.
- Forestry Residues.
- Mill Residues.
- Agricultural Residues.
- Urban Wood and Yard Wastes.
- Dedicated Biomass Crops.
- Chemical Recovery Fuels.
- Animal Wastes.

PYROLYSIS

Pyrolysis is the heating of an organic material, such as biomass, in the absence of oxygen. Biomass pyrolysis is usually conducted at or above 500 °C, providing enough heat to deconstruct the strong bio-polymers mentioned above.

Pyrolysis is one of the technologies available to convert biomass to an intermediate liquid product that can be refined to drop-in hydrocarbon bio fuels, oxygenated fuel additives and petrochemical replacements. Pyrolysis is the heating of an organic material, such as biomass, in the absence of oxygen. Biomass pyrolysis is usually conducted at or above 500 °C, providing enough heat to deconstruct the strong bio-polymers mentioned above. Because no oxygen is present combustion does not occur, rather the biomass thermally decomposes into combustible gases and bio-char. Most of these combustible gases can be condensed into a combustible liquid, called pyrolysis oil (bio-oil), though there are some permanent gases (CO_2, CO, H_2, light hydrocarbons), some of which can be combusted to provide the heat for the process. Thus, pyrolysis of biomass produces three products: one liquid, bio-oil, one solid, bio-char and one gaseous, syngas. The proportion of these products depends on several factors including the composition of the feedstock and process parameters. However, all things being equal, the yield of bio-oil is optimized when the pyrolysis temperature is around 500 °C and the heating rate is high (1000 °C/s) fast pyrolysis conditions. Under these conditions, bio-oil yields of 60-70 wt% of can be achieved from a typical biomass feedstock, with 15-25 wt% yields of bio-char. The remaining 10-15 wt% is syngas. Processes that use slower heating rates are called slow pyrolysis and bio-char is usually the major product of such processes. The pyrolysis process can be self-sustained, as combustion of the syngas and a portion of bio-oil or bio-char can provide all the necessary energy to drive the reaction.

Bio-oil is a dense complex mixture of oxygenated organic compounds. It has a fuel value that is generally 50 - 70% that of petroleum bases fuels and can be used as boiler fuel or upgraded to renewable transportation fuels. The bio-oil's composition makes it thermally unstable and therefore difficult to distill or further refine, making additional research on producing higher quality bio-oil necessary. However, its density is > 1 kg L^{-1}, much greater than that of biomass feedstock, making it more cost effective to transport than biomass. Therefore, it's is possible to envision a distributed processing model where many small scale pyrolyzers (farm scale) covert biomass to bio-oil which is then transported to a centralized location for refining. To test this hypothesis, our group developed and constructed a mobile one-ton per day pyrolysis demonstration unit based on a reactor design called the combustion reduction integrated pyrolysis system (CRIPS). The CRIPS unit can produce bio-oil on location and can perform fast or catalytic pyrolysis to produce partially deoxygenated bio-oil.

Furthermore, the bio-char produced can be used on the farm as an excellent soil amender that can sequester carbon. Bio-char is highly absorbent and therefore increases the soil's ability to retain water, nutrients and agricultural chemicals, preventing water contamination and soil erosion. Soil application of bio-char may enhance both soil quality and be an effective means of sequestering large amounts of carbon, thereby helping to mitigate global climate change through carbon sequestration. Use of bio-char as a soil amendment will offset many of the problems associated with removing crop residues from the land.

