4.3 BIOMASS ENERGY CONVERSION PROCESS:

- There are a number of ways of converting biomass into electricity but the most common is to burn the material in a furnace, raising steam that is used to drive a steam turbine, an approach analogous to the use of coal in a coal-fired power plant. The main alternative to this is biomass gasification in which the fuel is converted into a combustible gas that can be burned to provide heat. The development of coal gasification systems is expected to drive improvements in biomass gasification.
- Biomass plants tend to be small compared to conventional coal-fired plants and less efficient. However, efficiency can be improved if they can provide heat as well as electricity in a combined heat and power plant, and this configuration is common, particularly in industries that use their own biomass waste for power generation. A further method that allows for more efficient use of biomass is co- firing. This involves adding a proportion of biomass to the coal in a coal fired power plant. Large modern coal plants can operate at high efficiency and, when co-fired, biomass is converted into electricity with similar efficiency.
- For some animal wastes it is also possible to generate a combustible gas using anaerobic digestion. This is the same process that occurs in landfill sites and generates methane. Digesters can be designed to generate methane from both animal and human wastes. The gas is then normally used to fire a gas engine to provide electric power.

4.3.1 DIRECT FIRING

- The direct firing of biomass involves burning the fuel in an excess of air inside a furnace to generate heat. Aside from heat the primary products of the combustion reaction are carbon dioxide and a small quantity of ash.
- The heat is absorbed by a boiler placed above the main furnace chamber. Water flows through tubes within the boiler where it is heated and eventually boils, producing steam that is used to drive a steam turbine.
- Direct firing technology was developed in the 19th century for coal combustion but has been adapted to other fuels including biomass. While the heat from a biomass furnace is normally used to generate steam in this way, it may be exploited directly in some industrial processes too.

- The simplest type of direct-firing system has a fixed grate onto which the fuel ispiled and burned in air that enters the furnace chamber from beneath the grate (under fire air). Further air (over fire air) is then added above the grate to complete the combustion process

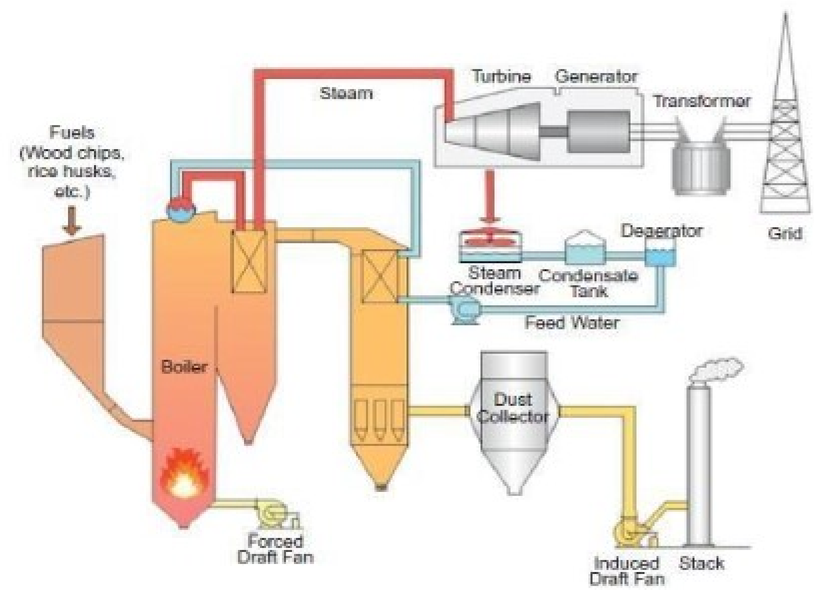
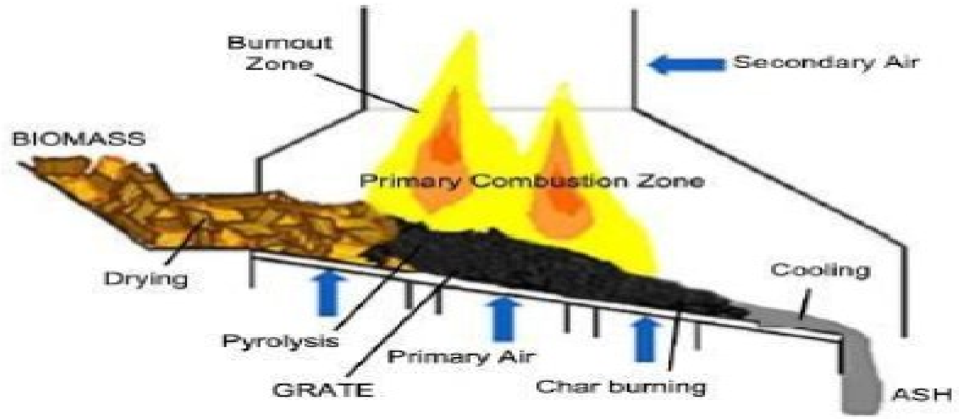


