Biomass Gasification Techniques

Current Focus

- **Platform technologies**
- **Sugar Platform Technology**
- **Thermochemical Platform Technology**

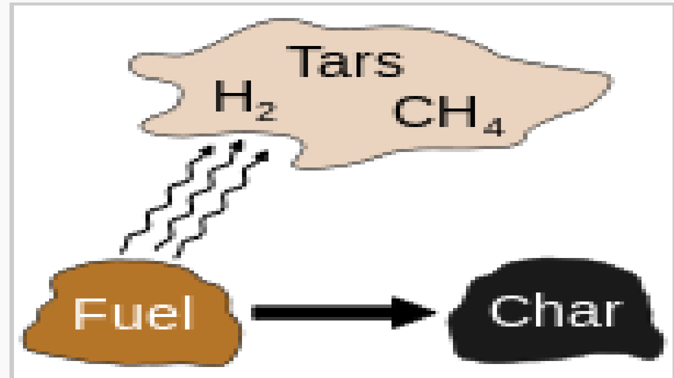
Gasification Technology

- Gobar gas Production
- Biogas
- Synthesis gas

Chemistry of Gasifier

1. Dehydration:

- around 100 C
- drying process



Pyrolysis of carbonaceous fuels

https://en.wikipedia.org/wiki/File:Pyrolysis.svg

2. Pyrolysis:

- around 200 -300 C
- volatiles are released & Char produced
- 70% weight loss

$$Pyrolysis: Biomass + Heat \rightarrow Chrcoal, Oil, Gas \qquad (a)$$

3. Combustion:

$$Combustion: Biomass + Stochiometric\ oxygen \rightarrow Hot\ combusion\ products\ (c)$$

- around 900 C
- Combustion of Char is exothermic

$C + O_2 \longrightarrow CO_2$(+ 393 MJ/kg mole)

$2H_2 + O_2 \longrightarrow 2H_2O$ (- 242 MJ/kg mole)

4. Reduction:

- Endothermic
- ability to reduce gas temperature

$C + CO_2 \longrightarrow 2CO$ (- 164.9 MJ/kg mole)

$C + H_2O \longrightarrow CO + H_2$ (- 122.6 MJ/kg mole)

5. Gasification:

- A process that uses heat, pressure, and steam to convert materials directly into a gas composed primarily of carbon monoxide and hydrogen.

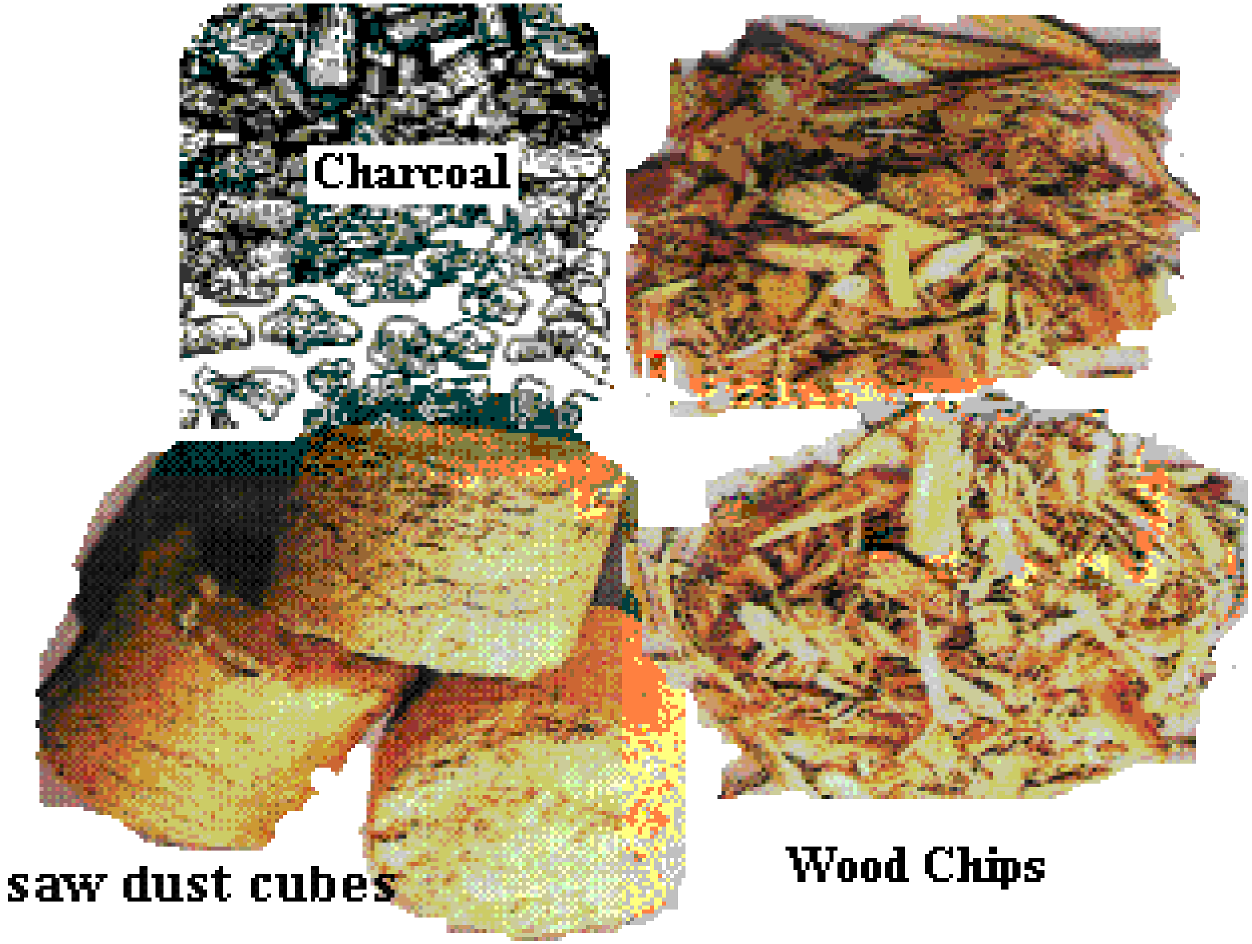
$$Gasification : Biomass + Limited\ oxygen \rightarrow Fuel\ gas \quad (b)$$

