Bio Energy - Introduction

**Biomass** means living organisms and those that recently died. It does not include those organisms that are already converted to fossil fuel. In energy generation, it refers to waste plants that are utilized to generate energy by combustion.

The methods of conversion to bio-fuel are numerous and largely classified as **chemical, thermal** and **biochemical**. This is the oldest as well as the most widely spread source of renewable energy. It has a variety of conversion methods.

**Direct combustion** was traditionally practiced using wood fuel. Advanced processes such as **pyrolysis** (the process of making charcoal), fermentation and anaerobic digestion convert these sources to a denser and easy to transport forms such as oil and ethanol. Coal is a product of pyrolysis process, which strengthens the matter by burning it in the absence of Oxygen.

**Bio-fuel** is a term that refers to fuel derived from biomass. As mentioned before, biomass is any organic matter both living and dead and ranges from plants to organic wastes. In most cases, biomass rich in oil or sugar is ideal for energy production.

The term **bio-energy** refers to energy obtained from organisms either living or dead. This does not include fossil fuels. We could classify bio-fuel by their sources or according to generation.

Classification of Bio-Fuel by Source

* **Wood fuel** − Derived from trees, bushes, or shrubs. Examples of wood fuel include charcoal and wood.
* **Agro-fuels** − Obtained from farm product biomass such as dead crops or from other plant parts such as cereal. Agro-fuel is majorly derived from sugar and oil crops.
* **Municipal by-products** − Derived from waste collected from major towns. There are two categories of municipal waste. Solid waste bio-fuel is derived from direct combustion of solid waste from industries or commercial institutions. Liquid/gas waste bio-fuel is obtained from fermentation of the wastes collected.

Classification of Bio-Fuel by Generation

* **First generation** − Processed from sugar vegetable oil and animal fats pressed into oil for combustion in engines or fermented and processed into ethanol for the same purpose. The final products are oils, bio-diesel, alcohol, syngas, solid bio-fuel and biogas.
* **Second generation** − Derived from cellulose and waste (non-food). This waste is derived from stalks of crops and wood, bio-hydrogen, bio-alcohol, dimethyl formamide DMF, wood diesel, mixed alcohol, and bio-dimethyl ether DME.
* **Third generation** − Found in algae, believed to produce high yield of energy at low cost. The energy from algae is known as oil-gae.

**Bio Energy - Biomass Production**

The organic material is converted into usable form known as bio-energy. The materials used in the process of energy production are termed as feedstock.

To better understand biomass, we will explore the various sources first.

Biomass production refers to the increase in the amount of organic matter. It is the addition of organic matter in a given area or population. Biomass is considered renewable energy because it is replenished as plants and animals grow.

There are two forms of production −

* **Primary production** refers to the generation of energy by plants through photosynthesis. The excess energy generated is stored and adds up to the total biomass in the ecosystem. Primary production could be estimated from the total forest cover in a given year.
* **Secondary production** is the absorption of organic matter as body tissues by organisms. It includes ingestion by animals i.e. feeding, whether on other animals or on plants. It also involves decomposition of organic matter by microorganisms. Secondary production could be estimated as the total meat produced per year.

Though biomass could be measured as mass of organisms living and dead in a given environment, production is harder to estimate. It can only be estimated as the increase in volume though part of the additional biomass may have been replaced through natural processes.

## Direct Combustion for Heat

Direct combustion for heat is the oldest method of biomass conversion to energy since the earliest civilizations. Thermochemical conversion (combustion) could be achieved in a number of ways using varied feedstock.

## Standalone Combustion

Biomass based generators use diesel derived from vegetable oils to fuel diesel generators. The generators burn the organic diesel to produce energy to produce electricity.

* Combined heat and power plants are known to cogenerate electricity and useful heat energy. Ceramic industries utilize the heat in drying products such as clay tiles.
* Some power plants use biomass to heat water and produce steam for electricity generation. The biomass is burnt to produce enough heat to boil water.
* Municipal solid waste plants burn solid wastes to generate electricity. This type is prone to criticism since solid wastes mostly contain toxic gases from plastics and synthetic fibers.