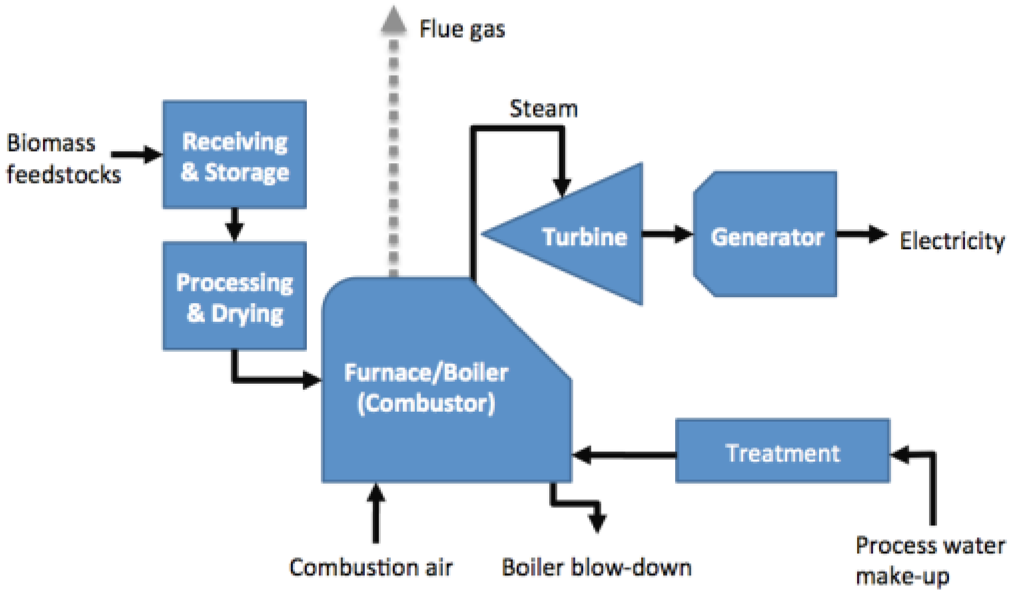
BIOMASS ELECTRIC POWER GENERATION

Many viable technologies convert biomass into electricity. As of 2009, biomass-power generating capacity in the United States totalled about 12 GW, representing about 1.1% of the total capacity . Table 1 shows a sampling of current biomass power plants in the United States. Total biomass generation capacity in the world is approximately 50 GW. Most of these power plants are well below 100 MW and are primarily located in the United States and Europe. However, biomass power capacity is expected to rise in future years.

Table 1. Select Biomass Power Plants in the United States

Plant Location	Capacity (MW)	Feedstock(s)	Year Online
Kettle Falls, WA	46.0	Primary Mill Residues	1983
New Meadows, ID	5.8	Wood Wastes	1983
Bethlehem, NH	15.0	Wood Wastes	1987
Tracy, CA	23.0	Wood Wastes	1990
Hurt, VA	79.5	Mill, Forest Residues	1994
Eagar, AZ	3.0	Forest Residues	2004
Snowflake, AZ	24.0	Wood Wastes, Mill Residues	2008

Currently, the primary approach for biomass conversion to electricity is also the most time-tested: combustion. Other biomass-to-power technologies are less straightforward and not yet as commercially demonstrable. For example, biomass gasification converts biomass into a volatile "synthesis gas" (or syngas), which is combustible. Another technology, anaerobic digestion of biomass, results in the formation of methane, which can be refined into various chemicals or similarly combusted. The System Advisor Model (SAM) biomass power model is limited to simple biomass combustion due to the known viability of the technology compared to more recent gasification and anaerobic digestion methods, as well as its direct applicability to generating electricity. Biomass power plants are very similar in operation to coal-fired power plants. The biomass is delivered to the plant where storage piles or silos accommodate extra biomass that is not immediately fed to the plant. Biomass can undergo various preprocessing steps including size reduction, separation, and drying before being fed to the combustor. In the combustor, biomass oxidation occurs under excess air. The exothermic reaction heats the combustion gases, which generate steam via heat exchangers to power a typical Rankine-cycle turbine and electric generator.