- Gasification technologies rely four key engineering factors

1. Gasification reactor atmosphere (level of oxygen or air content).
2. Reactor design.
3. Internal and external heating.
4. Operating temperature.

- **Typical raw materials** - coal, petroleum-based materials, and organic materials.
- The feedstock is prepared and fed, in either dry or slurried form, into a sealed reactor chamber called a **gasifier**.
- The feedstock is subjected to high heat, pressure, and either an oxygen-rich or oxygen-starved environment within the gasifier.

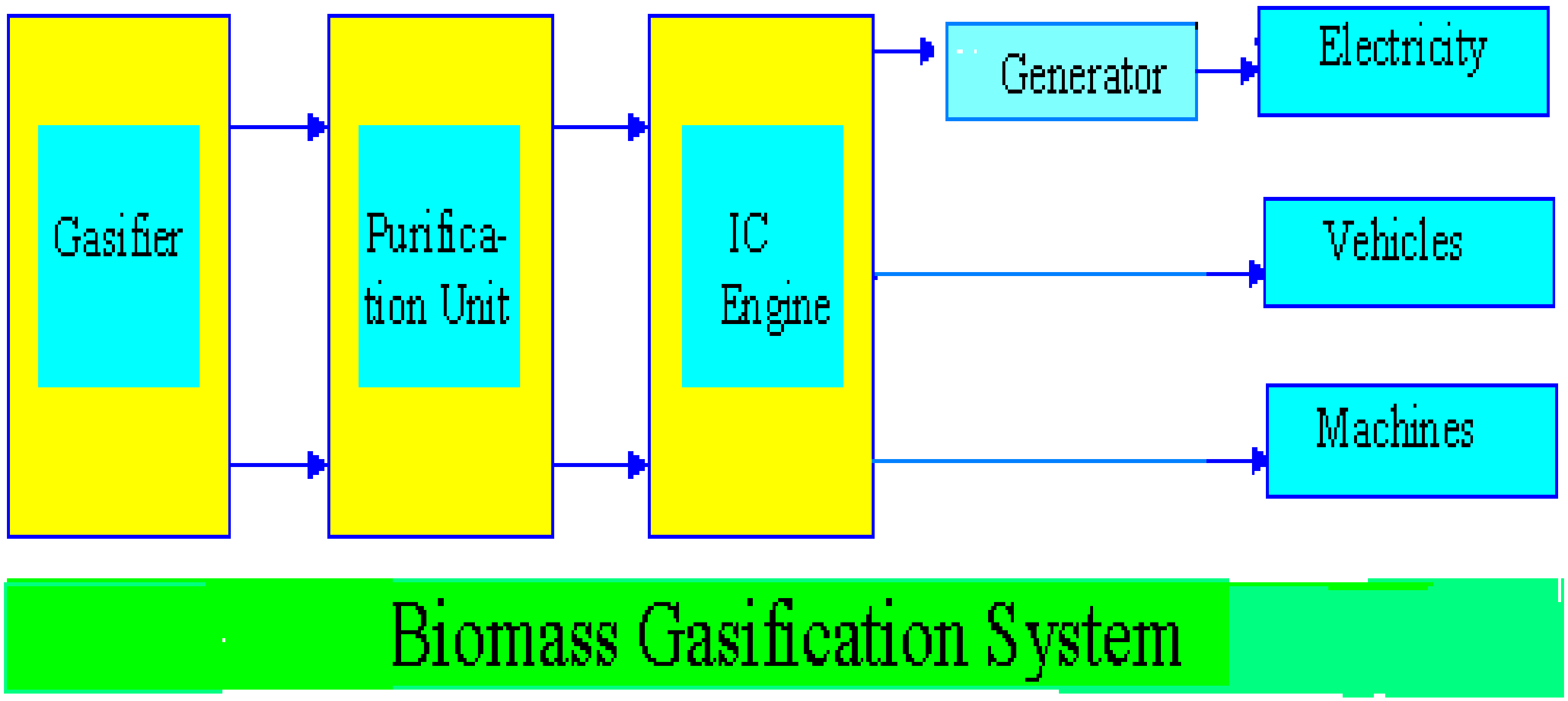
Raw Materials for Gasification



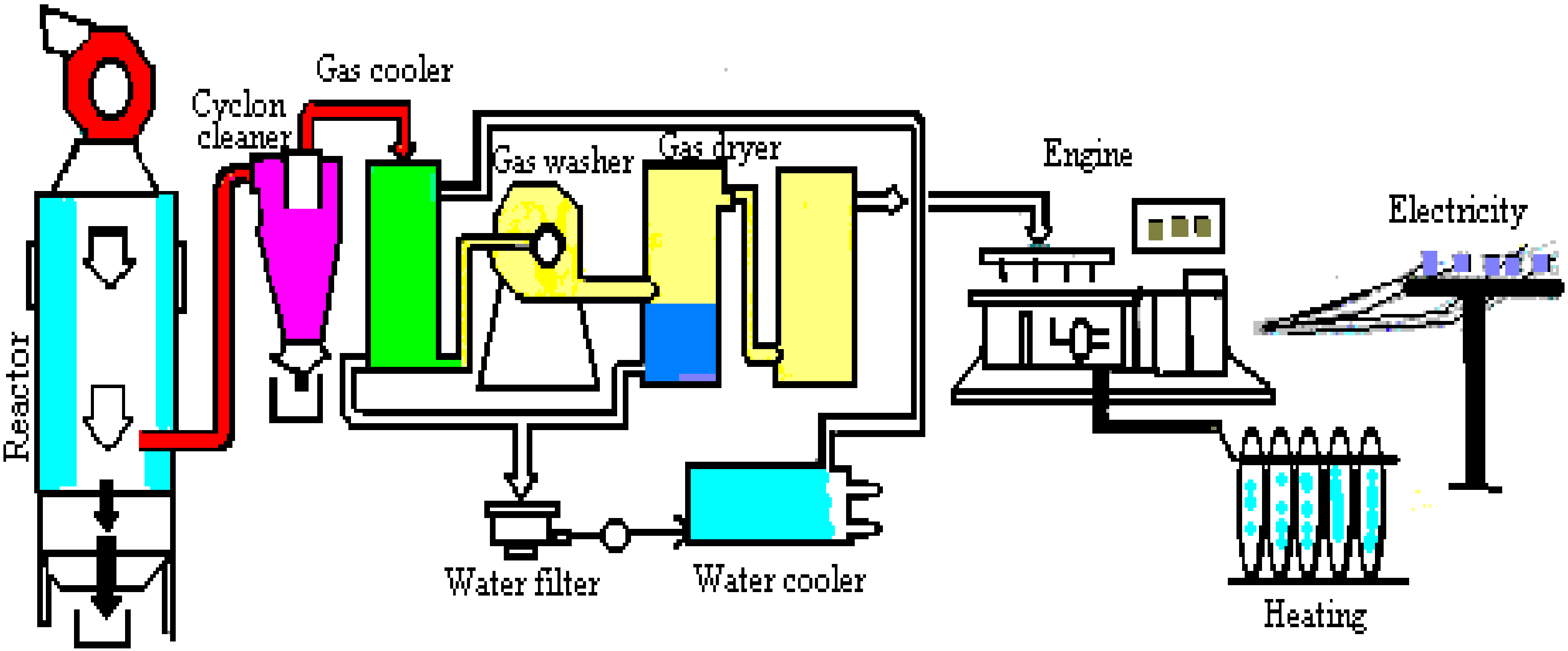
- **Products of gasification :**
  * Hydrocarbon gases (also called syngas).
  * Hydrocarbon liquids (oils).
  * Char (carbon black and ash).

