UNIT-III

THERMOCHEMICAL PROCESSING

To use the biomass effectively, one needs to process it

The degree of processing required can be determined depending on type of the end use in mind. The objective of processing is to make biomass easy to handle, with improved heating value or to convert to more suitable and usable forms like liquid or gaseous fuels

Processing could be—physical processing
chemical processing

Physical processing – dewatering, drying, and/or sizing

Chemical processing -- converting into char, liquids or gaseous fuels

Chemical Processes

- **Thermochemical**
  - **Combustion**
  - **Thermal Gasification**
  - **Pyrolysis**

- **Biochemical**
  - **Biogasification**
  - **Fermentation**

Secondary processing into liquid fuels or hydrogen

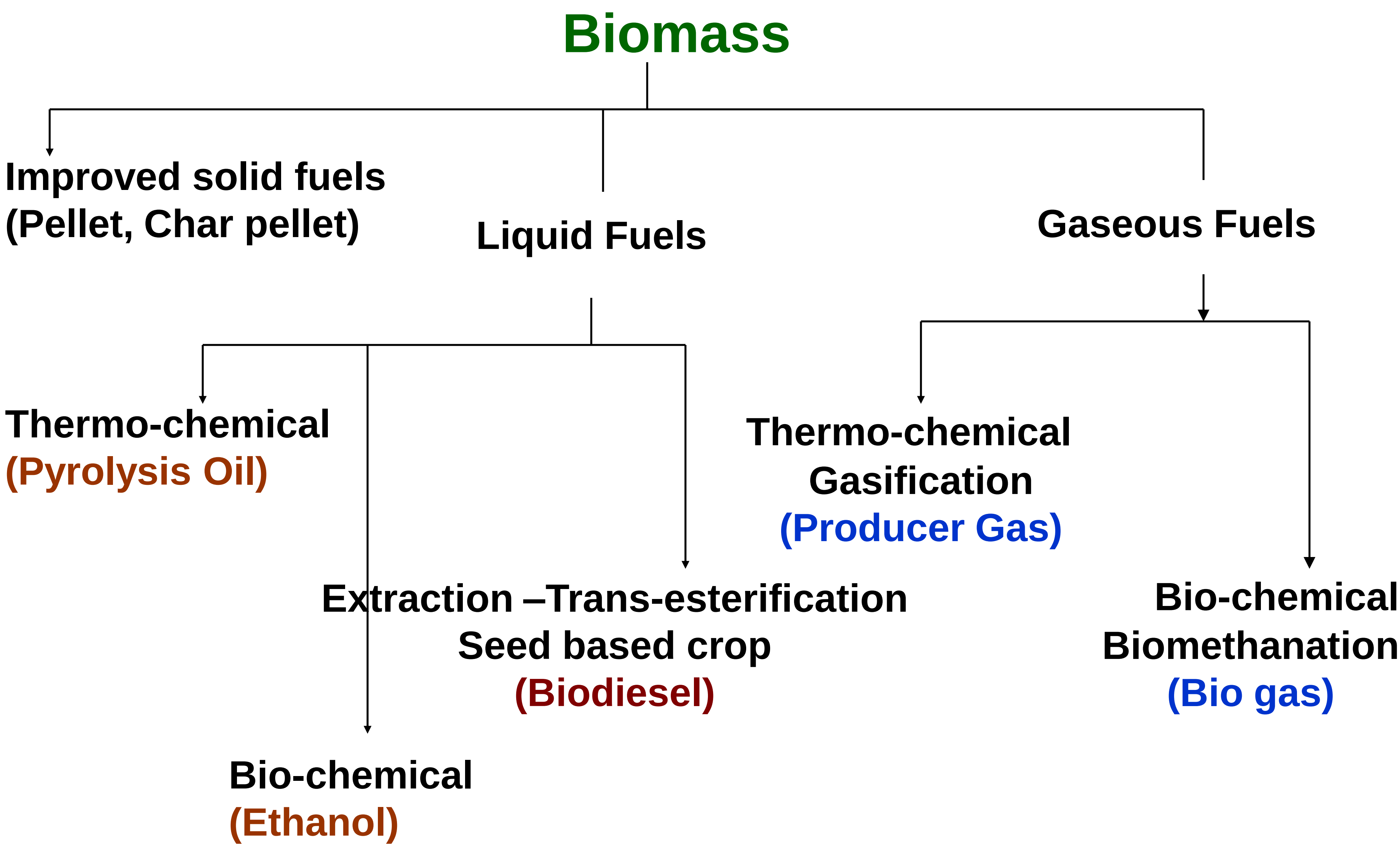
Combination of the two: methane converted chemically to methanol

