



UNIT-I

BIOMASS – TYPES – FUELS FROM BIOMASS

Organic matter derived from biological organisms (plants, algae, animals etc.) are called *Biomass* (The energy obtained from biomass is called *Biomass Energy*. The raw organic matter obtained from nature for extracting secondary energy is called *Biomass Energy Resource*. Biomass energy resources are available from botanical plants, vegetation, algae, animals and organisms living on land or in water. Biomass resources are broadly classified into two categories; 1. Biomass from cultivated fields, crops, forests and harvested periodically. 2. Biomass derived from waste e.g., Municipal waste (Urban Rubbish), Animal excreta/dung, forest waste, agricultural waste, bioprocess waste, butcherry waste, fishery waste/processing waste etc.

Biomass is considered as a renewable source of energy because the organic matter is generated everyday/ year. Biomass energy is well known from Agricultural Age (5000 years B.C.). Wood, cow dung etc. are used as fuels particularly in rural and tribal areas in India. The use of biomass as a fuel is well-known and wide-spread. The use of waste-to-energy processes by incineration, Biogas, Bio-chemicals etc. is comparatively recent.

Biomass energy is produced by green plants by photosynthesis in presence of sun light. Biomass energy is a result of solar energy converted to biomass energy by green plants. Only green plants are capable of photosynthesis. Other living organisms consume green plants or their byproducts and generate biomass).

Fossil Fuels (Coal, Petroleum Oil and Natural Gases) are produced from dead, buried biomass under pressure and in absence of air during several millions of years. However, they are considered separately as fossils and are not included in the category of Biomass.

Biomass cycle maintains the environmental balance of oxygen, carbon dioxide, rain etc. Hence Biomass Energy Technology is an environment friendly Technology. Energy scenario is changing rapidly and dramatically in favour of biomass technologies. New biomass fuels are being introduced in the list of energy resources. Biomass is being used for production of process heat and electricity, producing gaseous and solid fuels, liquid Chemicals etc. The scope of Biomass Energy is considered in three categories.

- Rural applications of biomass energy.
- Urban and Industrial applications of biomass energy.
- Biomass as a primary source for large scale Electrical Power Generation.

Present contribution of biomass energy is between 4% and 18% of total primary energy consumption of various developed and developing countries respectively. The situation is likely to be changed dramatically and rapidly during coming years with increase in the biomass energy consumption to 25-40% by 2015 A.D.

India has vast land based, aquatic, forest, rural, agricultural biomass, resources of every type. The



SNS COLLEGE OF TECHNOLOGY
Coimbatore – 641035
19AGB204- BIOMASS CONVERSION-LECTURE NOTES



biomass energy conversion technologies and their socio-economic adaptation have vast scope in India.

Biomass energy processes serve many purposes.

- Energy supply: Fuels, Biogas, Organic Chemicals.
- Rural development
- Waste disposal
- Environmental balance.

The range of these technologies covers plants of a few watts to a few hundred MW. For example, a domestic *chulha* which burns wood or charcoal is rated less than 2 kW, a large urban waste incineration power plant is rated 150 MW. Biogas plants are available in sizes from 3 m³ / day to 2000 m³ / day of biomass feed.

Biomass energy resources are *renewables* with *periodicity* varying from daily, yearly, three yearly, six yearly, etc.

Type of Biomass	Periodicity of Renewal
Urban Waste	Daily
Rural Waste (Dung)	Daily
Agricultural waste and Crops*	Yearly, six monthly
Forest Crops*	Three to six years
Aquatic Crops*	Three months to one year

*These biomass sources can be cultivated

Green plants absorb photo-energy from sun-light, oxygen from air, water and minerals from soil/water and *produce* organic matter by 'photosynthesis.' The other living organism derive the, energy from the green plants (Food). Organic matter' from all the living / dead organisms is called *Biomass*.