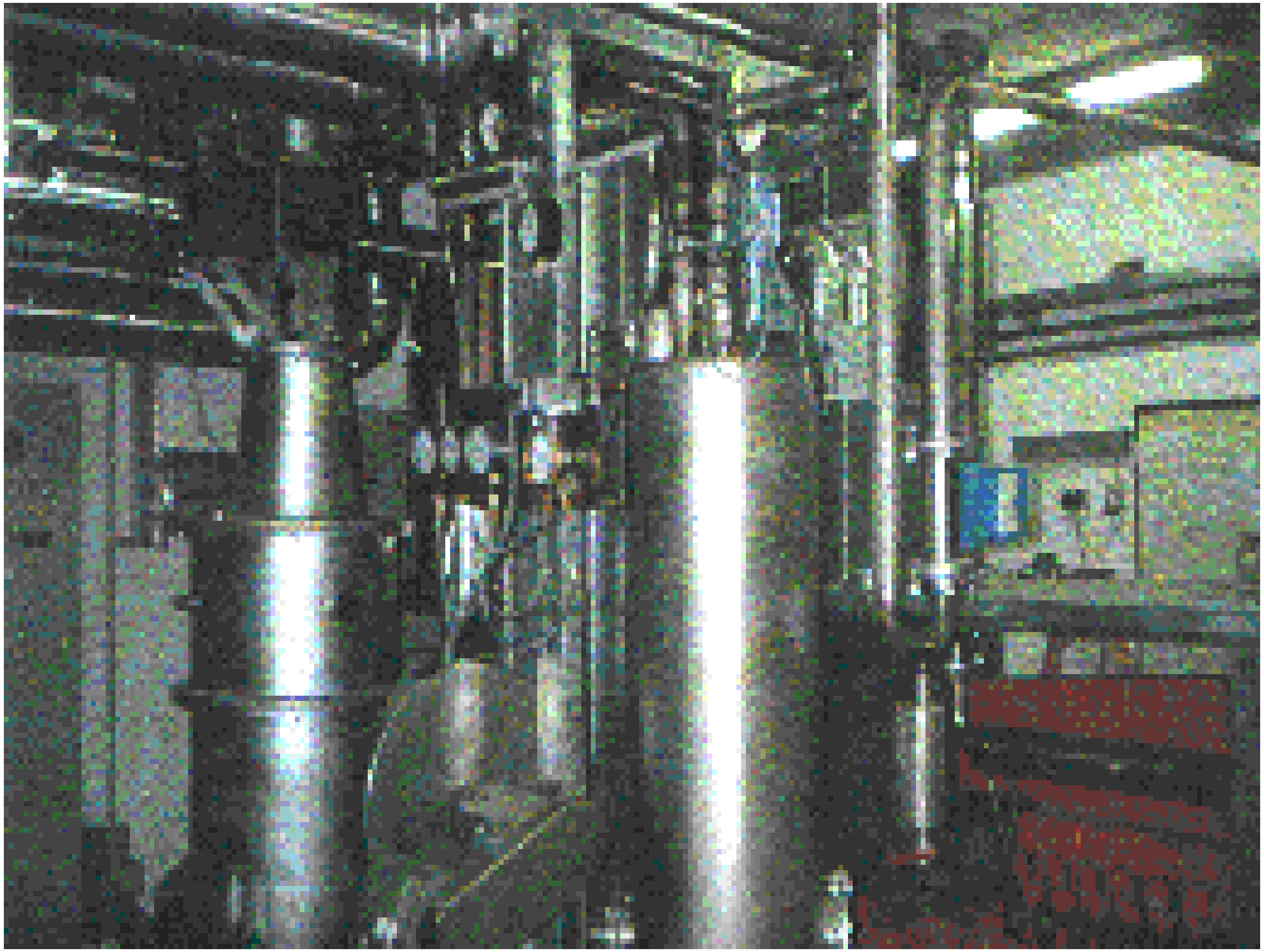
- **Syngas** is primarily carbon monoxide and hydrogen (more than 85 percent by volume) and smaller quantities of carbon dioxide and methane

