Definition

The thermal utilisation of biomass is the oldest form of energy production used by mankind. Thermal utilisation of biomass means the direct combustion of biomass in order to produce heat, electricity and steam.

1. FUELS

A range of materials is available as fuels for thermal utilisation. Alongside residues from forestry such as branches, stumps and bark, there are residues from agriculture such as surplus straw, cereal and rape screenings, rice husks, nut husks, coffee husks, sunflower husks and compressed cake from plant oil production as well as specific energy plants such as wood from short rotation plantations, perennial grasses and the Chinese reed.

In the following table, the energy contents for some of these raw materials in comparison to fuel oil are presented. The higher calorific values correspond with lower water contents and vice versa.

	Water content	Calorific value H_u	Debris density
	%	kWh/kg	kg/m³
Straw - loose	10-20	3.6-4.2	80
Rice husks	10-15	3.6-4.2	50-100
Whole cereal plants – loose	10-15	4-4.5	100
Wood - chipped	15-60	1.7-5.0	200-250
Light fuel oil		11.6	900

The calorific values shown in the above table are lower calorific values according to the following definition:

$H_u = H_o - r * w$, where

H_u = lower calorific value (kJ/kg)
H_o = upper calorific value) (kJ/kg)
r = heat of vapourisation of water (2442 kJ/kg at 25 °C)
w = free released water (kg)

This definition clearly shows the strong dependence of the energy yield upon the water content of the fuels. With a water content of more than 30%, the majority of heat is needed to vapourise the water.
In this regard, a reduction in the degree of effectiveness is associated with an increase in emissions.

2. BIOMASSE POTENTIAL

For the production of energy from the fuels referred to above, one assumes the following proportions:

Potential	Origin
50%	Residual wood from timber production
32%	Surplus straw and residues from agriculture
13%	Residual wood from the woodworking industry
3%	Street greenery, cemeteries and public parks
2%	Plywood and household waste wood

The division of the potential, as shown in the above table, is only an indicative value of proportions of the individual biogenic fuels in regard to the overall potential of these fuels and makes no statement about the total energy potential in any one particular region

The cultivation of renewable raw materials for thermal utilisation is still in the early stages of study meaning that the final potential which might result, from the business point of view, cannot be estimated. For the types that are currently common, one can assume the following related potentials on an yield per area basis:

Potential	Origin
59 MWh/ha*a	Perennial grasses
56 MWh/ha*a	Short rotation tree plantations (wood)
48 MWh/ha*a	Whole cereal plants

3. COMBUSTION PROCESS

The combustion process takes place several stages.

The biomass is transformed to water vapour, carbon dioxide (CO_2), nitrogen (NO_X), carbon monoxide (to a small degree)(CO), hydrocarbons (to a small degree) (C_XH_Y) und soot (to a small degree), in the various stages. Cinders, fine ash and coarse ash remain as residues.

The combustion process occurs in three phases .

The **first phase** is **drying** in which water vapour is almost exclusively released.
The **second phase** is **pyrolysis** in which combustible gases such as hydrocarbons, carbon monoxide and hydrogen are released.
The **third phase** is **oxidation** in which the gases formed during pyrolysis are combusted to form carbon dioxide and water.

In this regard, total combustion is characterised by making a high use of the fuels used and very low levels of emissions of carbon monoxide. In contrast, partial combustion is characterised by high emissions of combustible gases and a high carbon content in the ashes.

