CH2356 Energy Engineering

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Energy from Biomass

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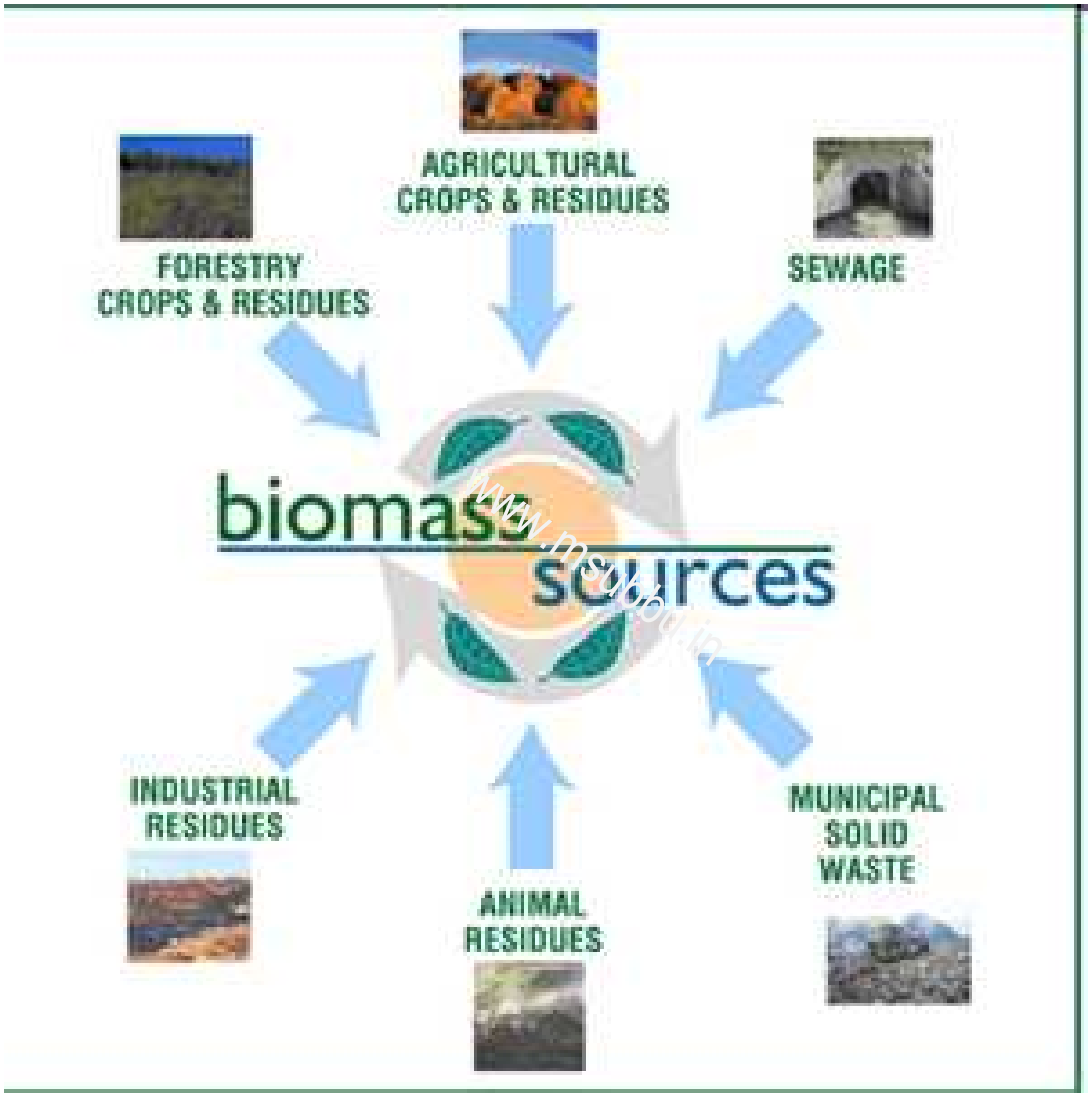
Introduction

- Plants derive their energy to grow from the Sun's radiation. The primary process is photosynthesis in which CO_2 and water are converted to carbohydrate and oxygen. Animals eat plants and other animals and the whole of animal and plant material is called biomass.