Producer gas converted to methanol bio-chemically

Growth of Algae

Mechanical Process---extraction of oils

Routes for Utilisation of Biomass



Thermo chemical conversion technologies

Process	Products	Equivalence Ratio
Combustion	CO_2, H_20, and heat	$ø \geq 1$
Gasification	CO, H_2, CH_4, CO_2, N_2	$ø < 1$
Pyrolysis	char, liquids and gases	$ø = 1$

Where equivalence ratio is the (A/F actual)/(A/F stoichiometric)

Table 1.1 Thermochemical conversion technologies, primary products and applications [2]

Technology	Primary product	Application
Pyrolysis		
Fast or flash pyrolysis	Liquid	Liquid fuel substitution, chemicals
Carbonization	Charcoal	Solid fuel or slurry fuel
Slow pyrolysis	Gas	Fuel gas
	Liquid tar	Liquid fuel substitution, chemicals
	Solid char	Solid fuel or slurry fuel
Liquefaction	Liquid	Oil or liquid fuel substitution
Gasification	Gas	Synthesis gas or fuel gas
Combustion	Heat	Heating

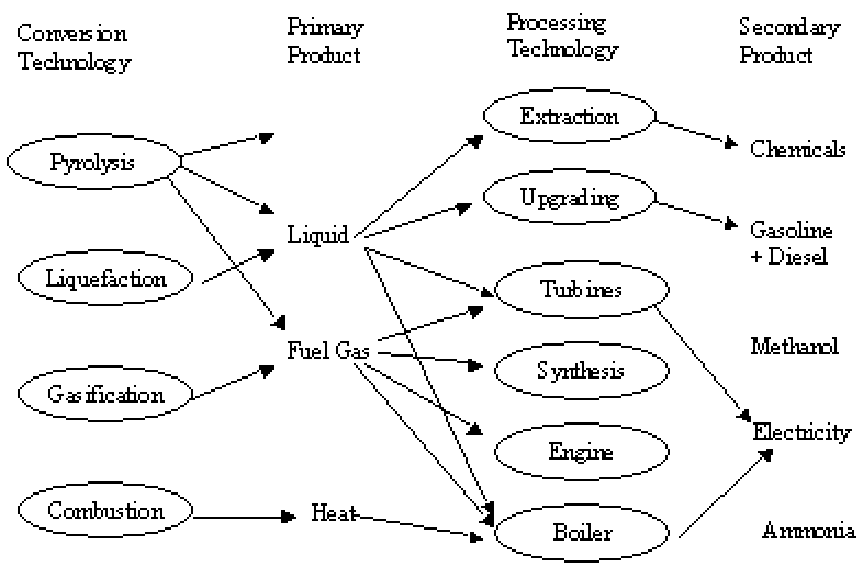
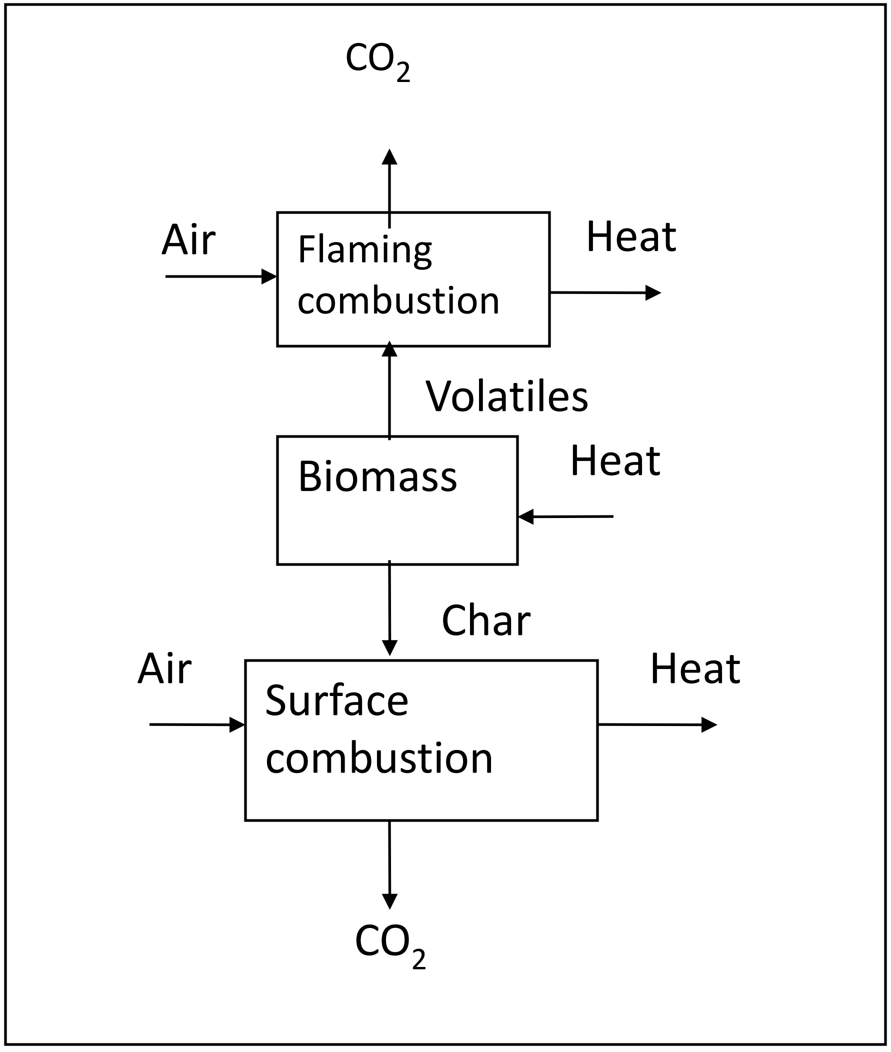