Biomass power process flow diagram

Biomass-fired power plants employ the same basic unit operations as a coal-fired power plant, making co-fired power plants that can run on either feedstock (or both in parallel) financially appealing. Since coal is more energy dense and the resource is more geospatially concentrated relative to biomass, coal transport can be economical over greater distances. Thus, most coal power plants are at least an order of magnitude larger than biomass power plants. Coal power plants can scale more easily, resulting in reduced expenses per megawatt (MW) capacity added. Additionally, larger plants can utilize higher pressures and temperature in steam cycles, leading to higher energy conversion efficiencies. The SAM biomass power model can be applied to solid-fuelled plants of any size and with any mix of biomass or coal fuels. Although the SAM model has no explicit limits on plant size, users should be aware of the feedstock input, component cost, and performance considerations and scale them appropriately to the system they are modeling.

Biomass cogeneration

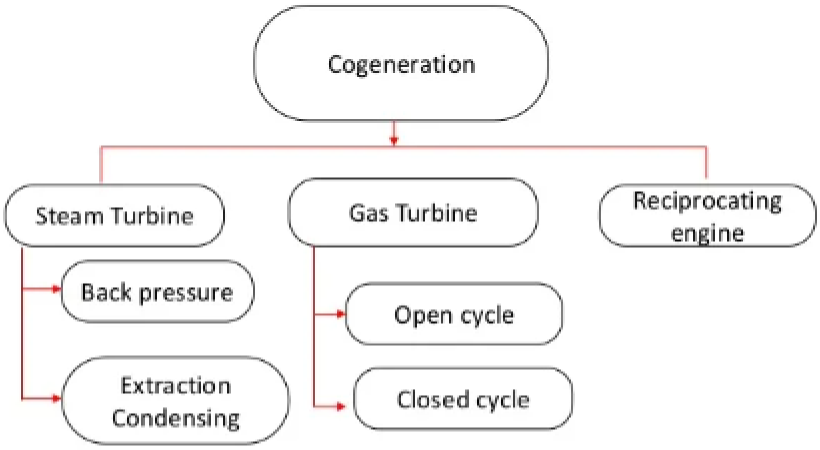
What is COGENERATION ?

- Cogeneration – 'Generating together'

In this processes wherein we obtain both heat and electricity from the same fuel at the same time .

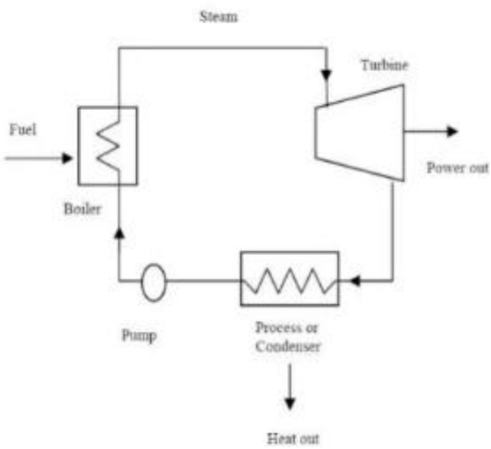
- The process Is also referred to as CHP , short for combined heat and power .
- A variety of fuel can be used for cogeneration including coal , natural gases and Biomass

Cogeneration Technologies



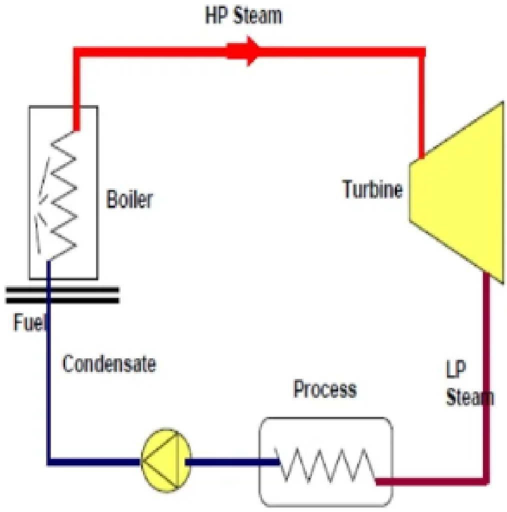
Steam Turbine cogeneration system

- Steam turbines work on the principle of the Rankine cycle, which consists of a heat source (boiler) that converts water into high-pressure steam.
- A multistage turbine allows the high pressure steam to expand, which lowers its pressure. The steam is then transported to a condenser, which is like a vacuum chamber and thus has negative pressure and converts, or condenses, the steam into water.