- In an energy context biomass refers to plant and animal-derived material such as straw, logs, dung, and crop residues that are used either directly or indirectly as fuels. These fuels are often called biofuels.

- The burning of biomass or of materials derived from biomass is an important source of energy in the world, providing in 2006 about 4% of the world's requirements.

- The main dangers of extensive biomass fuel use are deforestation, soil erosion and the displacement of food crops by fuel crops.



Prosopis Juliflora trees (வேலி கருவை) – growing in barren lands of Tamil Nadu, is being used as a source of biomass energy

Biomass from Prosopis Juliflora tree – formed as a heap, so as to get converted into charcoal.

Sweet sorghum (சோளம்)

Carbon Neutrality

- The attraction of biomass as a source of energy is that it is carbon-neutral, as the amount of CO_2 released in its combustion has been previously removed from the atmosphere when CO_2 was converted by photosynthesis into making the plant material.

- We therefore have a sustainable source with zero net production of CO_2, provided we renew the biomass consumed.

Energy Content of Biomass Materials

- The heat energy available in combustion, equivalent in practice to the enthalpy or the net energy density, ranges from about 8 MJ/kg (un-dried 'green' wood) and 15 MJ/kg (dry wood), to about 40 MJ/kg (fats and oils) and 56 MJ/kg (methane).

- Biomass yield ≈10 t / ha / year ≈ 5 kW/ha = 0.5 W/m^2

- Solar energy to biomass energy conversion efficiency is about 0.5%.

Biomass Potential and Use

- The global biomass potential is ~50 TW (from only land area; ~ 142 TW by including the area of ocean). Of this we use ~1.6 TW as source of energy, and ~0.5 TW for food. Biomass therefore supplies ~12% of the global energy usage.

- The current use of biomass for energy is mainly (~70%) for residential cooking and heating in developing countries. In the developing countries biomass provides ~1/3 of the energy consumption with, for example ~20% in China and ~40% in India.

- When used for cooking most of the biomass energy is wasted, as open fires are very inefficient with only ~5% of the available heat being used.

Biomass Potential of World

- From the land area on the surface of the earth of **13 Gha**, about 5.0 Gha (38%) is presently used for agriculture, 3.9Gha (30%) is under forest cover, and 4.1Gha (32%) includes a range of semi-natural vegetation types such as savannas, tundra's and scrubland, build-up land and barren land.

Biomass Potential of India

Biomass from crop residue:

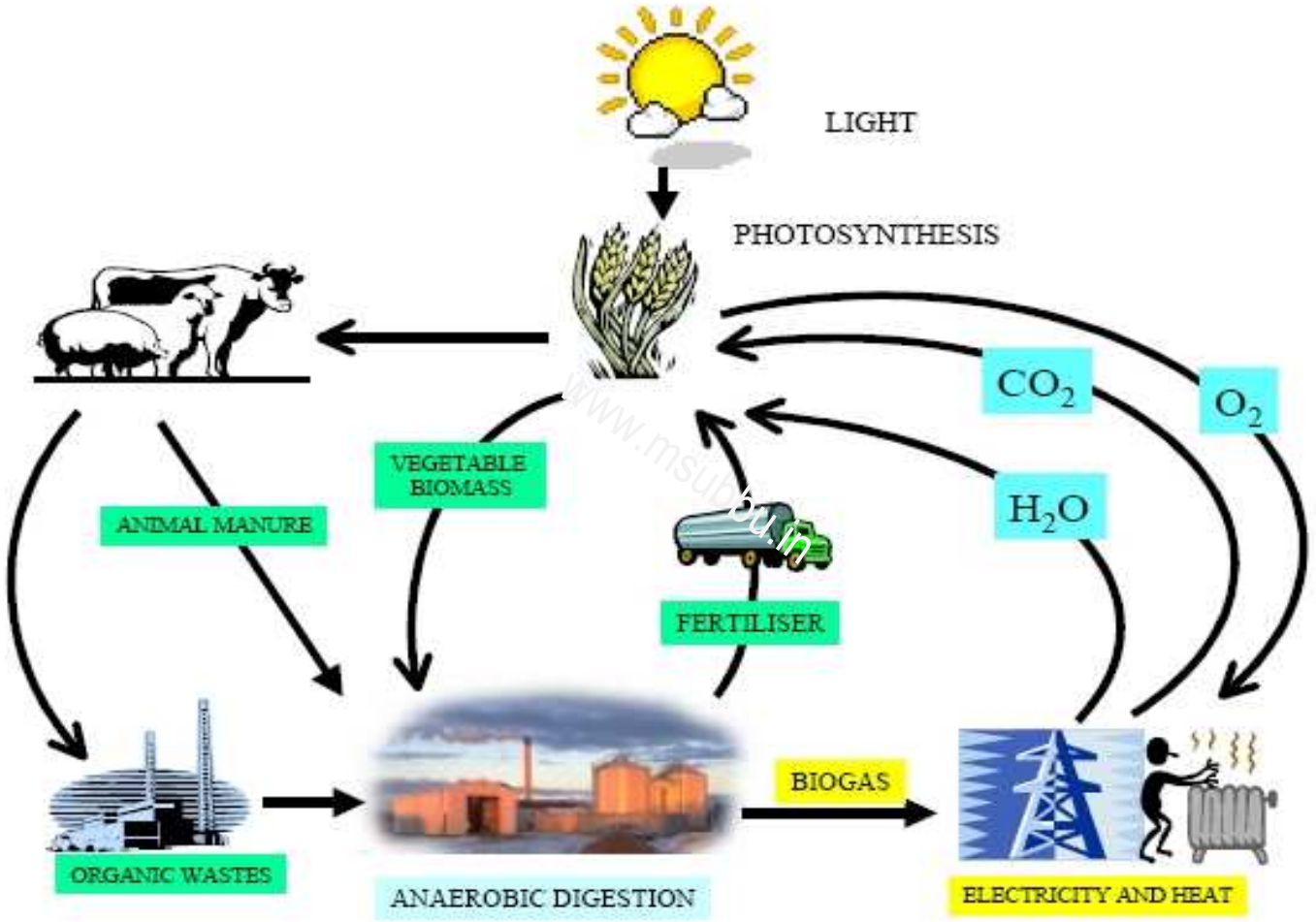
- Biomass which is available for power production, is about 125 million tonnes per annum [B. Buragohain et al. / Renewable and Sustainable Energy Reviews 14 (2010) 73–92]

- Taking the average calorific value of 16 MJ/kg, and thermal to electrical energy conversion of 27%, the power potential of biomass in India is about: 18 GW. However, the installed capacity is only about 1.8 GW. Hence a lot of potential is to be tapped.

Power generation by biomass power installations in various states of India.

S.N.	Programme/process	Total cumulative power generation as on 31.03.2009
1.	Biomass (agro-residue and plantation)	703.3 MW
2.	Cogeneration (bagasse)	1048.73 MW
3.	Cogeneration (non-bagasse)	170.78 MW
4.	Biomass gasifier	242.9 MWeq.
5.	Energy recovery from waste	34.06 MWeq.

Source: MNES Annual Report 2008–09.


LIGHT
PHOTOSYNTHESIS
CO_2
O_2
H_2O
VEGETABLE BIOMASS
ANIMAL MANURE
FERTILISER
BIOGAS
ORGANIC WASTES
ANAEROBIC DIGESTION
ELECTRICITY AND HEAT

Biomass Energy Processes

- Thermochemical
- Biochemical
- Agrochemical

Thermochemical Processes

- **Direct combustion**
  - For immediate heat
  - Dry homogeneous input is preferred

- **Pyrolysis**
  - Biomass is heated either in the absence of air or by the partial combustion of some of the biomass in a restricted air or oxygen supply.
  - The products are extremely varied, consisting of gases, vapors, liquids and oils, and solid char and ash. The output depends on temperature, type of input material and treatment process.
  - In some processes the presence of water is necessary and therefore the material need not be dry.
  - If output of combustible gas is the main product, the process is called **gasification**.

