Bioenergy technologies

The material of plants and animals, including their wastes and residues,is called biomass. It is organic, carbon-based material that reacts with oxygen in combustion and natural metabolic processes to release heat.

Such heat, especially if at temperatures >400°C, may be used to generate work and electricity. The initial material may be transformed by chemical and biological processes to produce *biofuels*, i.e. biomass processed into a more convenient form, particularly liquid fuels for transport. Examples of biofuels include methane gas, liquid ethanol, methyl esters, oils and solid charcoal. The term *bioenergy* is sometimes used to cover biomass and biofuels together.

The initial energy of the biomass oxygen system is captured from solar radiation in photosynthesis. When released in combustion, the biofuel energy is dissipated, but the elements of the material should be available for recycling in natural ecological or agricultural processes, Thus the use of industrial biofuels, when linked carefully to natural ecological cycles, may be non-polluting and sustainable. Such systems are called *agro-industries* of which the most established are the sugar cane and forest products industries; however, there are increasing examples of commercial products for energy and materials made from crops as a means of both diversifying and integrating agriculture.

The dry matter mass of biological material cycling in the biosphere
The success of biomass systems is regulated by principles that are often not appreciated

1- Every biomass activity produces a wide range of products and services. For instance, where sugar is made from cane, many commercial products may be obtained from the otherwise waste molasses and fiber. If the fiber is burnt, then any excess process heat may be used to generate electricity. Washings and ash can be returned to the soil as fertilizer.
2- The full economic benefit of agro-industries is likely to be widespread and yet difficult to assess. One of many possible benefits is an increase in local 'cash flow' by trade and employment.
3- Biofuel production is likely to be most economic if the production process utilizes materials already concentrated, probably as a by-product, and so available at low cost or as extra income for the treatment and removal of waste. Thus there has to be a supply of biomass already passing near the proposed place of production, just as Hydro-power depends on a natural flow of water already concentrated by a catchment. Examples are the wastes from animal enclosures, offcuts and trimmings from sawmills, municipal sewage, husks and shells from coconuts, and straw from cereal grains. It is extremely important to identify and quantify these flows of biomass in a national or local economy before specifying likely biomass developments.

Unless concentrated biomass already exists from previously established systems, then the cost of biomass growth and/or collection is often too great and too complex for economic benefit. Short-rotation crops may be grown primarily for energy production as part of intensive agriculture

4-Negative and unjustifiable impacts of extensive biomass fuel production on a large scale include deforestation, soil erosion and the displacement of vital food crops by fuel crops.

5- Poorly controlled biomass processing or combustion can certainly produce unwanted pollution, especially from relatively low-temperature combustion, wet fuels and lack of oxygen supply to the combustion

6- Using sustainable bioenergy and other renewables in place of fossil fuels abates the emission of fossil-carbon dioxide and so reduces the forcing of climate change. Recognizing this is a key aspect of climate change policies

Biomass is largely composed of organic material and water. However, significant quantities of soil, shell or other extraneous material may be mixed with harvested biomass, which is assessed according to either its wet- or its dry-matter mass, together with its moisture content. If m is the total mass of the initial material and m0 is the mass when completely dried, the moisture content is:

$w = (m - m_0)/m_0$… [dry basis]

$w' = (m - m_0)/m$… [wet basis]

The moisture is in the form of both extracellular and intracellular water, which has to be mostly removed from the initial crop for preservation by drying . When harvested, the wet basis moisture content of plants is commonly 50%, and may be as large as 90% in aquatic algae, including seaweed (kelps). The material is considered ‘dry’ when it reaches long-term equilibrium with the environment, usually at about 10 to 15% water content by mass. Carbon-based fuels may be classified by their reduction level . When biomass is converted to CO_2 and H_2O, the energy made available is about 460 kJ per mole of carbon (38 MJ per kg of carbon; ~16 MJ per kg of dry biomass), per unit of reduction level R. This is not an exact quantity owing to other energy changes. Thus sugars (R = 1) have a heat of combustion of about 450 kJ per 12 g of carbon content. Fully reduced material (e.g. methane CH4 (R = 2)) has a heat of combustion of about 890 kJ per 12 g of carbon (i.e. per 16 g of methane).

If combusted, moisture in wet and damp biomass solid fuel causes significant reduction in useful thermal output, because (i) evaporation of water requires 2.3 MJ per kg which is generally not recovered;(ii) the temperature of the combustion is reduced; and (iii) polluting smoke emission is likely. In contrast, dry fuel is a delight. This affects how the heat value of the fuel is measured. With *condensing boilers*, much of such latent heat can be recovered by condensing the water€ vapor in the emission so that the incoming cold water is preheated. The density of biomass, and the bulk density of stacked fibrous biomass, are important, especially for transportation and storage. In general, three to four times the *volume* (not mass) of dry biological material has to be accumulated to provide the same energy as coal. Thus suitable transport and fuel handling is required if the biomass is not utilized at source.