Figure 4.2

[Source: "Renewable Energy Sources and Emerging Technologies" by D.P.Kothari, K.C Singal, Rakesh Ranjan, Page: 283]

- . This type of direct-firing system, called a pile burner, can burn wet and dirty fuel but its overall efficiency is only around 20% at best. The fixed grate makes it impossible to remove ash except when the furnace is shut down, so the plant cannot be operated continuously either, a further disadvantage for this design.
- An improvement over the pile burner is the stoker combustor. This type of combustor allows fuel to be added continuously, either from above (overfeed) or from below (underfeed), and has a mechanism for continuously removing ash. The stoker grate was first developed for coal combustion in the 1920s and in the 1940s the Detroit Stoker Co. designed a stoker boiler for wood combustion.

- Fuel is distributed more evenly in a stoke grate than in a pile burner, allowing more efficient combustion. Air still enters the furnace from beneath the grate and this air flow cools the grate. The airflow determines that maximum temperature at which the grate and thus the furnace can operate and this in turn determines the maximum moisture content of the wood that can be burned, since the dampest wood will require the highest temperature if spontaneous combustion is to be maintained.
- For an underfeed stoker combustor, fuel is added from beneath and the grate behaves like a slowly erupting volcano. Ash, when it is formed, falls down the flanks of the fuel pile and is removed from the sides. In an overfeed stoker combustor, the grate itself normally moves via some form of chain mechanism allowing fuel to be added from one side and ash removed from the other.
- This type of design is called a mass-feed stoker. A second type, called a spreader stoker, disperses finely divided fuel pneumatically across the whole surface of the great with finer particles burning in the region above the grate. There are a number of other refinements to the stoker combustor such as an inclined and water-cooled grate. Even so, maximum overall efficiency is only 25%.
- Most modern coal-fired power plants burn finely ground coal that is fed into the power plant furnace through a burner and then ignites in midair inside the furnace chamber, a process called suspended combustion. It is possible to burn biomass in this way but particle size must be carefully controlled and moisture content of the fuel should be below 15%. Suspended combustion of biomass, while it can provide a higher efficiency, is not widely used in dedicated biomass power plants. However, it does form the basis for co-firing, which is discussed at greater length in the following section.



Cross-section of a moving grate for biomass combustion.

Figure: 4.3.1

[Source: "Renewable Energy Sources and Emerging Technologies" by D.P.Kothari, K.C Singal, Rakesh Ranjan, Page: 285]

- The main alternative to the stoker combustor for modern direct-fired biomass plants is the fluidized bed combustor. This type of combustor can cope with fuels of widely differing type and quality, making it much more versatile than a stoker combustor. The fluidized bed contains a layer of a finely sized refractory material, such as sand, that is agitated by passing air through it under pressure so that it becomes entrained and behaves much like a fluid. Fuel is mixed with this refractory material where it burns (when the bed is at its operating temperature) to release heat as in a conventional furnace. Depending on the pressure of the air that is blown through the fluidized bed it will be a bubbling bed, behaving much like a boiling fluid, or a circulating bed in which the particles are entrained with the air and those that escape the boiler are subsequently captured in a cyclone filter and recycled. Fuel content within the bed in usually maintained at around 5%.
- Fluidized beds can burn a wide range of biomass fuels with moisture content as high as 60%. For low-quality fuels the bubbling bed is preferred, whereas the circulating bed is better for high-quality fuels. Overall efficiency is again only 25% at best, similar to a stoker combustor.

