Chapter - 20
Bioenergy

Introduction

With the improvement in the living standard of man there is continuous increase in the demand of energy. These days per capita consumption of energy is considered as an indicator of development of a country. Gross national production is directly proportional to the consumption of energy.

According to an estimate, about 82% of the total energy consumption by the industrial processes in the world is provided by the non-renewable resources and the remaining 18% is obtained from the renewable sources. Out of the 82% non-renewable sources energy, its 76% energy is obtained from fossil fuels and only 6% is contributed by the nuclear energy sources. Similarly, out of the 18% energy provided by the renewable sources 11% energy is being provided by the biomass and 7% is being obtained from hydro electricity, geothermal, solar and wind energy.

Non-renewable sources of energy are those resources whose quantity is fixed and it is reduced with its consumption. Therefore it is sure that a day will come, which will be the last day of these resources. Regeneration and recycling of these resources is not possible. Coal from the underground mines, mineral or fossil fuels (petrol, diesel), natural gases, nuclear materials (uranium-235) etc, all these are non-renewable sources of energy. There are many sources of energy whose regeneration can be done. Such sources are termed as renewable resources of energy. Solar energy, hydro-electric power, wind energy, tidal energy and bio energy resources are mainly included in this category. In this chapter, we shall study various aspects of bioenergy.

Bioenergy

Energy produced by biomass or living sources is called bioenergy. In general, the meaning of biomass is "that weight or material which is produced by photosynthesis". Thus, the dry weight of plant is biomass. But we all know that all animals directly or indirectly survive by using plants and plant products as their food. Therefore, the total amount of organic material produced by all the living beings (living kingdom) can be termed as biomass. From the view point of energy production during mythological period, plants and their wood burning was the source of energy. With the scientific progress various forms of energy sources have developed. Today's urgent need is that maximum use of such an energy be adopted which can be produced in the form of renewable bioenergy because followings are the useful characters of this energy –

1. It is cheap, renewable and can be produced at local level.
2. It produces lesser amounts of CO_2 and SO_2 due to which there is less possibility of environmental pollution.
3. For its production, raw material is easily available. Waste and garbage is also useful for its production.

4. Because its recycling is possible, therefore its continuous availability can be maintained.

Main sources of bioenergy

Following are the important sources of bioenergy –

1. Biomass
2. Fire wood
3. Biogas or methane
4. Biodiesel
   (i) From vegetable fatty oils
   (ii) From petroplants
5. Ethanol from starch and lignocelluloses
6. Algal hydrogen factory

(I) Biomass – The main source of bioenergy is sun light. Of the total solar energy reaching the earth, approximately its 0.2% part is stored by the plants as biomass by photosynthesis. All those materials which are synthesized by photosynthesis are called biomass. These are renewable source of energy. All those living substances or their wastes which may be a source of energy, are grouped under biomass, such as –

(i) Plants with lignocelluloses, such *as Eucalyptus, Pinus, Leucaena,* maize, sugarcane, beetroot etc.

(ii) Aquatic plants like water hyacinth (*Eichornia*).

(iii) Waste materials such as manure, garbage, wood, crop residues like straw, peels of citrus fruits, molasses, biogases, coconut, litter of leaves and flowers, dung etc.

2. Wood – wood is the commonest source of fire, which is being used for centuries by man in the form of fuel. About more than 50% of the populations of India uses fire wood for small scale industries and domestic use. In the under developed and developing countries of Africa and Asian continents, wood is the main source of energy. Use of wood as fuel is one of the important factor responsible for forest destruction and environmental pollution in our country. Fire wood has the following characteristics –

(i) It is easily available and for collecting or obtaining it does not require any technical knowledge.

(ii) Its recycling or renewal is a regular process.

(iii) 99% of the pure wood is combustible.

(iv) Many plant species are used in the form of fire wood.

(v) It can be used in domestic to small scale industrial level.

Following are the characters of a good fire wood –

(i) It should have high combustive power

(ii) It should provide high calorific value upon combustion.

(iii) It should not break or form pieces upon combustion.

(iv) It should have less amount of moisture and resins so that it can be dried soon.

(v) It should yield less smoke and no bad odour upon combustion.