Renewable Energy by Photosynthesis in Green Plants (Origin of Biomass)

Biomass is organic matter from plants, animals and micro-organisms grown on land and in water and their derivatives. Biomass includes forest crops, crops from agricultural fields, animal manure, urban and rural organic wastes, etc. *Energy farms* are specially cultivated forests/agricultural crops/aquatic farms. Biomass gets converted into *fossil fuels* after several million years under certain conditions of pressure, temperature air etc. Fossil fuels are not renewable and are not called biomass.

The origin of biomass energy resources is explained by the *Photosynthesis* by green plants under sunlight. Green plants consume atmospheric carbon dioxide gas, moisture, minerals 'and water from earth/water and photo energy from the sunlight and produce biomass energy. Photosynthesis means synthesis with light. Green plants absorb carbon dioxide gas from air and water from ground and deliver biomass energy plus oxygen.

The *biomass* is stored in the green plants in the form of complex organic compounds of carbon, hydrogen, nitrogen etc. Waste biomass residues from biogas plants are fed in to the algae pond. Sun light



SNS COLLEGE OF TECHNOLOGY
Coimbatore – 641035
19AGB204- BIOMASS CONVERSION-LECTURE NOTES



gives the photo-energy. Algae species having faster growth and higher energy content are cultivated. Algae are extracted as primary, renewable energy source and are processed to get *methane*. (Biogas)

Algae biomass is another important renewable source of energy produced by photosynthesis. After extracting the biogas, the organic *residue* from the biogas-plant is added to the *algae pond*. This acts as a food to the algae in the pond. *Special fast growing and energy packed algae species are developed by genetic research. The algae bacterial combination consumes the waste organic water in the pond and absorbs solar energy and results in rapid growth of algae (a type of biomass energy resource).*

The *algae farms* produce algae as a source of renewable energy. *Algae* contain organic matter which can be converted into methane gas (a useful fuel) in a simple biogas plant by the process called anaerobic digestion. *Alga crops* are likely to be cultivated on large scale to obtain renewable energy. *The algae energy technology* is in infant stages.

The *green plants* fix the organic matter by photosynthesis. Non green plants, micro-organisms and animals derive the organic matter from green plants in the form of food. The *biomass* is obtainable from:

- land based plants and animals
- aquatic plants and animals
- micro-organisms, algae etc.,

The *biomass* can be converted to useful secondary energy forms such as

- heat
- gaseous fuels
- solid fuels
- organic chemical
- liquid fuels

There are several alternative routes for producing useful secondary energies from biomass. Biomass Technologies deal with the entire processes of *producing biomass, processing the biomass* and delivering the *useful secondary energies*.

Photosynthesis is the *mother process* in the life cycle and is developed by green plants. The photosynthesis can be represented in simple equation given above. The other plants and animals derive the organic matters generated by the green plants. The photosynthesis is light actuated. In addition to C, H and O, the plants also incorporate nitrogen and sulphur in the organic material via the light dependant biochemical reactions. *Photosynthesis converts solar energy and chemical energy into biomass energy.*

The process of photosynthesis was probably developed about 2 billion years ago when blue - green algae acquired the ability to split water into hydrogen and oxygen. In the past photosynthesis has given fossils from Biomass coal, petroleum oils, natural gas, fuel wood, food, fibres, chemicals etc. These sources had fixed carbon in various proportions. *Fossil fuels* find their origin in *photosynthesis*. However, fossil fuels have taken



SNS COLLEGE OF TECHNOLOGY
Coimbatore – 641035
19AGB204- BIOMASS CONVERSION-LECTURE NOTES



several million years for formation and are getting rapidly consumed.

The natural process of photosynthesis is continuing and will continue to fix about 2×10^{11} tonne of carbon per year with energy content of 3×10^{21} J, This is about 10 times World's annual energy needs. The result is a renewable energy source of organic matter containing fixed carbon.

Biomass energy obtained from the plant photosynthesis is likely to solve the energy problem in the coming years in a significant way, Energy strategies of various countries are focusing their attention on biomass resources.