Biochemical Processes

- **Aerobic digestion**
  - In the presence of air, microbial aerobic metabolism generates heat with emission of CO_2
  - Not used significantly for commercial bioenergy

- **Anaerobic digestion**
  - In the absence of free oxygen, certain microorganisms can obtain their own energy supply by reacting with carbon compounds to produce both CO_2 and methane.
  - The process may also be called 'fermentation', but is usually called 'digestion' because of similar processes that occurs in digestive tracts of ruminant animals.
  - The evolved mix of CO_2, CH_4 and trace gases is called **biogas** as a general term, but may be named *sewage gas* of *landfill gas* as appropriate.

Biochemical Processes (contd.)

- **Alcoholic fermentation**
  - Ethanol is a volatile liquid fuel that may be used in place of refined petroleum. It is manufactured by the action of micro-organisms and is therefore a fermentation process.
  - Conventional fermentation has sugars as feedstock.

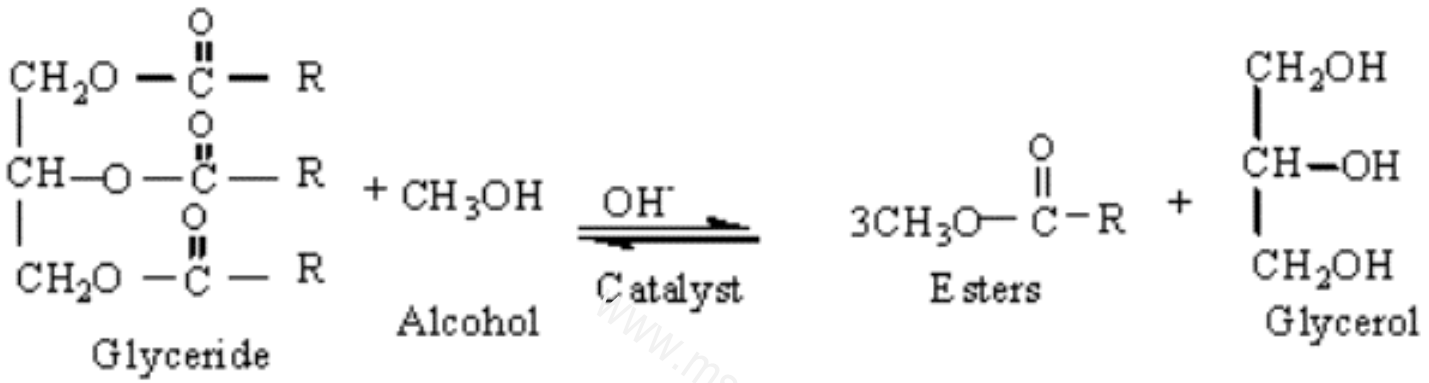
- **Biophotolysis**
  - Photolysis is the splitting of water into hydrogen and oxygen by the action of light. Certain biological organisms produce, or can be made to produce, hydrogen in biophotoloysis.
  - Commercial exploitation of these process has not yet occurred.

Agrochemical Processes

- **Fuel Extraction**
  - Occasionally, liquid or solid fuels may be obtained directly from living or freshly cut plants. (e.g. natural rubber latex)

- **Biodiesel**
  - Concentrated vegetable oils may be used directly as fuel, or by converting the vegetable oil to the corresponding ester.

Biodiesel



Vegetable oil

(triglycerides)

Biodiesel

(mono-esters)

The transesterification reaction: R is a mixture of various fatty acid chains. The alcohol used for producing biodiesel is usually methanol.

Transesterification is the process of exchanging the organic group R″ of an ester with the organic group R′ of an alcohol. These reactions are often catalyzed by the addition of an acid or base catalyst.

About Biodiesel

- Biodiesel can be produced from a great variety of feedstocks. These feedstocks include most common vegetable oils (e.g., soybean, cottonseed, palm, peanut, rapeseed/canola, sunflower, safflower, coconut) and animal fats (usually tallow) as well as waste oils (e.g., used frying oils).