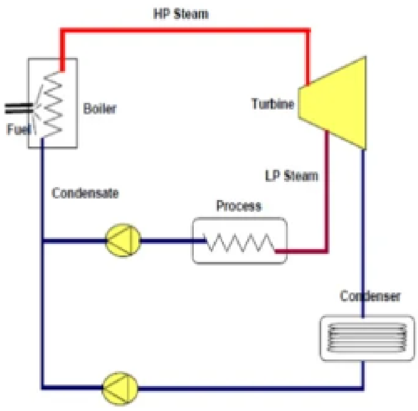
Back-pressure Steam Turbine

- Steam at a pressure higher or equal to atmospheric pressure is extracted from the turbine to the thermal load that is the point at which heat is required. At that point, the steam releases heat and gets condensed, or turns into water.
- The condensate (water) returns to the system at a flow rate that can be lower than the steam flow rate if some steam is used in the process.
  - This loss of steam is then compensated for in the cycle in the form of 'make-up' water fed into the boiler.



Extraction-condensing Steam Turbine

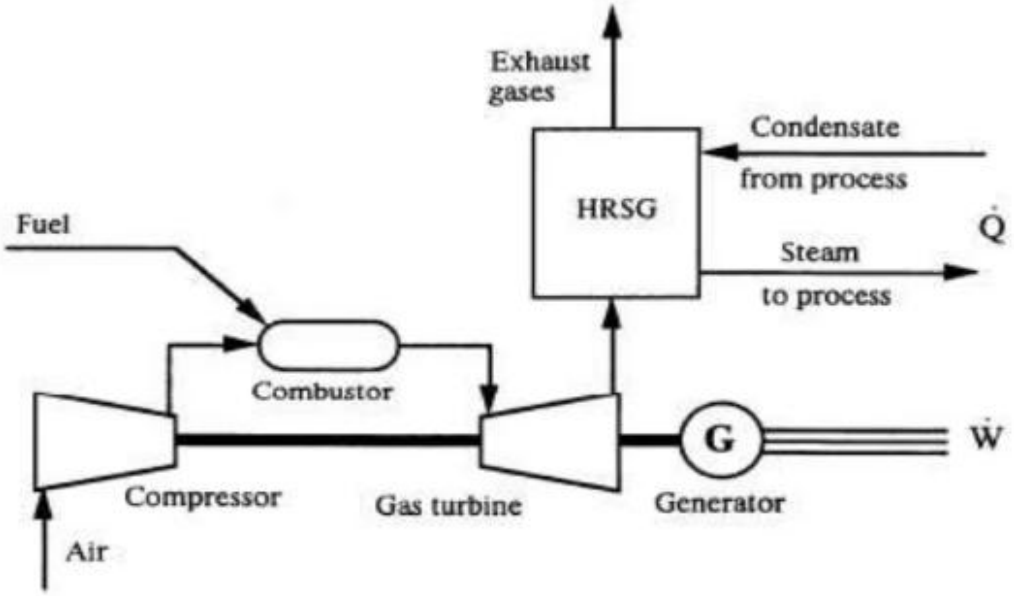
In extraction-condensing steam turbines, steam is extracted at one or more intermediate stages at the required pressure and temperature. The remaining steam from the turbine is transported to the condenser at very low pressure, as low as 0.05 bar (5 kPa), corresponding to a condensing temperature of approximately 33 °C.



Gas turbine cogeneration system ?