Following is a list of important plants which yield good fire wood –

	Local Name	Botanical Name
1.	Desi babul	*Acacia nilotica*
2.	Kumta	*Acacia senegal*
3.	Vilayati babul	*Prosopis juliflora*
4.	Khair	*Acacia catechu*
5.	Siris	*Albizia lebbek*
6.	Jamun	*Syzygium cuminii*
7.	Khejari	*Prosopis cineraria*
8.	Aadu	*Ailanthus excelea*
9.	Aam	*Mangifera indica*
10.	Salar	*Boswellia serrata*
11.	Dhokra	*Anogeissus pendula*
12.	Ronj	*Acacia leucophloea*

3. Biogas or methane – 70% population lives in villages in our country where livestock is abundantly available. Animal dung is commonly used in the form of dried cakes as fuel, while its proper use is in making compost manure and biogas formation. Animal dung should regularly be filled in pits of proper size for making good quality of

manure. The pit should be made at a higher elevation and its depth should not be more than a meter.

The gas produced by fermentation of organic substances by bacteria is called biogas. In India, for production of biogas, animal dung is most commonly used. For obtaining energy, biogas plants are in operation is many villages. This is not only a cheaper source of energy but it plays an important role in controlling pollution as well. In a biogas plant, anaerobic fermentation is completed in three steps:

(i) In the first step anaerobic facultative bacteria decompose the complex organic substances such as cellulose and hemicelluloses into simpler molecules.

(ii) During the second step partially aerobic and partially anaerobic bacteria first convert these simple molecules into organic acids and finally into acetic acid.

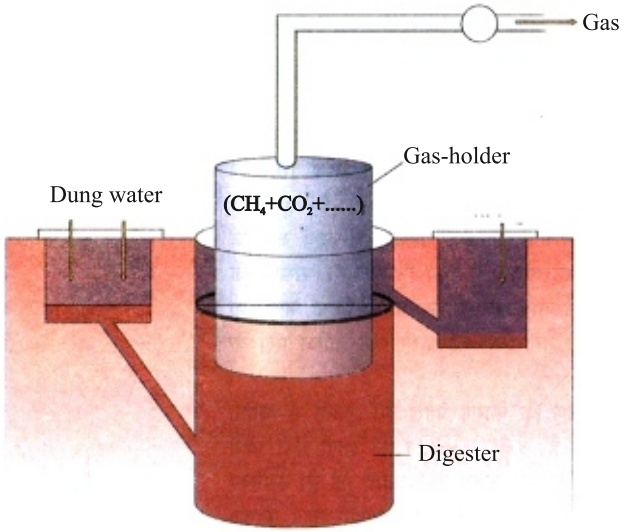

Fig. 20.1 : Gober gas plant

(iii) In the third step methano bacteria oxidize acetic acid into methane. Remaining material in the biogas plant – "Slurry" is dried and it can be used as manure.

The heating value of biogas is slightly less than that of the natural gas. The reason for this lesser energy yield of biogas is due to the presence of 31% carbon dioxide (CO_2) in it. If the amount of CO_2 is reduced in the biogas, its heating value can be increased. It is being experimented that by mixing various waste materials, gases with high heat value are produced by biological fermentation. Biogas Research Station was established in 1961 at Ajitmal is the Itawa district of Uttar Pradesh.

4. Biodiesel – Diesel like liquid material obtained from biological materials is called biodiesel. Biodiesel made up of vegetable oil, fat and latex is a non-polluting recycling fuel. Its chemical name is Fatty Acid Methyl Ester (=FAME).

Plants conserve the energy available from the Sun, in the form of fats, sugars, or starch. Plants accumulate a special store of hydrocarbons in the form of oil in their seeds which is used as a source of energy during germination. Hypothesis of biodiesel is based on this very oil. Discoverer of biodiesel – Rudolf diesel (1895) made an engine using these oils.

Bioresources –

Biotic sources of biodiesel can be divided into two parts –

(i) Vegetable fatty oils

(ii) Petro plants

(I) Vegetable fatty oils – Lipids or fatty oils an found in significant amounts in seeds of some plants such as soyabean, mustard, linseed, sunflower, ground nut, *Jatropha*, *Pongamia* etc. These lipids store huge amount of energy. The liquid obtained by esterification of fatty acids present in the lipids is known as biodiesel. This biodiesel in its pure form can directly by used in diesel engine without making any modification in it. But the price of edible oils in the developing countries remains higher than that of the diesel and production of edible oils is generally less in comparison to their demand. Therefore the possibility of the use biodiesel in the developing countries is meagre. But researches are under way by which non-edible oils obtained from other plants can be used for this purpose. Following plants deserve special mention from this point of view :