Figure 1.1 Thermochemical processing of biomass and their products [2]


CO2
Air
Flaming combustion
Heat
Volatiles
Biomass
Heat
Char
Air
Surface combustion
Heat
CO2

Charcoal and coal

- Charcoal is formed from biomass upon processing by man as against coal which is made from fossils upon processing by nature
- Coal properties therefore depend on the site of mining, the weathering conditions it has gone through
- Charcoal properties will largely depend on the biomass of origin and the processing conditions

Pyrolysis in which charcoal production is maximised is called carbonisation (* carbonistation is also used for pyrolysis of coal to make coke)

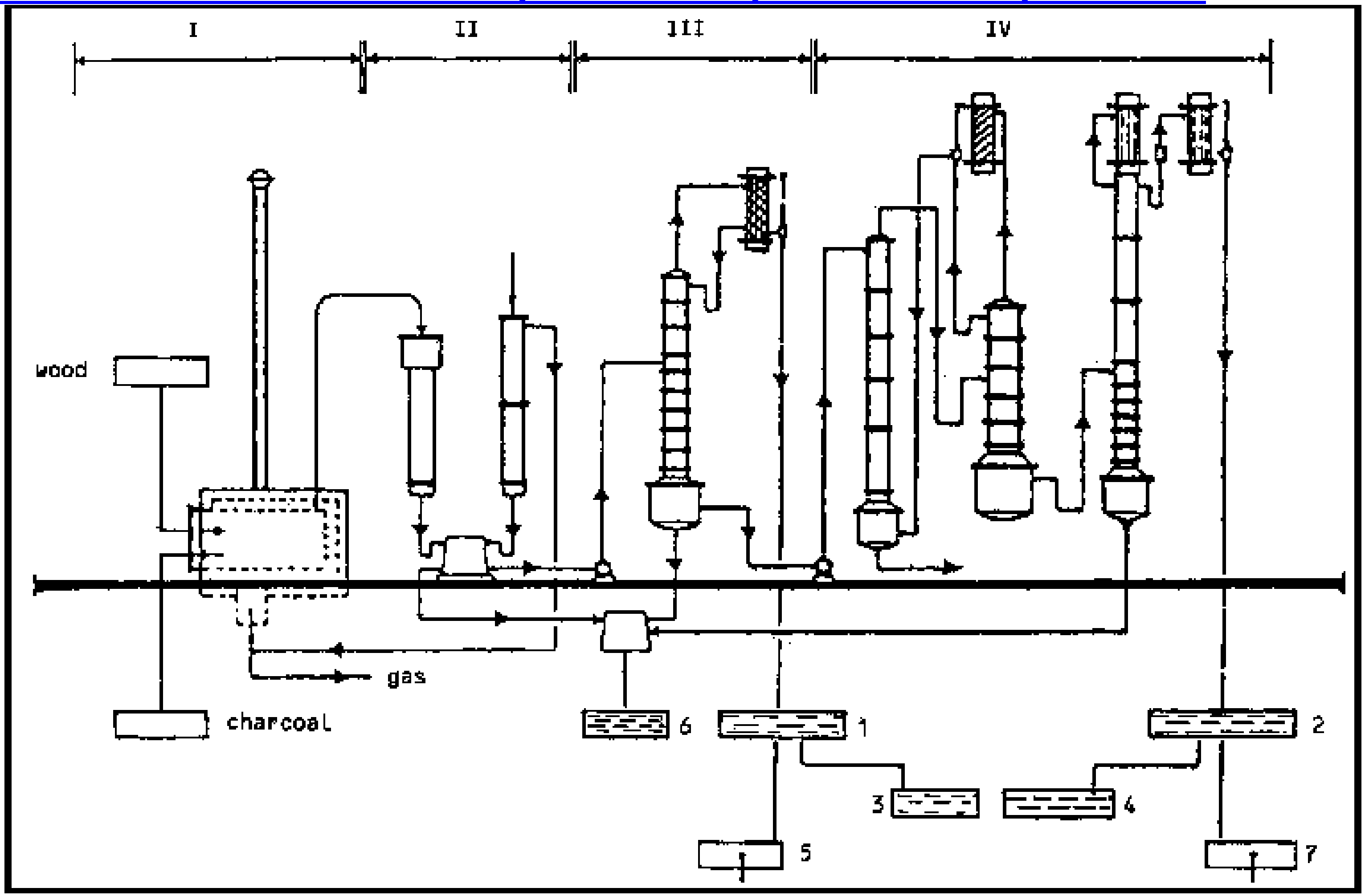
Uses of charcoal:

Domestic fuel, Barbeque, Heating, Feed material for gasifiers, Activated carbon and *metal industry*

Useful byproducts are recoverable

Fuelwood is the primary raw material but these days agroand forest residues are also potential candidates

Fig. 6 Charcoal Plant with Refinery for Recovery of Chemical By-Products



I. Carbonisation
II. Pyrolygneous acid recovery
III. Crude methanol plant
IV. Acetic acid concentration

1. Crude methanol
2. Crude acetic acid
3. Methanol
4. Acetic acid
5. Methylating spirit
6. Tar
7. Waste water disposal

Yield per 1,000 kg of air dry wood	
Acetic acid	50 kg
Methanol	16 kg
Acetone and Methyl Acetone	8 kg
Soluble tars	190 kg
Insoluble tars	50 kg

Charcoal properties as a fuel

i. Burns with less smoke and flame

(depending upon the yield—25%-40%)

(volatile content 5%—25%)

ii. Requires little or no preparation before use

iii. High energy content per unit mass

(also dependent on yield---typically 22-30MJ/kg)

iv.Stored easily—is in the form of briquettes (natural or pelletised)

EFFECT OF WOOD MOISTURE CONTENT ON ENERGY USE

Moisture %	Energy used MJ/m^3	Circulating gas m^3	Electricity kWh
5	35	210	2.5
10	40	270	3.2
15	154	490	4.4
20	293	770	5.2
25	460	1050	7.2
30	648	1400	9.0

There are two route for making charcoal briquettes

1. B-C (densification and carbonisation
2. C-B (carbonisation and briquetting

B-C –machines are available for different techniques, raw material and capacity for densification and then followed by carbonisation in kilns

Advantages: intermediate products in terms of uncarbonised pellets are available, and conventional kilns can be used

Disadvantages: Higher pressures required, therefore higher energy input, more wear and tear of the parts and tend to disintegrate to more fines.and also on exposure to water

C-B – carbonisation followed by briquetting.

Advantages: energy input is less, and less wastage as fines are pelletised, binders are used

Disadvantages: yield of charcoal is less, and difficult to use the intermediate product.

Binders used

Organic ---starch, molasses etc

Inorganic– bentonite clay

Organic binders burn well and are used for making briquettes for industrial purposes

Inorganic binders are used when briquettes are to be used for special applications where heat release rates are to be reduced,