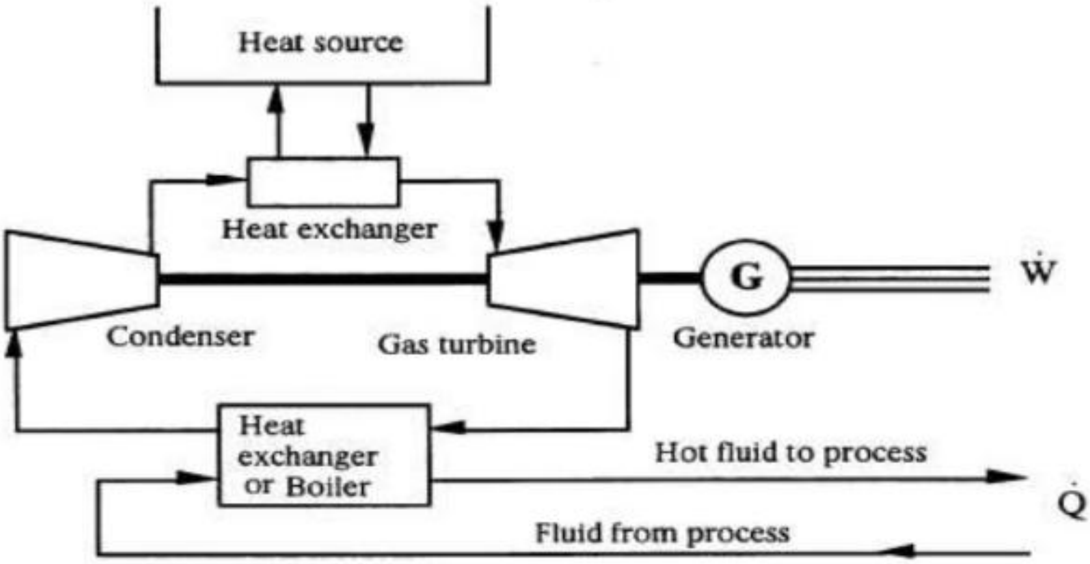
- Gas turbine cogeneration systems work on the principle of the Brayton cycle, in which atmospheric air is compressed, heated, and then expanded, producing more power.
- A variety of fuels can be used: natural gas, light petroleum distillates such as gas oil and diesel oil, products of coal gasification, etc.

Open cycle gas turbine



- Most of the currently available gas turbine systems work on the open Brayton cycle, in which the compressor takes in air from the atmosphere and sends the compressed air to the combustor. The air temperature also increases because of compression.
- The steam produced in the heat recovery boiler can be at high pressures and temperatures, which makes the steam suitable not only for thermal processes but also for running a steam turbine to produce additional power.
- The exhaust gases are finally released into the atmosphere, after extracting maximum heat in the various components of the cogeneration system.

Closed cycle gas turbine



- In the closed cycle system, the working fluid (usually helium or air) circulates within a closed circuit. The heat is supplied to the closed cycle through a heat exchanger, instead of direct combustion of the fuel in the working fluid circuit.
- On exiting from the turbine, the working fluid cools down, releasing its useful heat in the form of mechanical energy to produce electricity.
- The capacities of such systems range from 2 to 50 MWe.

Digester design

Biogas digester dimensions and materials of construction are important factors of consideration during the design and fabrication phase. The aim of this study is to provide a detailed analysis of the design and fabrication of a 2.15 m^3 pilot plastic biogas digester for biogas generation. To establish this, a design equation covering the volume of the digester, inlet and outlet chambers, and digester cover plate were developed considering the shape of the digester. The digestion chamber of the biogas digester under study was fabricated using high-density polyethylene (HDPE) plastic, while the inlet and outlet chambers were constructed with bricks/cement. The study was motivated due to some limitations such as leakage associated with previous designs. In the present study, a ventilation test was conducted after the fabrication to ensure the digester is leak free. Results obtained showed a total volumetric methane gas yield of 2.18 m^3 (54.50%) and carbon dioxide yield of 1.77 m^3 (44.25%) making up a total biogas yield of 4.00 m^3. In addition, the percentage concentration of methane and carbon dioxide were found to be 60% and 30%, respectively. The developed plastic biogas digester has been found to be appropriate for biogas production using cow dung as substrate.