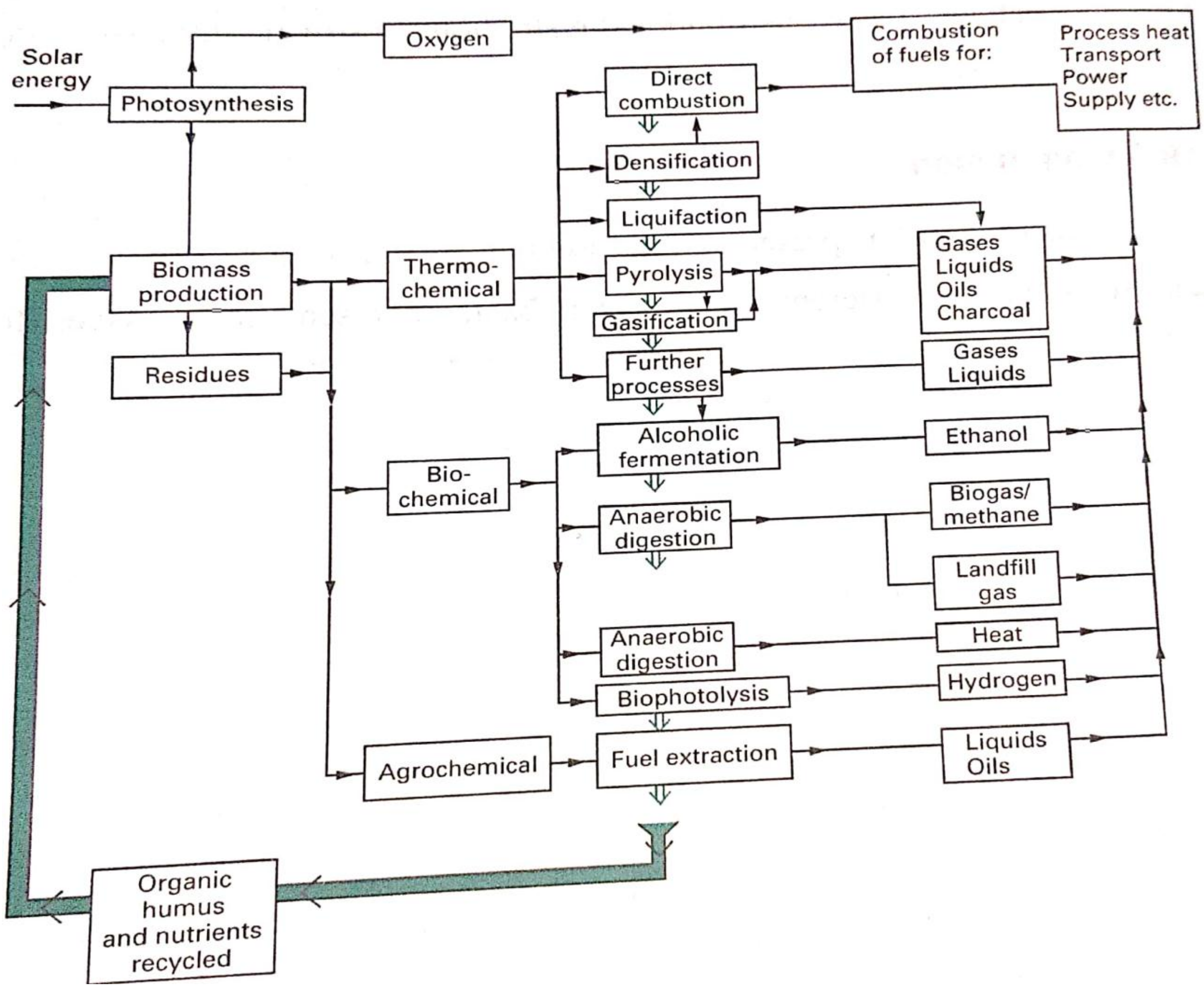

Fig 1 Biofuel production processes.

BIOFUEL CLASSIFICATION

is an energy and materials flowchart that explains the complex details of biofuel processes. It starts top left with solar energy and the photosynthesis of biomass crops and residues, which we follow across the page to the three main classes of biofuel energy processes: thermochemical, biochemical and agrochemical. Each of these classes has named subsidiary processes and biofuel products that eventually react with oxygen to release heat in combustion. Note that as we move from left to right across the diagram, the initial mixed content solid biomass is processed into specific solid, liquid and gaseous fuels.

Thermochemical heat

There are many classifications, as also detailed in later sections.

(a) Direct combustion for immediate heat . This is the major use of firewood and logs in both the developing and developed world. Dry homogeneous input is much preferred. Best results have the (dry) wood burning in a stove, oven or boiler, with control of the incoming air so that there is full, but not excessive, combustion

(b) 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.

(c) Other thermochemical processes . A wide range of pre-treatment and process operations are possible. These normally involve sophisticated chemical control and industrial scale of manufacture; methanol production is such a process (e.g. for liquid fuel).Of particular importance are processes that break down cellulose and starches into sugars, for subsequent fermentation.

Biochemical

(a) Aerobic digestion. In the presence of air, the microbial aerobic metabolism of biomass generates heat with the emission of CO_2, but not methane. This process is of great significance for the biological carbon cycle (e.g. decay of forest litter), and for sewage processing, but is not used significantly for commercial bioenergy.

(b) Anaerobic digestion In the absence of free oxygen, certain micro-organisms can obtain their own energy supply by reacting with carbon compounds of medium reduction level to produce both CO2 and fully reduced carbon as methane, CH4. The process (the oldest biological 'decay' mechanism) may also be called 'fermentation', but is usually called 'digestion' because of the similar process that occurs in the digestive tracts of ruminant animals. The evolved mix of CO2, CH4 and trace gases is called biogas as a generalÂ€ term, but may be called sewage-gas or landfill-gas as appropriate.

(c) Alcoholic fermentation. Ethanol is a volatile liquid fuel that may
be used in place of refined petrol (gasoline). It is manufactured by the action of micro-organisms and is therefore a fermentation process. Conventional ('first generation') ethanol has sugars as feedstock, which may have been produced from starch (e.g. maize, wheat, barley) by other micro-organisms in a preliminary process of malting.

(d) Biophotolysis. Photolysis is the splitting of water into hydrogen and
oxygen by the action of light. Recombination occurs when hydrogen
is burnt or exploded as a fuel in air. Certain biological organisms produce, or can be made to produce, hydrogen in biophotolysis. Similar results can be obtained chemically, without living organisms, under laboratory conditions.