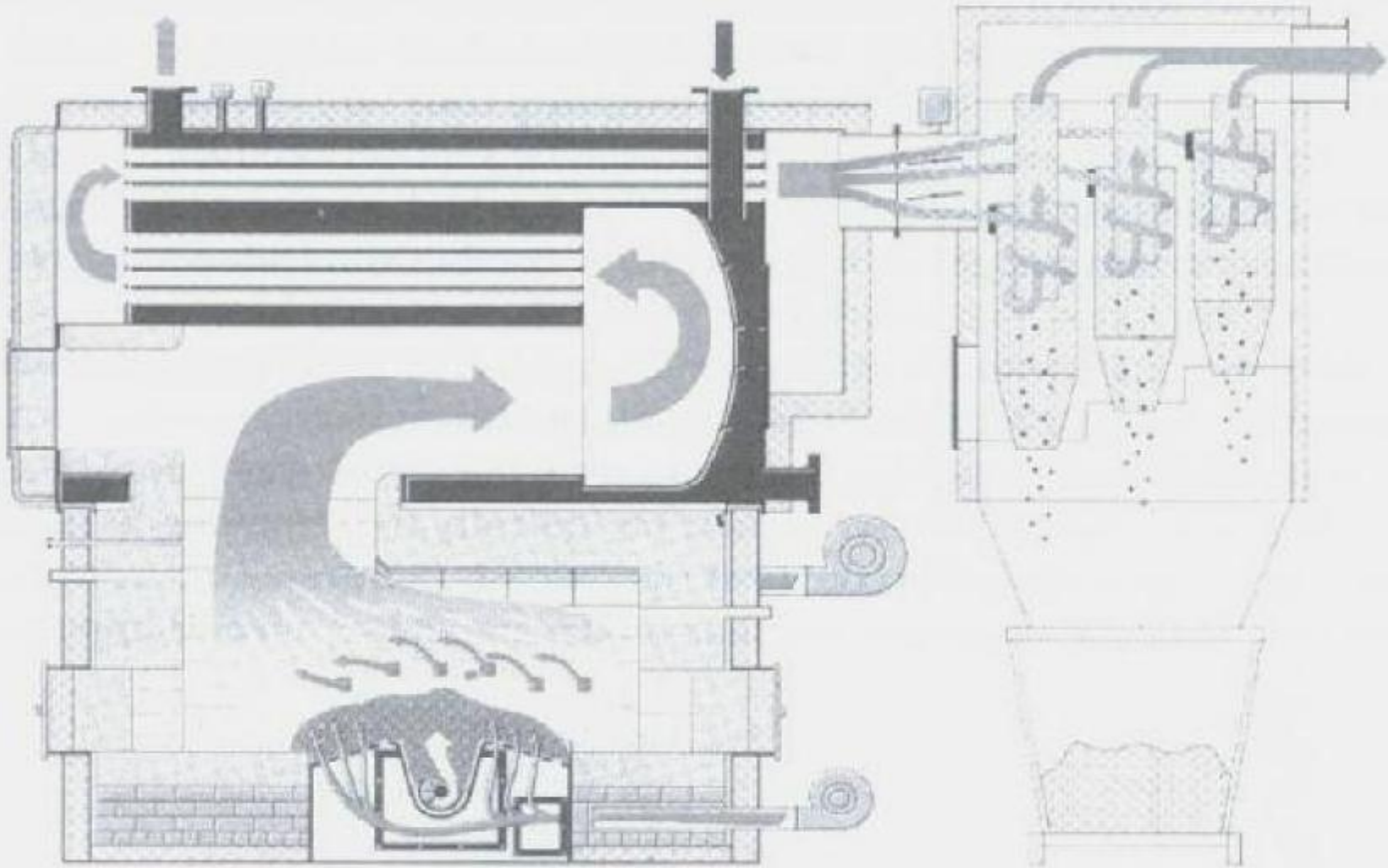
Biomass Combustion

Biomass combustion :

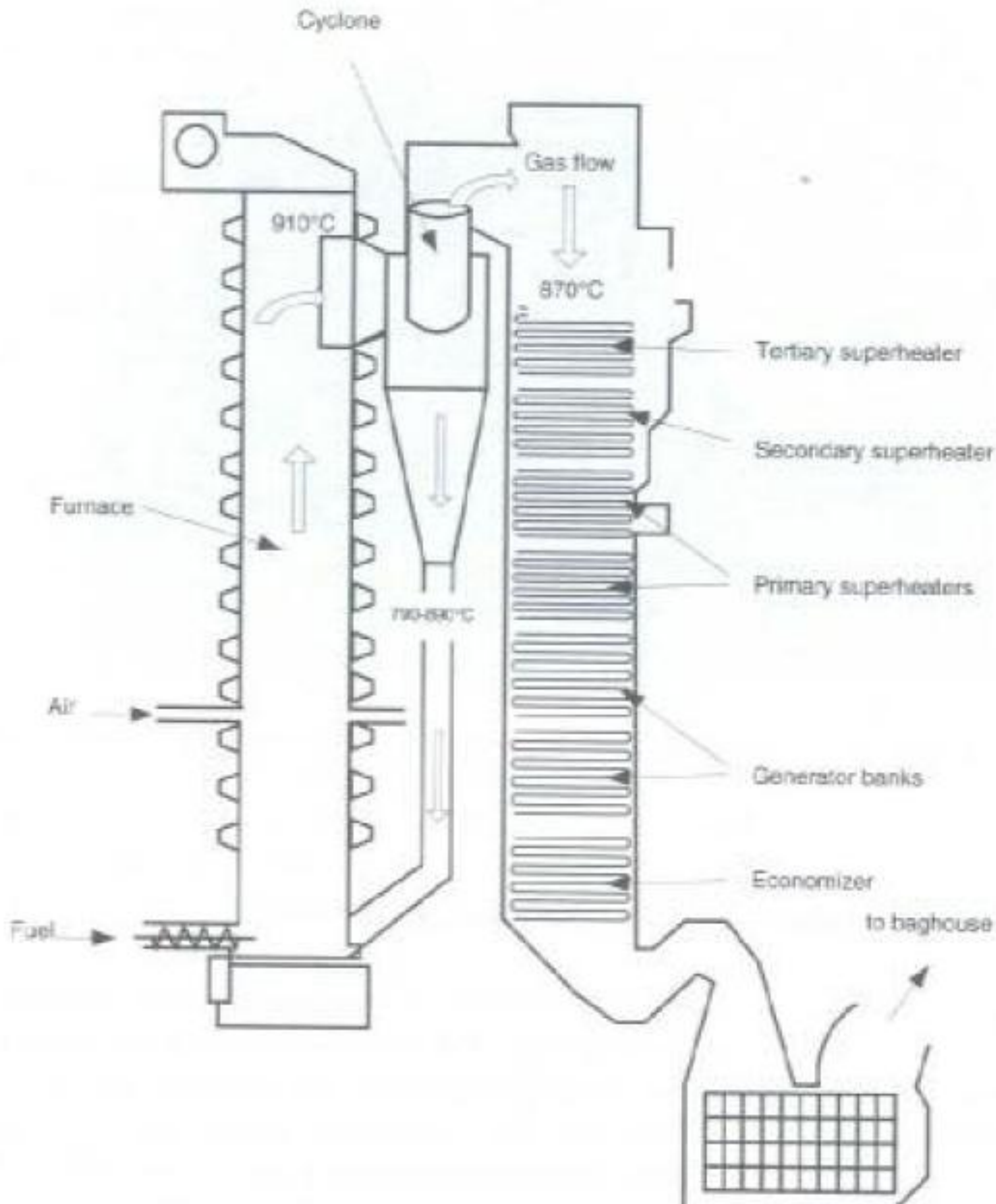
Domestic cooking ---wood stoves
Domestic boilers ---wood fuelled boilers
Industrial boilers for process heat
Industrial Boilers for power generation
Industrial Boilers for CHP applications