## Biomass Co-combustion

Apart from stand-alone combustion, biomass could be blended with other fossil fuels and burnt to generate energy. This is called co-firing.

* Biomass could be directly burnt as coal. This is referred to as direct co-combustion.
* In other cases, the biomass is first processed to gas and then converted to syngas.
* The third case is where fossil fuel is burnt in a different furnace and the energy produced is then used to preheat water in a steam power plant.

Types of Combustion

The various types of combustion are −

* **Fixed bed combustion** − This is a method where solid biomass is first cut into small pieces and then burnt on a flat fixed surface.
* **Moving bed combustion** − In this method, a grate is set to constantly and evenly move leaving ash behind. The fuel burns in combustion levels.
* **Fluid-bed combustion** − Fuel is boiled under high pressure mixed with sand. The sand serves to distribute the heat evenly.
* **Burner combustion** − In this method, wood dust and fine dust are placed in a burner similar to that of liquid fuel.
* **Rotary furnace combustion** − A kiln furnace is used to burn organic matter with high moisture content. Such waste as food residue or other moist farm waste is burnt this way.

Pyrolysis

**Pyrolysis** is another form of processing bio-fuels by burning under very high temperatures without oxygen, which could cause complete combustion. This causes irreversible physical and chemical changes. The absence of oxidation or halogenations processes results in a very dense bio-fuel that could be used in combustion, co-combustion or converted to gas.

* **Slow pyrolysis** occurs at about 400oC. It is the process of making solid charcoal.
* **Fast pyrolysis** occurs between 450oC to 600oC and results in organic gas, pyrolysis vapor, and charcoal. The vapor is processed by condensation to liquid form as biooil. This must be done within 1 second to prevent further reaction. The resultant liquid is dark brown liquid denser than wood biomass and has equal content in terms of energy.

Bio-oil has a number of advantages. It is easier to transport, burn, and store. Many kinds of feedstock can be processed through pyrolysis to produce bio-oil.

The diagram given below explains the process in converting energy in to a usable form from bio-fuels through Pyrolysis.

Alcoholic Fermentation

Alcoholic fermentation is the process that converts sugars into cellulose. The process results in ethanol and carbon dioxide as the by-products. This process is considered anaerobic since it takes place in the absence of oxygen. Apart from bread baking and manufacturing alcoholic beverages, this process produces alcoholic fuel. The chemical formula for alcoholic fermentation is given by −

$C\_{6}H\_{12}O\_{6}+yeast\longrightarrow\:2C\_{2}H\_{5}OH+2CO\_{2}$

Sugarcane is the main feedstock for this process especially in dry environments. Corn or sugar bits are used in temperate areas.

Application of Products

The products have the following applications −

* **Acetone** is a product used for production of food additives, dissolving glue, thinning of paint, grease removers and in cosmetic products.
* **Hydrogen** is used as a cooling agent in power industry. It is also used in hydrogen cells for energy production.
* **Butanol** provides better fuel than ethanol. It is also used as an ingredient in paint, cosmetic products, resins, dyes, polymer extractions and in the manufacture of synthetic fiber.
* **Ethanol** is used as fuel, paint component, and an additive in antiseptics. It is also used in alcoholic beverages.

Anaerobic Digestion of Biogas

**Anaerobic digestion** is the biological process by which organic matter is broken down to produce biogas in the absence of Oxygen. Microorganisms such as Acidogenetic bacteria and acetogens convert the biodegradable matter to biogas. Apart from being a source of energy, it is also a waste deposition method and environmental conservation technique.

The main equation for this conversion that yields carbon dioxide and methane is as follows −

C\_{6}H\_{12}O\_{6} 🡪 3CO\_{2}+3CH\_{4}

The step-by-step process is explained below −

* **Step 1** − Breakdown of organic matter to sizable molecules for conversion. This process is known as hydrolysis.
* **Step 2** − Acidogens act on the decomposed matter converting them into volatile fatty acids (VFAs) alongside ammonia, CO2 and hydrogen sulfide. The process is called acidogenesis.
* **Step 3** − The VFAs are further broken down into acetic acid, carbon dioxide and hydrogen.
* **Step 4** − The final stage is the combination of emissions above to produce methanol, carbon dioxide, and water.