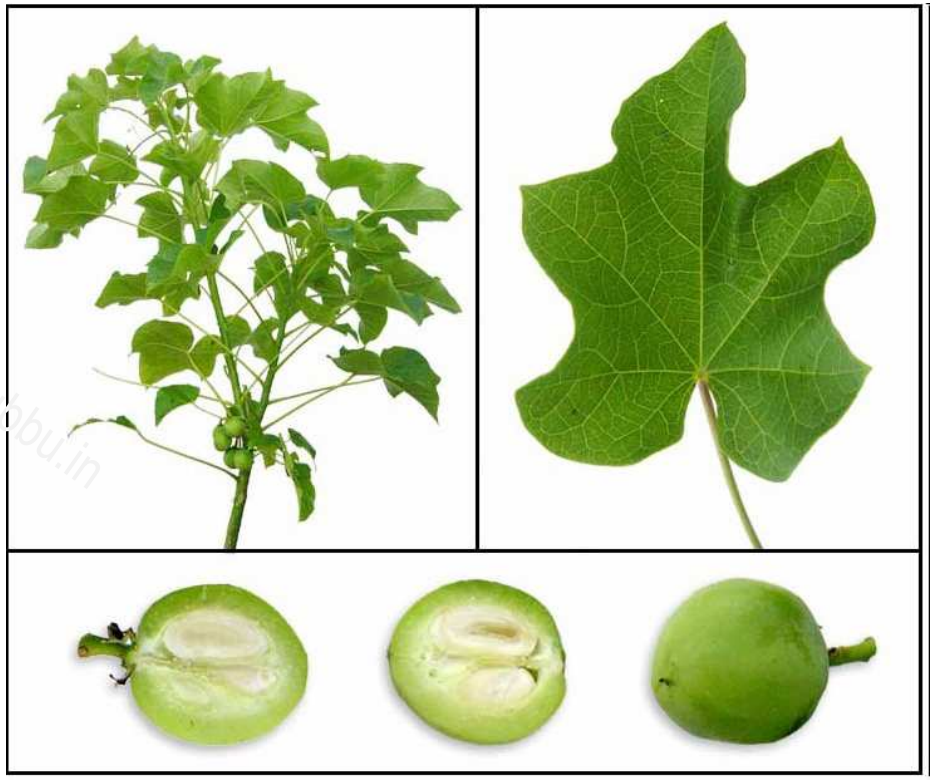
- Biodiesel is miscible with petrodiesel in all ratios. In many countries, this has led to the use of blends of biodiesel with petrodiesel instead of neat biodiesel.

- Often blends with petrodiesel are denoted by acronyms such as B20, which indicates a blend of 20% biodiesel with petrodiesel.

- The raw materials used at present in India are, Jatropha curcas (jatropha; காட்டாமணக்கு) and Pongamia pinnata (karanja; புங்க மரம்). Oils from both the plants contain toxins and hence are non-edible.

Pongamia pinnata (karanja; புங்க மரம்).

Jatropha curcas (jatropha; காட்டாமணக்கு)