In developing countries fuel-wood constitute about 75% of energy needs of rural areas. It is covered in the category 'non-commercial energy resource'. Deforestation is a serious problem created by the use of wood as a fuel. However, by planned forestation of fast growing trees as a source of energy, wood is likely to be an important renewable source of energy.

Waste biomass serves double purpose

- disposal of waste in a safe, economical and environmentally healthy manner.
- generating useful energy locally from the waste.

Dry biomass can be burned to get thermal energy. In some processes, *Chemical energy* is derived from biomass in the form of methane (CH_4). Several hydrocarbons are used as liquid and gaseous fuels. These are excellent sources of energy.

A hydrocarbon may be represented by a general chemical formula of molecule C_nH_m , where m is a function of n and depends on the family of hydrocarbon. Hydrocarbon has chains of C and H in their molecules. The number of carbon atoms in a hydrocarbon molecule is identified by the prefix meth, eth etc. This prefix are as follows:

- | | | | | |
|---------|---------|---------|--------|----------|
| 1. meth | 2. eth | 3. prop | 4. but | 5. pent |
| 6. hex | 7. hept | 8. oct | 9. non | 10. dec, |

Straight chain molecules are often called normal and are preceded by the letter n . For example methane. *The most important fuels from biomass are methane and organic oils.*

The biogas derived by anaerobic digestion of biomass contains about 55% methane and about 45% CO_2 . Products depend upon process, temperature, time from start etc.

Biomass Energy Resources

The biomass used for producing secondary energy forms (useful energy forms) are called Biomass Energy Resources. There are several ways to classify the biomass resources. The most accepted classification is:

- Biomass from cultivated crops. (energy farms)
- Biomass from waste organic matter.



SNS COLLEGE OF TECHNOLOGY
Coimbatore – 641035
19AGB204- BIOMASS CONVERSION-LECTURE NOTES



Both these are *renewable sources of energy*. Table 1.1 gives a list of Biomass Energy Resources

Cultivated Biomass

The biomass can be grown specially in energy farms for obtaining renewable energy resource periodically. Fast growing trees, farm crops, aquatic farms (of algae and aquatic plants) etc. are in this category.

For energy farming, special species are cultivated (cultured) through genetic research. The special species of energy resources include fast growing trees (Supertrees), fast growing land based or aquatic crops and algae, etc. having high energy density (J / kg).

The cultivated biomass (Biomass from energy farms) includes :

1. Sugar cane crops, Sweet sorghum crops, Sugar beets
2. Herbaceous crops which are non-woody plants which can be converted into biogas or biochemical fuels.
3. Cereals, potatoes and other carbohydrate fruit crops, etc. grown for producing infeeds to the fermentation plants.
4. Forests crops (Silviculture) of fast growing energy intensive trees (Super trees), specially grown as source of energy.
5. Aquatic crops grown in fresh water, sea water, muddy water etc. These crops include submerged plants, surface plants, and include seaweeds, marine algae, *water hyacinth*, floating kelp etc. Algae is considered to be a promising aquatic biomass.

Several land areas and ocean/lake areas which are presently not used fully may be used as energy farms for growing the *energy crops*. Large *forests* are being cultivated as source of renewable energy. The trees of fast growing, energy intensive species are grown on regular basis. The processes of conversion from tree to usable energy are being optimised.

Large *aquatic farms* are being cultivated to grow fast growing, energy intensive, aquatic plants, weeds, algae. The processes for rapid growth of these energy crops and their conversion to use able energy are being optimised. Large energy intensive agricultural crops are being envisaged. The farms will have commercial food products as well as energy from waste.

Algae ponds are being developed as 'energy ponds'. Fast growing, energy intensive species of algae are being cultured. Algae will be grown on shelves arranged in the pond. Algae will be harvested periodically (3 months), The algae will be fermented by anaerobic digestion process to get *methane* gas.