Incinerator, stove, combustor, boiler

Stoker-fired boiler



Circulating fluidised bed boiler



Biomass Gasification

Thermo-chemical gasification of biomass:

Definition:

Thermo-chemical gasification is conversion of biomass into gaseous fuels and more commonly is partial-combustion of biomass in an oxygen-deficient atmosphere

Types of thermo-chemical gasification:

Classification 1:

Four types: Depending upon the gasifying medium used

- Pyrolysis
- Air gasification
- Oxygen gasification
- Hydro-gasification (steam gasification)

Classification 2:

- Atmospheric gasification
- Pressurised gasification

The main reactions are

1. Combustion Reaction:

$$C + O_2 \longleftrightarrow CO_2 + 393800 \text{ kJ/kg mole}$$

2. Boudouard Reaction:

$$C + CO_2 \longleftrightarrow 2CO - 172600 \text{ kJ/kg mole}$$

3. Water Gas Reaction:

$$C + H_2O \longleftrightarrow CO + H_2 - 131400 \text{ kJ/kg mole}$$

$$C + 2H_2O \longleftrightarrow CO_2 + 2H_2 - 88000 \text{ kJ/kg mole}$$

4. Water Shift Reaction:

$$CO + H_2O \longleftrightarrow CO_2 + H_2 + 41200 \text{ kJ/kg mole}$$

5. Methane Reaction:

$$C + 2H_2 \longleftrightarrow CH_4 + 75000 \text{ kJ/kg mole}$$

EQUIVALENCE RATIO: [weight of oxidant/weight of dry fuel]

[stoichiometric oxidant /fuel]