History of Biodiesel Development

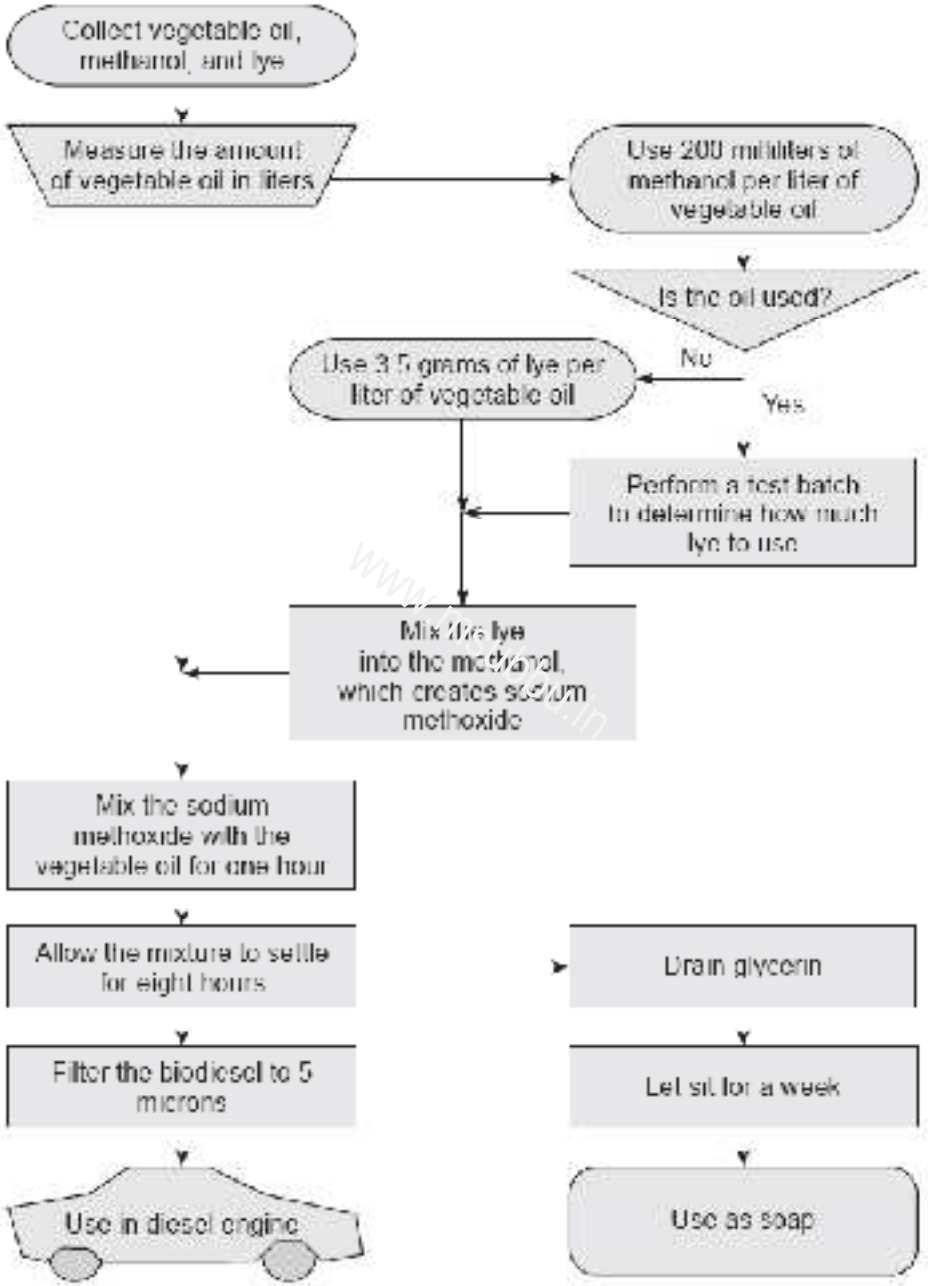
- Prior to biodiesel, biofuel was developed by Rudolph Diesel, the inventor of compression ignition (CI) engine in 1900. Peanut oil was used as a fuel to run the diesel engine. At that time, crude oil was available in plenty and was just refined to run the diesel engines. Hence, vegetable oils got neglected as a source of fuel. But, in recent times, due to realization that crude oil is limited and poses threat to well being of mankind from emissions of exhaust gases, vegetable oil has been revisited for its scope as a fuel in CI engines.

- However, due to high viscosity and low volatility, its longterm use posed different problems such as deposition, ring sticking and injector choking in engine. Hence, improvement in the vegetable oil was foreseen to improve the quality of the fuel. To lower the viscosity of vegetable oil, chemical and thermal processes were tried to make vegetable oil compatible with CI engines:

  - The well-known thermal process, pyrolysis, resulted in production of low value materials and sometimes resulted in more production of gasoline instead of diesel.

  - The most suitable process for reducing the viscosity found was the chemical process, transesterification, where triglycerides from vegetable oils react with a lower alcohol to produce fatty acid alkyl esters possessing properties similar to mineral diesel

Making Biodiesel Flow Chart



Electricity from sugarcane bagasse in Brazil

- The production process of sugar and ethanol in takes full advantage of the energy stored in sugarcane.
- Part of the baggasse is currently burned at the mill to provide heat for distillation and electricity to run the machinery.
- Brazil, being the largest sugarcane producer in the world, produces ethanol which is used to run 40% of its fuel powered cars

Sugar/Ethanol Plant located in Piracicaba, São Paulo State. This plant produces the electricity it needs from bagasse residuals from sugarcane left over by the milling process, and it sells the surplus electricity to the public grid.