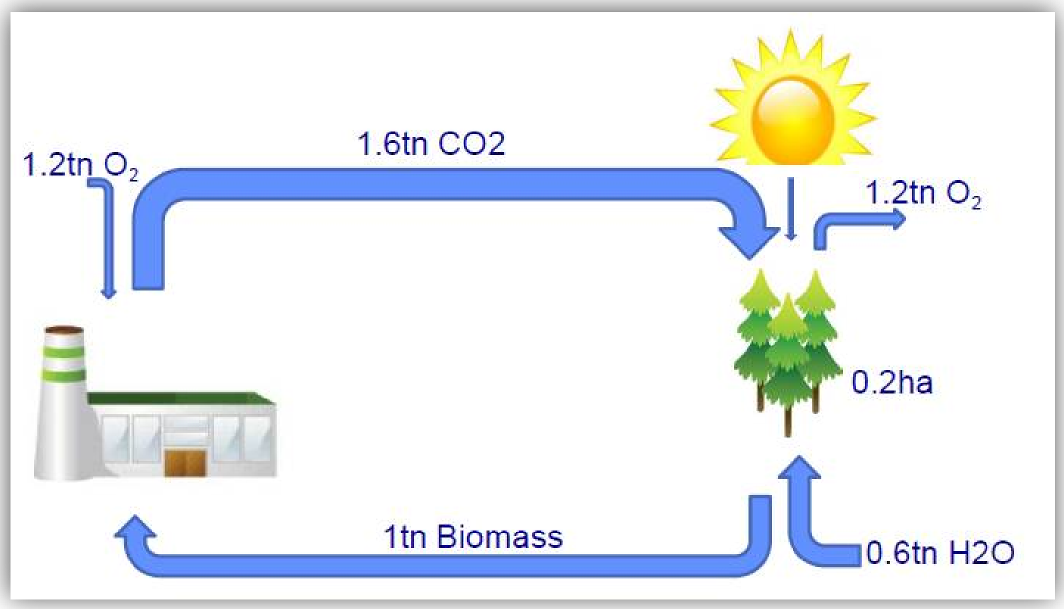
BIOMASS AND ITS USAGE IN ELECTRICITY-HEAT GENERATION

ENEVA ENERGY SYSTEMS ENGINEERING INDUSTRY & TRADE LTD.
info@enevaenerji.com.tr

BIOMASS MAIN BENEFITS

- Political reasons such as reducing foreign dependency in energy.
- It requires more manpower than other fuels and provides a high amount of workspace (up to 20 times).
- Minimizing negative effects such as; lower greenhouse gas emissions and acid rains.



BIOMASS USAGE LEVELS

- Drying; Below 100 °C, the water evaporates and becomes dry, this heat reduces the combustion temperature. For example, woods with a moisture content of more than 60% do not burn in wood stoves.
- Pyrolysis; without the use of air, the volatiles in the fuel go away and tar is formed. This coke can be used in industry, domestic use (charcoal etc.).
- Gasification using air or oxygen creates combustible calorific gases. If air is used, low calorie (4-7 MJ/m3) oxygen is used, medium calorie 1(0-18 MJ/m3) gases are formed, these gases can be used in heat power generation after being improved (methanol).
- Combustion is the complete oxidation of the fuel. Drying, pyrolysis and gasification are the stages of combustion.
- Liquefaction; at low temperature (350-400 °C) and high pressure (100-200 bar) low oxygen high calorific fuel is formed.
-

BIOMASS FUEL PARAMETERS AND ITS EFFECTS

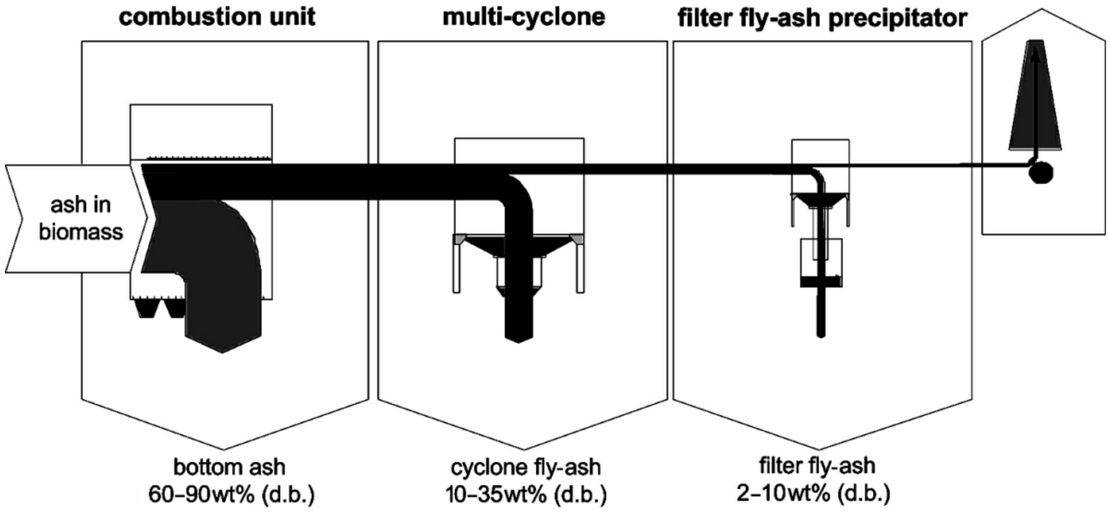
• The higher amount of moisture lowers the combustion temperature and increase the residence time. It may cause incomplete combustion and increase in emissions.