ER ≥ 1 ---- combustion

ER < 1 ---- gasification/ pyrolysis

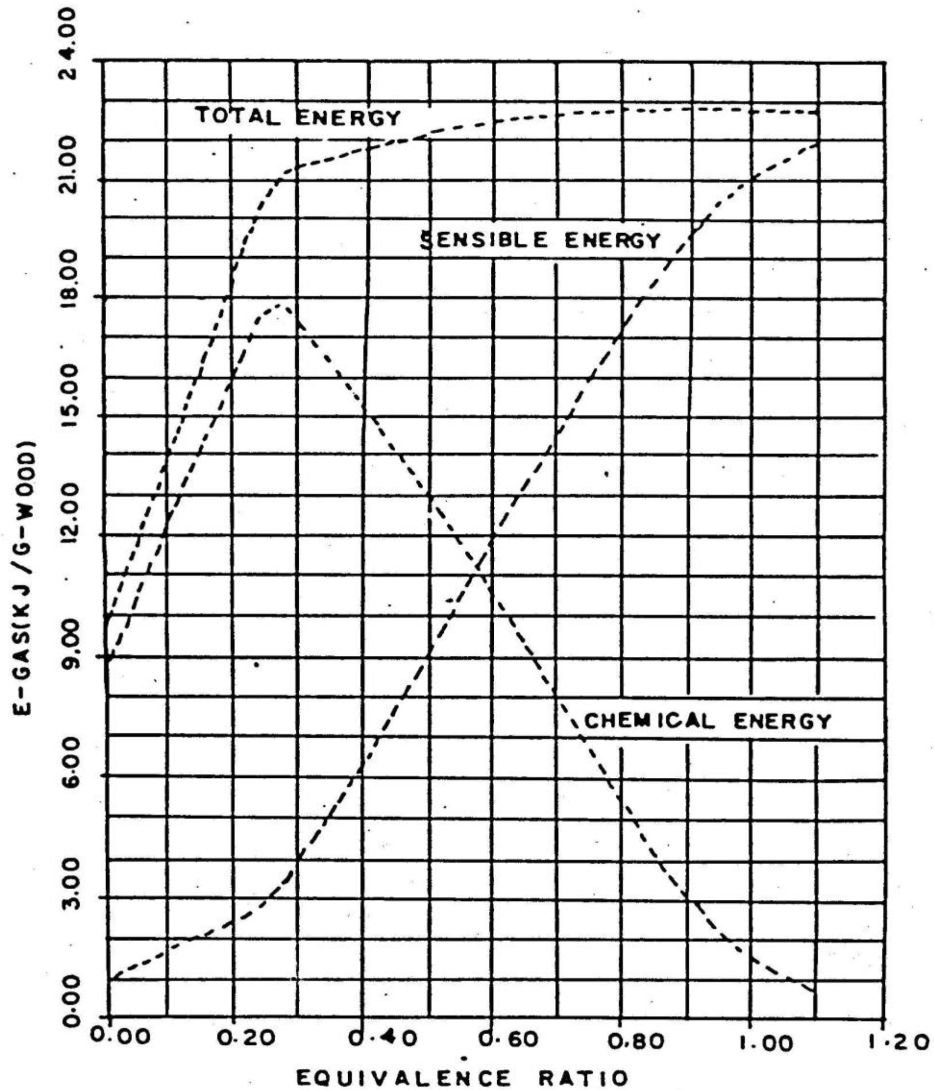
ER = 0 ---- pyrolysis

SPECIFIC GASIFICATION RATE: Amount of gas generated per unit area per unit time

Or amount of biomass gasified per unit area per unit time

Higher for down draft gasifies in order to achieve good cracking of tar

SELECTION OF EQUIVALENCE RATIO



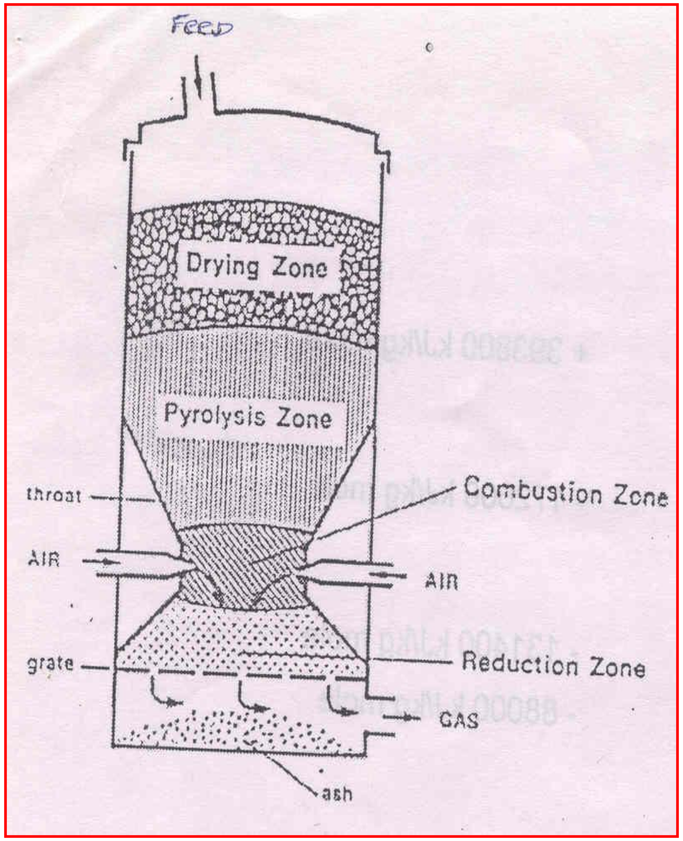
Thermo-chemical Air-Gasification of Biomass:

Thermochemical Air Gasification is effected in Reactors called Gasifiers

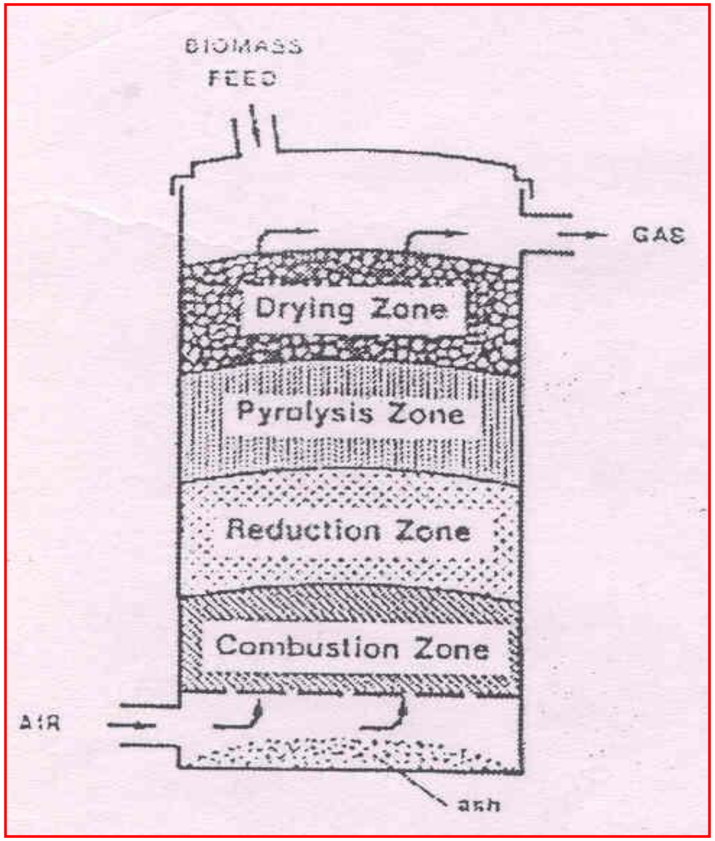
Four types of gasifiers: Based upon the direction of gas/air flow