- Where the fuel quality is low, gas or coal can be used to raise the bed temperature sufficiently at startup for combustion to commence. An additional advantage of the fluidized bed is that material can be added to the bed to capture pollutants like sulfur that would otherwise result in atmospheric emissions.
- Direct-fired biomass power plants typically have a generating capacity around 25– 50 MW. This small size, combined with the relatively low combustion temperature in the furnace (biomass is more reactive than coal and so tends to burn at a lower temperature), are the two main reasons for these plants‘ low efficiencies compared to coal plants where overall efficiencies above 40% are now common in new facilities.
- Improvements are possible. Increasing the size of the typical plant to 100–300 MW would allow larger, more efficient steam turbines to be used, and several 300 MW are being planned in Europe. New small steam turbines that incorporate advanced design features currently found only in large coal plant turbines will also improve efficiency. Adding the ability to dry the biomass fuel prior to combustion an result in a significant increase in performance. With these changes, direct- fired biomass plants should be able to achieve 34% efficiency.

4.3.2 CO-FIRING

- ✓ Much more efficient conversion of biomass into electricity can be achieved quite simply and on a relatively large scale in another way—by the use of co-firing. Co- firing involves burning a proportion of biomass in place of some of the coal in a coal-fired power plant. Since most coal stations operate at much higher efficiencies than traditional direct-fired biomass plants, co-firing can take advantage of this to achieve conversion efficiency of 40% or more in a modern high-performance coal-fired facility.
- ✓ There is another form of co-firing in which a predominantly biomass combustion plant uses a fossil fuel, normally natural gas, to both stabilize and supplement the biomass fuel. This technique will normally be used in a dedicated biomass plant to increase performance and flexibility.
- ✓ Co-firing of the first type is attractive to coal plant operators because it allows them to burn biomass and therefore reduce their net carbon dioxide emissions with very little plant modification. Biomass co-firing can also reduce sulfur emissions because biomass

contains virtually no sulfur. Since coal-fired plants can burn large quantities of biomass this also offers a means of establishing the biomass infrastructure needed to enable biomass power generation to develop into a large-scale industry.

- ✓ The most efficient and common type of coal-fired power plant in operation is the pulverized coal (PC) plant that burns coal that has been ground to a fine powder. Plants of this design can burn up to 10% biomass with little modification to their plant. Biomass is simply mixed with the coal before it is delivered to the coal mills where the mixture is ground prior to injection into the combustion chamber. For a 1000 MW power plant this would be equivalent to a 100 MW biomass plant, but with much higher efficiency than a dedicated plant.
- ✓ Simple co-firing of this type is limited by the type of biomass fuel that can be used and by the proportion of co-firing possible. To overcome both these limits another approach is to have a dedicated biomass fuel delivery line. Fuel from this line can either be mixed with the powdered coal before combustion or delivered to dedicated biomass burners in the furnace. The latter are usually located lower down the combustion chamber allowing a longer transit time to completely burn the biomass fuel. This will allow a plant to burn up to 15% biomass by heat content. Higher proportions are possible but generally require greater plant adaptation and consequently more expense.
- ✓ An alternative to conventional co-firing involves gasification of the biomass in a dedicated biomass gasifier attached to the coal plant. The combustible gas is then burned in the coal-fired furnace. This approach is more expensive than the simple co-mixing of fuels but it avoids some of the problems that can be associated with conventional co-firing and allows a greater proportion of biomass to be burned.
- ✓ Third approach is called parallel co-firing. This involves having a separate biomass furnace, with the hot gases generated by combustion of biomass being mixed with the hot coal-flue gases. In a variation of this approach, the biomass has its own steam-raising boiler too with the steam flows blended before entering the steam turbine. Again this is more costly than conventional co-firing.

- ✓ Conventional co-firing remains the favored approach but it does have its problems. Some wastes such as sawdust can block fuel feed systems and need to be avoided. Other biomass fuels such as grasses have a high alkali content that can cause problems in coal-fired boilers. Biomass is also more volatile than coal when burned so much of the combustion takes place higher in the combustion chamber and more over fire air may be necessary to ensure complete combustion.
- ✓ Additionally, the ash from a co-fired boiler has a different composition to that from a plant that burns only coal. Coal plant ash is often used in various ways by the building industry but the reuse of the ash from a plant that burns biomass has led to regulatory difficulties in the past