• The heating value varies between 18-22 MJ/kg. C, H and S in the fuel have a positive effect, while N, O and ash have a negative effect.

• Temperature, residence time, stoichiometry; some causes of incomplete combustion; insufficient mixing can create rich mixing in some areas (incomplete combustion), low combustion temperature, low residence time,

• Biomass is generally highly volatile and low carbon, making it a highly active fuel. Its porosity increases the rate of mass loss. It increases its activity.

• The residence time is shortened as the fuel size decreases and the process control becomes easier as the size homogeneity increases.



BIOMASS FIRING

• In pulverized coal combustion systems, coal is ground under 75 microns. For biomass, this grinding energy is quite high, so pulverized combustion is not seen very often in biomass applications. Instead, grate combustion or fluidized bed combustion in the form of large particles is more common.

• In fluidized bed combustion, particle sizes must be below an upper limit to ensure fluidization and complete combustion. In the circulating system, fluidization can be achieved with air velocity, and the unburned particle can be fed back from the cyclone. In bubbles, however, the air velocity is kept low so that no particles are missed.

• Particles are large in grate combustion systems, the system should be designed to complete the combustion of coarse particles on the grate.

• Fuel size can vary from micron to 50 cm. Fuel size and homogeneity determines the fuel transfer system and combustion system.

• Biomass volatile rate is quite high compared to coal. (70-86%) Therefore, most of the combustion takes place in a homogeneous environment after the volatile is separated.

• High ash ratio is undesirable in terms of ash collection system and heat transfer surfaces.

Table 2.6 *Fuel-specific ash content of biomass fuels*

Biomass fuel used	Ash content
Bark	5.0–8.0
Woodchips with bark (forest)	1.0–2.5
Woodchips without bark (industrial)	0.8–1.4
Sawdust	0.5–1.1
Waste wood	3.0–12.0
Straw and cereals	4.0–12.0
Miscanthus	2.0–8.0
Olive residues	2.0–4.0

Explanations: Ash content in wt% (d.b.), ash content measurement according to ISO 1171–1981 at 550°C.

Some Notes on Its Use

• While Ca. and Mg. in the ash increase the ash melting temperature, K. and Na. decrease it.

• Straw, grain, grass and olive waste contain less heavy metal than wood and bark. The reason for this is that heavy metals can accumulate in a long time and the pH of the forest floor is suitable for heavy metal dissolution.

TABLE 3.2: BIOMASS POWER GENERATION TECHNOLOGIES AND FEEDSTOCK REQUIREMENTS

Biomass conversion technology	Commonly used fuel types	Particle size requirements	Moisture content requirements (wet basis)	Average capacity range
Stoker grate boilers	Sawdust, non-stringy bark, shavings, end cuts, chips, hog fuel, bagasse, rice husks and other agricultural residues	6 - 50 mm	10 - 50%	4 to 300 MW many in 20 to 50 MW range
Fluidised bed combustor (BFB or CFB)	Bagasse, low alkali content fuels, mostly wood residues with high moisture content, other. No flour or stringy materials	< 50 mm	< 60%	Up to 300 MW (Many at 20 to 25 MW)
Co-firing: pulverised coal boiler	Sawdust, non-stringy bark, shavings, flour, sander dust	< 6 mm	< 25%	Up to 1500 MW
Co-firing: stokers, fluidised bed	Sawdust, non-stringy bark, shavings, flour, hog fuel, bagasse	< 72 mm	10 - 50%	Up to 300 MW
Fixed bed (updraft) gasifier	Chipped wood or hog fuel, rice hulls, dried sewage sludge	6 - 100 mm	< 20%	5 to 90 MW_{th} + up to 12 MW_e
Downdraft, moving bed gasifier	Wood chips, pellets, wood scrapes, nut shells	< 50 mm	< 15%	~ 25 - 100 kW
Circulating fluidised bed, dual vessel, gasifier	Most wood and chipped agricultural residues but no flour or stringy materials	6 - 50 mm	15 - 50%	~ 5 - 10 MW
Anerobic digesters.	Animal manures & bedding, food processing residues, MSW, other industry organic residues	NA	65% to 99.9% liquid depending on type (i.e. from 0.1 to 35% solids)	

SOURCE: US EPA, 2007.