(i) Jatropha curcas – White castor or Ratanjot

(ii) Pongamia pinnata – Karanj

(iii) Madhuca indica – Mahua

(iv) Ricinus communis – castor

(v) Azadirchta indica – Neem

(ii) Petro Plants – Considering the possibility of exhaustion of conventional resources of energy in future, scientists have discovered a group of such plants, whose products can be used in place of petrol, diesel etc. Many plants of different families like Apocynaceae, Asclepiadaceae, Asteraceae, Euphorbiaceae, Sapotaceae, Urticaceae etc. produce petro-substances. Product of photosynthesis gets converted into latex in these plants. This latex contains abundant amount of hydrocarbons. Thus, this latex can be used in the vehicles in place of petrol or after mixing it with petrol.

Research work is being carried out continuously on hydrocarbon producing plants at Indian Institute of Petroleum, Dehradun. By the chemical analysis of the latex obtained from *Euphorbia lathyrus,* a gas similar to gasoline has been obtained. The latex obtained from Calotropis procera possesses a very high amount of hydrocarbons. This latex contains 78.03% carbon, 1.22% hydrogen and 10.71% oxygen. The ratio of carbon and hydrogen is similar to the of gasoline or fuel oil. Because these plant can be alternative resources of liquid fuel in near future these plants are called petro plants and their cultivation is known as petro crops.

Some latex producing petro plants –

1. Many speices of *Euphorbia* such as *Euphorbia lathyrus, E. antisyphilitica, E. caducifolia, E. tirucalli* etc. 2. Para-ruber- *Hevea brasiliensis 3.* Pagoda tree – *Plumeria* species 4. Aak, Madar – *Calotropis procera 5. Ficus* speices 6. Sapota – *Achras sapota*

Production of biodiesel in Rajasthan and India –

At present, India is producing only 30% petroleum of its total use. 70% petroleum of its total requirement is being imported. If 5% biodiesel in mixed with diesel, it can save several crores rupees each year.

Researches have revealed that the oil produced by "Ratan jot" (*Jatropha curcas*) can safely be used as biodiesel 'Policy Commission' has made a plan to grow trees of 'Ratan jot' and Karanj. (*Pongamia pinnata*) as source of biodiesel. These trees can easily be grown on waste land. The commission has identified 200 districts of 18 states where 'Ratan jot' will be cultivated. This includes Rajasthan as well. Government of Rajasthan has constituted 'Biofuel Mission' under the chairmanship of chief minister. This mission will establish trans-esterification plant along with establishment of units for oil extraction of the seeds.

Cultivation of Ratan jot will not be important for production of biodiesel only but the waste land of the country will be made useful. Cultivation on the waste land will be helpful to control soil erosion which will prove useful to save biodiversity and the ecosystem. Along with this it will provide an opportunity of employment and earning to the weaker sections of the society and the marginal farmers.

Importance of biodiesel :

Following is the importance of biodiesel –

(i) Biodiesel works as lubricant which enhances the efficiency of the engine and the cost of maintenance is lowered down.

(ii) By the use of biodiesel the quantity of carbon monoxide and suspended particles emitted by the automobile vehicles is comparatively low.

(iii) This is a very powerful alternative source of energy which may be helpful in self reliance, employment and income in the rural areas.

(iv) Biodiesel may play an important role in financial self sufficiency, national restructuring and indigenous development by way of making proper use of less fertile land, saline soils, unirrigated land, fallow land and road side land etc.

Biodiesel is the best alternate source of fuel which can be produced on less fertile and saline soil. While providing high quality fuel, biodiesel may be useful in the conservation and safety of environment, in increasing the efficiency of

vehicles, in helping rural employment and self reliance along with saving on expenditure on petro products.

5. Manufacture of ethanol from starch and lignocelluloses - Starch crops (cereals, millets and tubers) and sugar crops (sugarcane and beet root) are the important crops for production of biomass. By proper use of these renewable resources many products can be obtained. Starches and sugars obtained from these crops can be converted into ethanol.

Cellulose is an important constituent of plants. By the help of cellulase enzyme, cellulose can be broken down into glucose and from glucose, ethanol can easily be obtained. In woody plants, lignin is present with cellulose in the form of ligno cellulose. Ligno cellulose is broken down into sugars with the help of some enzymes. Later on ethanol is manufactured by fermentation by mixing yeast in the sugar. Some plants, like sugarcane, potato, maize, beet root etc. are used as raw materials for production of ethanol. Such plants from which ethanol is produced are called **energy plants**. Such techniques have been developed by which ethanol obtained from starch and sugars can be used as fuel in the automobile vehicles. Brazil is pioneer in this regard. Brazilean National Alcohol Programme was initiated in 1975 in Brazil. Today all cars are being run either on pure alcohol or 20% alcohol petrol mixture in Brazil.