The design installed biogas digester

For future energy security and improvement in the use natural resources, the depletion of conventional energy resources such as fossil fuel can be solved by the use of renewable energy sources. In the midst of numerous renewable energy sources and their production means is the sustainable generation of biogas through anaerobic digestion technology. Anaerobic digestion is a microbial process whereby organic carbons are converted by subsequent oxidation and reductions to its most oxidized state (CO_2) and reduced form (CH_4). It is a biological route that is catalyzed by the activities of microorganism in the absence of oxygen. Biogas is a gaseous fuel obtained from waste fermentation, which is of interest in producing energy for electricity, cooking, heating, and bio fuels for vehicles. The production of biogas from waste fermentation offer some additional benefits, namely, reduction in pathogens, foul odor, and methane emission from landfill sites where these wastes are ordinarily disposed. Anaerobic digestion of organic waste in digesters occurs in four stages, namely, hydrolysis, acidogenesis, acetogenesis, and methanogenesis in a system called biogas digester. These four stages results in production of biogas comprising of methane (55–70%) and carbon dioxide (30–45%) with traces of other gases such as hydrogen sulphide, hydrogen, and nitrogen. Interestingly, biogas is considered a low carbon fuel source, which is of interest to rural communities in meeting their energy need for cooking.

Biogas digesters are mostly designed and constructed using bricks, cement, metals, and reinforced concrete, while in some cases, the dome of the gas holder is made up of fiber glass. These biogas digesters encounter some challenges such as leakages at the edges of the brick structure after a short period of operation. There are some few biogas digester designs that utilize reinforced plastic; however, some of the reinforced plastic of the biogas digester deteriorates and creates holes due to the effect of ultraviolet (UV) radiations. Furthermore, the effect of corrosion that mostly occurs in biogas digesters built from metals results in their failure. In addition to the limitations aforementioned, the construction of the biogas digester using bricks or cement block is quite expensive due to high labor cost and materials. To overcome these weaknesses and challenges associated with the various materials mentioned, an alternative construction material was investigated in this study. Therefore, to minimize the high cost of construction of these previous designs, a more cost-effective design is proposed. Thus, the study employed a high-density polyethylene (HDPE) plastic to fabricate the digestion chamber and bricks/cement for the construction of inlet and outlet chambers. The choice of a plastic for the study is based on it being noncorrosive, a good insulator, cost-effective, and easy to maintain. The uniqueness of the present study stem from the use of composite materials (bricks/cement and plastic). Another factor that made the present study different from previous design is the subjection to the ventilation test to ensure leak free, which will result to more biogas yield and production. The introduction and use of this technology involving composite materials will help to generate biogas for research purposes and serve as a perfect fertilizer used in the university farm; all these motivated the need for this study. Therefore, the study fills this knowledge gaps existing in biogas digester designs, hence making it easier to consider a composite material for biogas digester design. The aim of the study was to design and fabricate a biogas digester using high-density polyethylene (HDPE) as an alternative material of construction/fabrication. The detailed knowledge of the design equations and the nature of material used in the construction of the biogas digester will be helpful to the energy engineer, researcher, and academic contributions to the development of biogas technology. Hence, the objective of the study is to formulate a design equation used for the construction of the biogas digester and to carry out a ventilation test to certify the digester a leak free one, which is not usually common in previous studies.

PHOTOSYNTHESIS

Photosynthesis is a process by which phototrophs convert light energy into chemical energy, which is later used to fuel cellular activities. The chemical energy is stored in the form of sugars, which are created from water and carbon dioxide.

Photosynthesis produces glucose, which is subsequently utilised to power numerous cellular functions. This physio-chemical process produces oxygen as a by product. Glucose molecules (or other sugars) are made from carbon dioxide and water in a light-driven process, with oxygen released. Glucose molecules give two essential resources to organisms: energy and fixed organic carbon.

$$6CO_2 + 6H_2O + \text{Sunlight} \longrightarrow C_6H_{12}O_6 + 6O_2$$

(Carbon Dioxide + Water + Sunlight ———> Glucose (simple sugar) + Oxygen)

Using light energy, six carbon dioxide molecules (CO_2) mix with 12 water molecules (H_2O). The final output is a single carbohydrate molecule ($C_6H_{12}O_6$, or glucose) and six oxygen and water molecules each.