BIOMASS COMBUSTION SYSTEMS

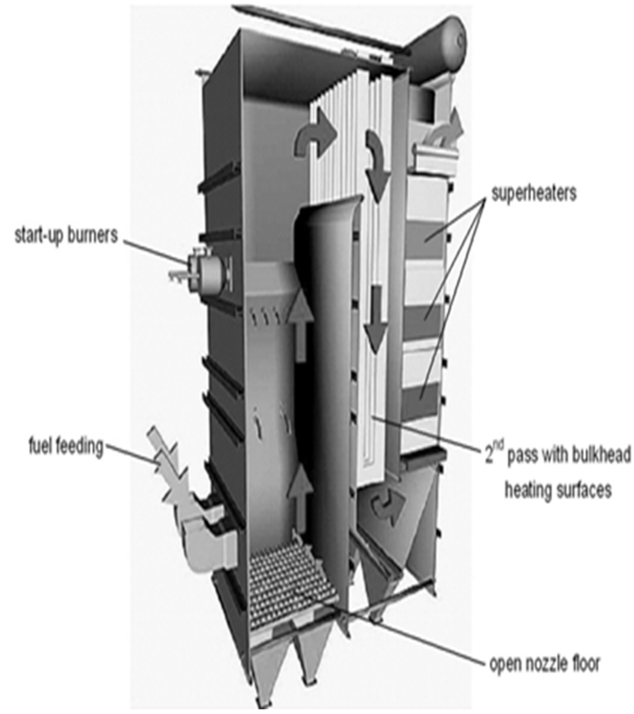
• On-screen combustion is suitable for fuels with high humidity, variable size and high ash content.

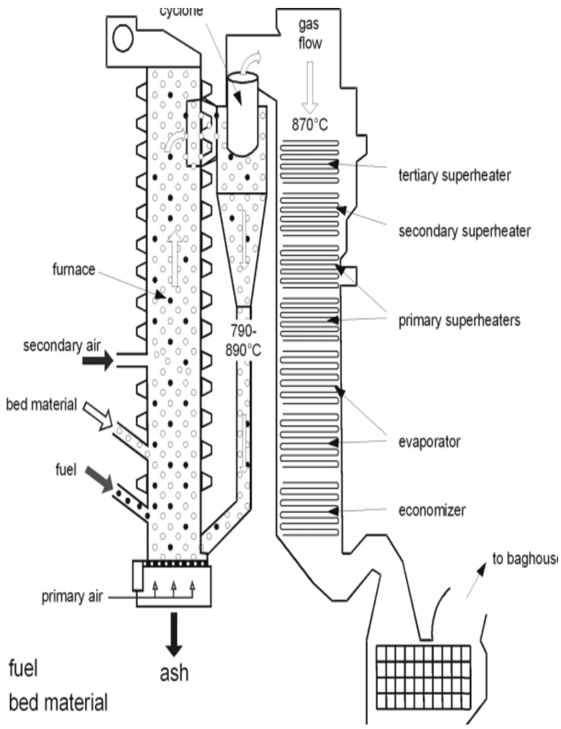
• Stoker combustion systems can be used up to 6 MWth capacity. Stoker combustion systems are suitable for fuels with low ash content (sawdust, pellets, etc.) and small particle size 0-50 mm. Fuels with high ash content and low melting temperature can cause problems.

• In the fluidized bed combustion system, 90-98% of the bed is lining material. Excess air is around 10-20% for CFB **(Circulating Fluidized Bed)** and 20-30% for BFB **(Bubbling Fluidized Bed)**. The bed temperature is between 650-900 °C in terms of NOx and ash sintering. It is more flexible to fuel type and quality due to good mixing. Fluidized bed boilers enter the regime in a longer time than other combustion systems (8-15 hours).

• Bubble fluidized system (BFB) up to 20 MWth capacity can be used. The bedding material is sand and has a size between 0-1 mm. Biomass should be fed into the bed, not on top of it. (Because it is more reactive than coal) The air fed to the bed can be up to 35%, the combustion temperature is low and it can burn fuels with low ash melting temperature. The partial load rate can be between 60-100%.