Among cash crops, sugarcane is being produced in many states of India as main crop. Molasses is a by product of sugar industry. Ethanol with 65.5% purity is obtained from molasses. For mixing in petrol, ethanol with 66.8% purity is required. By making some modifications in the distillation plants refined ethanol having 66.8% purity can be achieved. Government of India has established three plants at Bareilly in Uttar Pradesh, Manmad and Miraj in Mahashtra on experimental basis to mix 5% ethanol in petrol.

6. Algae Hydrogen factory - Algae are the photosynthetic plants which grow in water. Like higher plants algae synthesize carbohydrates and oxygen by photosynthesis. In the year 2000, Anastasios Melis made it clear through experiment that during day time if supply of sulphur and oxygen is banned, the metabolic process of algae gets changed and algae start producing hydrogen in place of oxygen in the process of photosynthesis. We all know that hydrogen is a highly inflammable gas, thus it may be important in the form of energy production. If this experiment becomes successful, it will develop as a big source of energy.

Important Points

1. Gross national productivity is directly proportional to the consumption of energy.
2. Non-renewable resources of energy are available in limited amounts in the nature.
3. The entire cellular dry weight or organic material produced by an organism is called biomass.
4. Energy produced by biotic factors is called bioenergy.
5. Good quality fuel should give high calorific energy, high combustion power and should yield less smoke upon combustion.
6. Gas produced by anaerobic fermentation of organic materials by bacteria is called biogas.
7. Biogas is a mixture of gases-methane, carbon dioxide, nitrogen etc.
8. Many plants belonging to families like Apocynaceae, Asclepiadaceae, Euphorbiaceae, Sapotaceae, Urticaceae, Asteraceae produce petro materials.
9. Petro plant may become alternative resource of liquid fuels in near future. Therefore, the cultivation of these plants is called petro plants.
10. Cultivation of ethanol producing plants is called energy crops and these plants are known as energy plants.
11. Bio-diesel formed by vegetable oil and fats is a non-polluting recycling fuel.
12. Oil produced by the seeds of *Jatropha curcas* can be used as biodiesel.

Practice Questions

Multiple Choice Questions –

1. Example of fossil fuel is –
   (a) Alcohol (b) Biogas
   (c) Petrol (d) Hydrogen
2. Main gases found in biogas are –
   (a) CO_2 & H_2 (b) CH_2 & H_2
   (c) CH_2 & CO_2 (d) CO_2 & So_2
3. Energy obtained from biological sources factors is called –
   (a) Bioenergy (b) Nuclear fuel
   (c) Mechanical energy (d) Solar energy
4. Due to the presence of which gas, the efficiency of biogas is lower than that of natural gas?
   (a) H_2 (b) CH_2
   (c) CO_2 (d) SO_2
5. The chemical material, which is used in automobile vehicles, mixed with petrol is –
   (a) Ethanol (b) Methanol
   (c) Propanol (d) Butenol

Very short Answer Questions –

1. Fill in the blanks –
   (I) …….. resources are in limited amounts in nature.
   (ii) Energy produced by biological sources is called ……..
   (iii) All those materials which are produced by photosynthesis are known as ……..
   (iv) Gas produced by fermentation of organic materials by bacteria is called ……..
   (v) Percentage of carbon dioxide in biogas is ……..
2. Write names of two petro plants.
3. What is petro crop?
4. What is energy crop?

Short Answer Questions –

1. What is biodiesel?
2. Throw light on importance of biodiesel.
3. Write characteristics of wood suitable for fuel.
4. Why the efficiency of biogas is less than that of the natural gas?
5. Write benefits of the use of alcohol as fuel.
6. Write example of petro-plants.
7. What is biomass?

Essay Type Questions –

1. Describe briefly the energy resources used in place of fossil fuel.
2. Explain the process of biogas formation.
3. How alcohol is obtained from starch and sugars? Explain.
4. Write an essay on "Biodiesel may become an alternative source of liquid fuel in future".

Answer Key-

1. (c) 2. (c) 3. (a)
4. (c) 5. (a)

Very short Answer Questions –

1. (i) Non-renewable energy
   (ii) Bioenergy
   (iii) Biomass
   (iv) Biogas
   (v) 31%