Table 1.1 Principal Biomass Energy Resources

Category	Name of the Biomass source	Conversion process
Cultivated energy	1. Trees (Wood Chips, Saw dusts)	Burning to produce heat and electricity



SNS COLLEGE OF TECHNOLOGY
Coimbatore – 641035
19AGB204- BIOMASS CONVERSION-LECTURE NOTES



resource			
	2.	Aquatic crops, algae, green plants	Producing biogas and biochemicals.
	3.	Agricultural Crops	Production of wood-gas, wood gasification
	4.	Fruit farms	Production of wood oil and charcoal. Wood to oil process.
Waste – Biomass resources from farms and bio-industry	1.	Rice and wheat husk	Production of ethyl alcohol by fermentation of molasses, beet root, fruits, potatoes, cereals.
	2.	Bagasse of sugarcane	Production of producer gas
	3.	Coconut husk, groundnut shell, straw of rice, wheat etc.	Production of producer gas
	4.	Waste of furniture industry, wood industry	Production of producer gas
	5.	Waste of poultry industry, fishery industry, food industry, brewery tannery, butchery etc.	Production of biogas
	6.	Carbohydrates, glucose, fructose etc.	Production of ethyl alcohol

Waste to Biomass Resources: The waste-to- energy processes convert organic wastes to intermediate or secondary energy forms such as heat, biogas, alcohol, fuels, chemicals etc. The waste is **classified as**

- **Urban (Municipal) waste.**
- **Industrial organic waste, Process waste.**
- **Agricultural farm waste**
- **Rural animal waste**
- **Forest waste**
- **Fishery, Poultry, Butchery waste**
- **Animal and human excreta.**

Table 1.1 gives a list of biomass energy resources from wastes.

The major energy technology of waste-to-energy is cogeneration plant producing heat, steam, electrical energy from *incineration of biomass*. Such plants are located in large cities. Their capacity is in *MW range*. Another technology is of *landfill gas* produced from urban waste. The urban waste is dumped in landfill. Landfills are subjected to organic decomposition by bacterial decay. The gas contains about 50% methane by volume. The gas is extracted from landfill sites. The gas is then transported to the consumer site.

Agricultural waste may be converted into useful heat! Biogas / biochemicals by various processes such as combustion, biochemical and biothermal reactions. Biogas contains *methane*. Biogas plants produce *methane* by the process called *anaerobic digestion*. Several *biomass plants* have been installed in India for supplying energy to rural areas.

Biomass includes wood-waste, sugar cane bagasse, etc. When the biomass is converted to heat by



SNS COLLEGE OF TECHNOLOGY
Coimbatore – 641035
19AGB204- BIOMASS CONVERSION-LECTURE NOTES



combustion, much of its bulk containing moisture is wasted. It is not economical to transport the bulk biomass to remote site for converting into thermal energy. However, *the biomass can be converted into gaseous or liquid fuels called biogas and biochemicals respectively. The energy density (J / kg) of biogas and biochemicals is much higher than that of raw biomass.* The biogas and biochemical can be transported over long distances for further use as a secondary energy source. *Thus the energy routes of biomass energy are:*

Table 1.2 list of biomass energy resources from wastes

Raw biomass	-->	Biothermal conversion	-->	Biogas Biochemical fuels
Biomass	-->	Biochemicals	-->	Biochemical fuels (Biogas)
Biomass	-->	Combustion	-->	Heat for cogeneration (Heat, Steam, Electricity)

The biogas and biochemicals can be transported over long distances and then used as secondary source of energy. The biochemicals and biogas have higher energy density (J/kg) than that of raw biomass. Most of the biomasses are used as fuels either directly or after obtaining biogas / biochemicals. *Biomass is an important renewable source for obtaining organic fuels.* Recently, biomass has been recognized as an important renewable to produce electrical energy. The routes are:

Biomass	-->	Incineration	-->	Steam thermal electric power plant
Biomass	-->	Biogas	-->	IC engine – generator electric power plant