• By increasing the fluidization rate (10 m/s) and reducing the size of the bed material (0.2-0.4 mm), a circulating system (CFB) is formed. It is larger in size, more expensive, requires lower sized fuel (0.1-40 mm) than bubbled, so fuel processing costs may be incurred. CFB systems are suitable for capacities above 30 MWth.

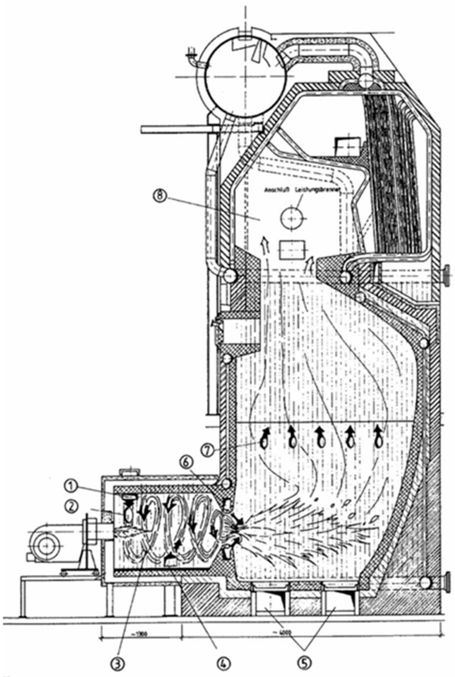


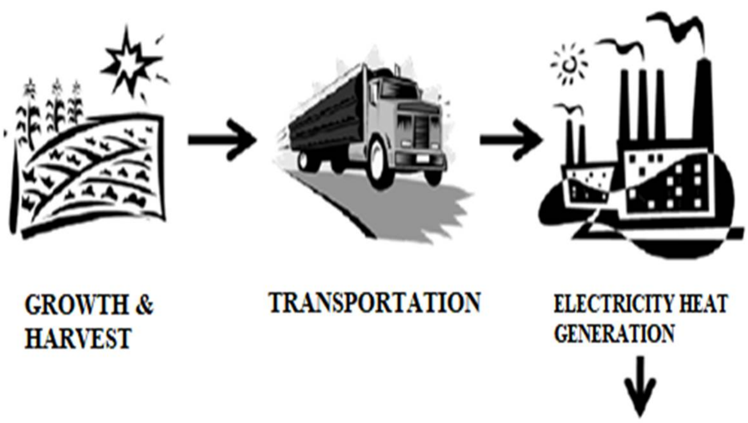


• In pulverized combustion systems, sawdust-like fuels can be burned, but the fuel quality should not be ever-changing.

• Fuel size can be up to 20-30 mm, humidity max. It should be 20%. Fuel transport air is also primary air.

• Since the fuel size is small and burning fast, it is successful in sudden load changes. Low excess air (1.3-1.5) NOx can be achieved with air cascading.





COMPARISON OF BIOMASS COMBUSTION SYSTEMS – 1

Table 5.1 *Overview of advantages, disadvantages and fields of application of various biomass combustion technologies*

Advantages	Disadvantages
Grate furnaces	
• low investment costs for plants < 20MW$_{th}$ • low operating costs • low dust load in the flue gas • less sensitive to slagging than fluidized bed furnaces	• usually no mixing of wood fuels and herbaceous fuels possible (only special constructions can cope with such fuel mixtures) • efficient NO_x reduction requires special technologies (combination of primary and secondary measures) • high excess oxygen (5–8vol%) decreases efficiency • combustion conditions not as homogeneous as in fluidized bed furnaces • low emission levels at partial load operation require a sophisticated process control
Underfeed stokers	
• low investment costs for plants < 6MW$_{th}$ • simple and good load control due to continuous fuel feeding and low fuel mass in the furnace • low emissions at partial load operation due to good fuel dosing • low flexibility in regard to particle size	• suitable only for biomass fuels with low ash content and high ash-melting point (wood fuels) (< 50mm)

Advantages	Disadvantages
BFB furnaces	
• no moving parts in the hot combustion chamber • NO_x reduction by air staging works well • high flexibility concerning moisture content and kind of biomass fuels used • low excess oxygen (3–4 Vol%) raises efficiency and decreases flue gas flow	• high investment costs, interesting only for plants > $20MW_{th}$ • high operating costs • reduced flexibility with regard to particle size (< 80mm) • utilization of high alkali biomass fuels (e.g. straw) is critical due to possible bed agglomeration without special measures • high dust load in the flue gas • loss of bed material with the ash without special measures