- ✓ Down draft gasifiers
- ✓ Updraft gasifiers
- ✓ Cross draft gasifiers
- ✓ Fluidized bed gasifiers

Each type has its specific virtues and is better suited for specific application and in a specific situation

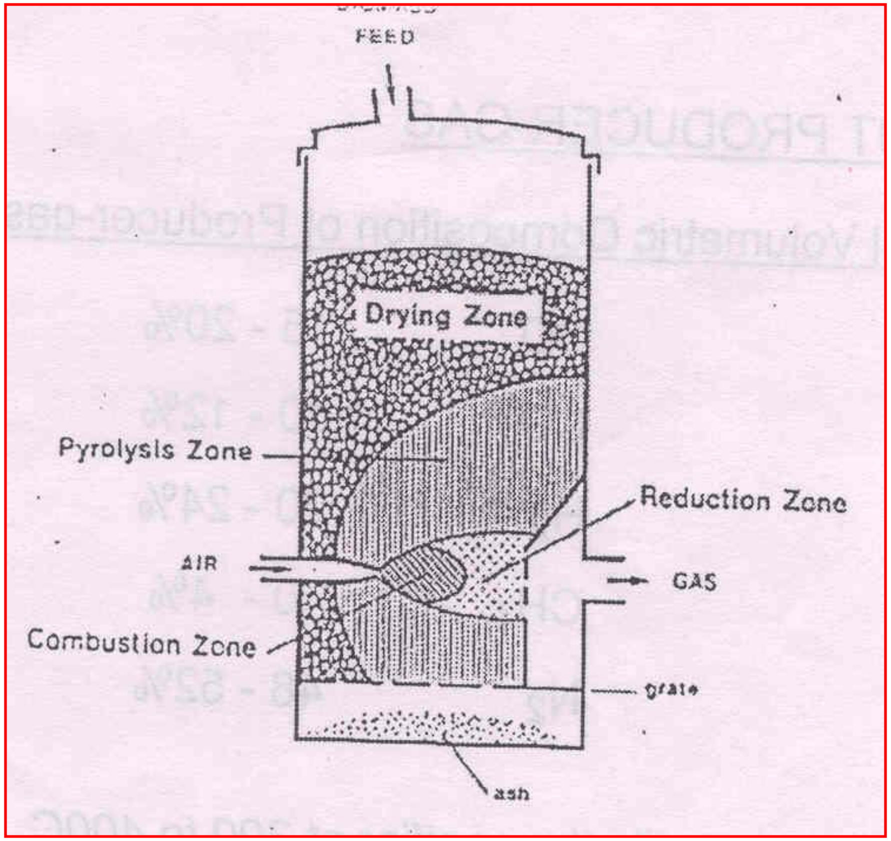


Downdraft gasifier



Updraft gasifier

Cross Draft Gasifier



About producer gas:

Typical volumetric composition of producer gas is:

CO	15-20%
CO_2	10-12%
H_2	20-24%
CH_4	0-4%
N_2	48-52%

Producer gas exits the gasifier at 300 to 400^{0}C

Contains measurable quantity of Condensibles (Tar) & Particulates

(ash, soot etc.,)

This gas is required to be cooled and cleaned before it can be used as an engine fuel. It can however be used as it comes for Thermal Applications.

Producer gas compared with other fuels:

Fuel		Gasoline	Diesel	Biogas	Producer Gas
Composition		--	--	CH_4 60-70% CO_2 30 – 40%	CO 15-20% H2 20-24% CH4 0-4% CO2 10-12% N2 48-52%
Density (kg/m^3)		713-730	800-840	1.090	1.014
Calorific Value	kcal/kg	~10,500	10,500	4,180	900-1200
	kcal/m^3	~7,130	8,000	4,560	900-1100

Producer Gas is a LCV gas as against biogas which can be termed as MCV and Natural Gas as HCV

THANK YOU