The main factors influencing the combustion process are primarily the calorific value, water content, oxygen supply and distribution, duration of the gases in the combustion chamber, combustion chamber temperature and combustion chamber form (adapted to the specific fuel)

Losses can exist because of radiation (depending upon construction, 3-7 %) and exhaust gas, (proportion of carbon dioxide in the exhaust gas and temperature relationship between the exhaust gas and air). A degree of effectiveness from 80 % (fire wood boiler) to 95 % (automatic chip fuelling or pelletised fuelling) is related to the heating performance. In comparison, the degree of effectiveness of an open fire amounts to ca. 5%

4. EMISSIONS

In association with the combustion of biomass, a range of undesirable emissions originate which, at maximum output, are over the limits set in the relevant legal regulations. The main area of attention has regard to the contents of carbon monoxide (CO) and nitrogen oxides (NO_x).
For example, in Germany, the following limits for wood and straw are applicable:

Natural wood:				
Plant performance	CO (g/m^3)	Dust (mg/m^3)	Org. C (mg/m^3)	NO_x (mg/m^3)
< 15 kW	Currently no limits			
15 - 50 kW	4	150	-	-
50 - 150 kW	2	150	-	-
150 - 500 kW	1	150	-	-
500 - 1000 kW	0,5	150	-	-
1000 - 5000 kW	0,25	150	50	500
5000 - 50000 kW	0,25	50	50	500
Straw and similar materials:				
< 15 kW				
15 - 100 kW	4	150	-	-
100 - 5000 kW	0,25	150	50	500
5000 - 50000 kW	0,25	50	50	500

The emissions are largely dependent upon the combustion process i.e. the technology used, the fuels used, and operating management. To reduce dust emissions, additional dust removal procedures are installed. Various processes are available such as textile filters (high investment and operating costs – very good degree of effectiveness), electro-filters (high investment costs, good degree of effectiveness), cyclones (low investment and operating costs, lower degree of effectiveness) or multi-cyclonic systems (median costs, median degree of effectiveness).

5. COMBUSTION PLANTS

The spectrum of combustion plants is extremely varied. It ranges from simple tile stoves through to fully automatic wood chip or pelletised furnaces.
Possible categorisation of the types of plant follows quite different criteria. In addition to plant size, these include the fuels used, the feeding systems or the furnace technology.
The following table provides a categorisation based upon plant size:

Smallest plant	< 15 kW
Small plant	15 kW - 500 KW
Middle sized plant	500 KW - 10 MW
Large plant	> 10 MW

With regard to the feed system, a differentiation is made between plants which work on a continuous and discontinuous basis as well as automatic and manual feed systems.
Continuous feed automatic furnaces are differentiated base stoker **furnaces** and forced air furnaces.

With regard to the furnace technology, differentiation is made between
- **Base stoker furnaces**
Sloping grate and reciprocating grate furnaces
Fluidised bed combustion furnaces
Pre-burner furnaces

Combustion plants for the utilisation of solid biomass as a fuel consist of the following plant components:

Fuel storage with an extraction apparatus (reciprocating feed/ moving floor, circular scraper)

Fuel transfer from the fuel storage area to the furnace (screw feed, conveyor, floor scraper, trough carriage, pneumatic carriage)

Transferring the fuel into the combustion chamber(screw drive, hydraulic punch or a discharge cyclone for the separation of carrier air /fuel)

Boiler (hot water boiler, steam boiler, air heater)

Air regulation with an oxygen sensor (primary air and secondary air system)

Flue gas cleaning (dust remover/cyclone, filter, denitrification).
Ash removal attachment.

In addition these listed plant types for the combustion of biomass, there are also the plant technologies of pyrolysis and gasification. The differentiation between pyrolysis, gasification and combustion is achieved by means of controlling the oxygen supply. Pyrolysis occurs in the absence of oxygen, gasification with a hypostoichometric oxygen supply and combustion with an optimal oxygen supply. The oxygen supply is characterised by the symbol λ :

Pyrolysis	$\lambda = 0$
Gasification	$0 < \lambda < 1$
Combustion	$\lambda > 1$

Pyrolysis and gasification plants are not described in the script because these types of plants are still in the developmental stage.

6. AREAS OF USE

The thermal utilisation of biomass generally covers base load heat consumption because biomass boilers work most effectively in the base loading area. Peak loadings are catered for by the use of conventional boilers that can be put on line as required. Larger biomass furnaces are also built as thermal power plants. These thermal power plants replace conventional power plants.