COMPARISON OF BIOMASS COMBUSTION SYSTEMS – 2

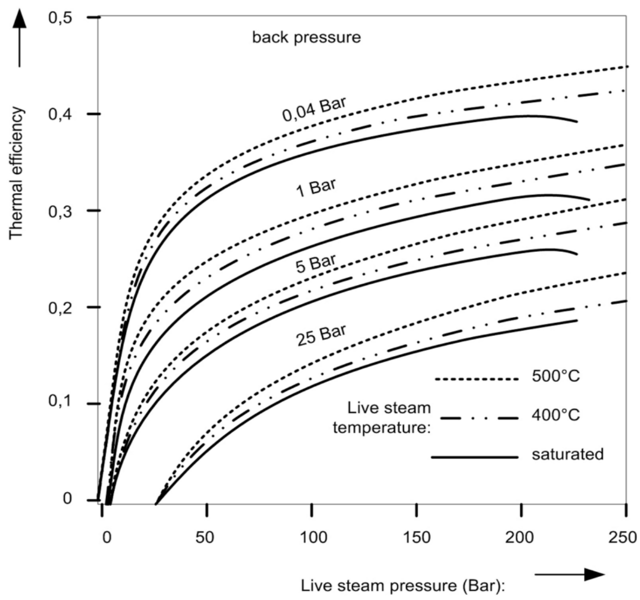
Advantages	Disadvantages
CFB furnaces	
• no moving parts in the hot combustion chamber • NO_x reduction by air staging works well • high flexibility concerning moisture content and kind of biomass fuels used • homogeneous combustion conditions in the furnace if several fuel injectors are used • high specific heat transfer capacity due to high turbulence • use of additives easy • very low excess oxygen (1–2vol%) raises efficiency and decreases flue gas flow	• high investment costs, interesting only for plants > $30MW_{th}$ • high operating costs • low flexibility with regard to particle size (< 40mm) • utilization of high alkali biomass fuels (e.g. straw) is critical due to possible bed agglomeration • high dust load in the flue gas • loss of bed material with the ash without special measures • high sensitivity concerning ash slagging
Pulverized fuel combustion	
• low excess oxygen (4–6vol%) increases efficiency • high NO_x reduction by efficient air staging and mixing possible if cyclone or vortex burners are used • very good load control and fast alteration of load possible	• particle size of biomass fuel is limited (< 10–20mm) • high wear rate of the insulation brickwork if cyclone or vortex burners are used • an extra start-up burner is necessary

POWER GENERATION AND COGENERATION WITH BIOMASS

Table 6.1 *Closed processes for power production by biomass combustion*

Working medium	Engine type	Typical size	Status
Liquid and vapour (with phase change)	Steam turbine	$500kW_e$ – $500MW_e$	Proven technology
	Steam piston engine	$25kW_e$ – $1.5MW_e$	Proven technology
	Steam screw engine	Not established, estimated range from $500kW_e$ – $2MW_e$	One demonstration plant with $730kW_e$ and turbine from commercial screw compressor
	Steam turbine with organic medium (ORC)	$400kW_e$ – $1.5MW_e$	Some commercial plants with biomass
Gas (without phase change)	Closed gas turbine (hot air turbine)	Not established, similar size as steam turbine, probably large due to cost and efficiency	Concept and development
	Stirling engine	$1kW_e$ – $100kW_e$	Development and pilot

COGENERATION AND EFFICIENCY RELATIONS WITH BACK PRESSURE



Typical steam pressures are 50-60 Bar, temperature is 400-500 °C, and the efficiency can vary between 20-30%.

Table 6.2 *Advantages and disadvantages of steam turbines for use in biomass combustion*

Advantages	Disadvantages
• Mature, proven technology • Broad power range available • Separation between fuel and thermal cycle, enabling the use of fuel containing ash and contaminants • High pressures and temperatures can be applied enabling high efficiencies for large plants • Co-firing of fossil fuels and biomass is possible to enable high efficiency	• Only limited efficiencies are reached in small, decentralized plants due to investment and technology limitations • High specific investment for low power ranges • High operation costs for small and medium plants • Low part-load efficiencies • Variations in fuel quality lead to variation of steam and power production • Superheater temperature (and therefore efficiency) can be limited due to high temperature corrosion and fouling, especially due to alkali metals, chlorine, and sulphur • High-quality steam is necessary

Ref : The Handbook of Biomass Combustion & Co-Firing, : Sjaak van Loo, Jaap Koppejan