The different anoxygenic photosynthesis processes can also be summarised into a single formula:

$$[CH_2O] + 2A + H_2O = CO_2 + 2H_2A + \text{Light Energy}$$

The symbol A stands for a variable in the equation, while H_2A stands for a potential electron donor. According to the medical and life sciences news site News Medical Life Sciences, “A” might stand for sulphur in the electron donor hydrogen sulphide (H_2S).

Factors affecting Photosynthesis

1. **Light Intensity:** As the intensity of light rises, the rate of the process of photosynthesis increases as well. Low light intensity leads to a decreased rate of photosynthesis. The CO_2 concentration is as follows: This rate is aided by a higher carbon dioxide concentration. Carbon dioxide in 300–400 PPM is usually sufficient for photosynthesis.

2. **Temperature:** A temperature range of 25° to 35° C is required for effective photosynthesis. When the temperature is low, the rate of photosynthesis is limited by the number of molecular collisions between enzymes and substrates and when the temperature is high, enzymes are denatured.
3. **Water**: Since water is such an indispensable component of photosynthesis, a lack of it might cause issues with carbon dioxide absorption. Due to a lack of water, stomatal openings do not keep the water stored inside.
4. **Pollution:** Pollutants from industry and other particles may settle on the surface of the leaves. This blocks the pores of stomata, making it difficult to take in carbon dioxide.

Types

1. **Oxygenic photosynthesis** is more prevalent than anoxygenic photosynthesis, occurring in algae, plants, and cyanobacteria. Light energy takes electrons from water (H2O) to CO2 to make carbohydrates during oxygenic photosynthesis. The CO2 is "reduced" or gains electrons, while the water is "oxidised" or loses electrons in this process. Carbohydrates and oxygen are both created. Oxygenic photosynthesis is similar to respiration but occurs oppositely. It absorbs CO2 generated by all breathing creatures and returns oxygen to the atmosphere.
2. **Anoxygenic Photosynthesis**: Anoxygenic photosynthesis does not create oxygen and uses electron donors other than water. Some examples that go through this process are phototrophic purple bacteria and green sulphur bacteria.

Importance of Photosynthesis

1. Photosynthesis's fundamental job is to transform solar energy into chemical energy and store it for future use. This mechanism is responsible for the majority of the planet's life systems. It's sobering to contemplate that our bodies' energy traverses 93 million miles in less than eight minutes.
2. It is also important to note that life has tapped into that energy stream. That energy is stored in biological systems for a brief period before continuing on its trip into the darkness of space.
3. Chloroplasts are the parts of a cell where photosynthesis takes place. Green plants absorb carbon, hydrogen, and oxygen from water and carbon dioxide molecules and recombine them into a new molecule called glucose. Of course, this occurs in the presence of sunshine. The bonds of the glucose molecule store energy. Glucose is a basic sugar that is easy to digest.
4. Trees and other green plants, like animals, undertake to breathe, but they also practise photosynthesis. This is why ecologists classify green plants as "producers", whereas most other living things are classified as "consumers."
5. Photosynthesis produces oxygen, while respiration produces carbon dioxide as a by-product. Trees are frequently attributed as the planet's primary source of oxygen, although this is incorrect. The major portion of the earth is covered with water, and humble algae's collective photosynthesis is the genuine oxygen machine. Trees and forests are substantial oxygen generators. We could easily survive without trees and forests if the only advantage they provided was oxygen. Fortunately, the advantages of trees and forests are substantially more extensive than that. Cellulose, a very complex sugar, makes up a large portion of the essential structural substance of plants and wood. Carbon, hydrogen, and oxygen molecules may be recombined to make a

variety of useful compounds, including ethanol, fragrances, bio plastics, textile fibres, and a variety of industrial components.