Gasifier Plant



Gasifier Plant

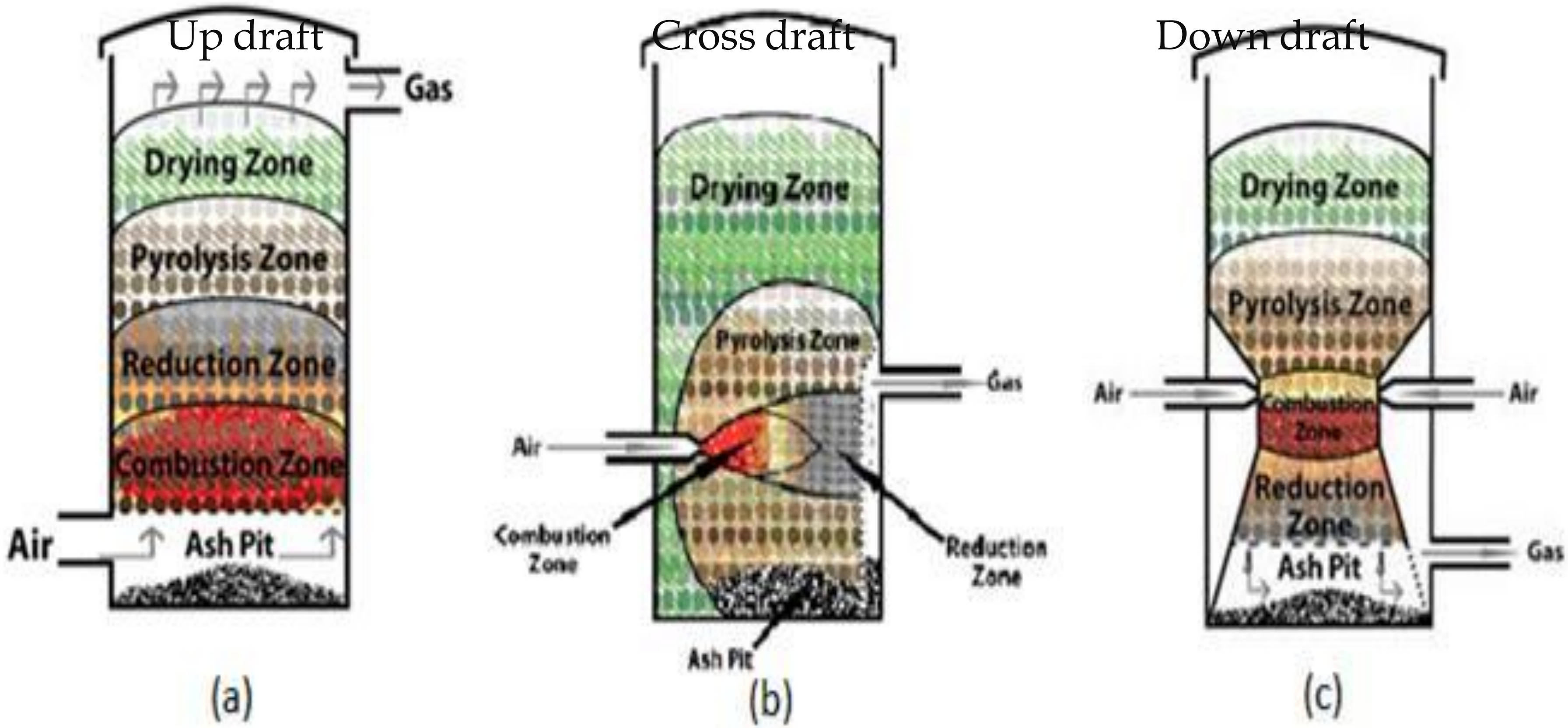




Wood gasifier for co-gen set

Types of Gasifier

1.As per position of inlet and outlet



http://www.oil-gasportal.com/wp-content/uploads/2015/03/Immagine41.png

2. Based on types of bed :

a. Fixed bed

b. Fluidised bed

3. As per output power :

a. Small size(up 10 kW)

b. Medium size(10 – 50 kW)

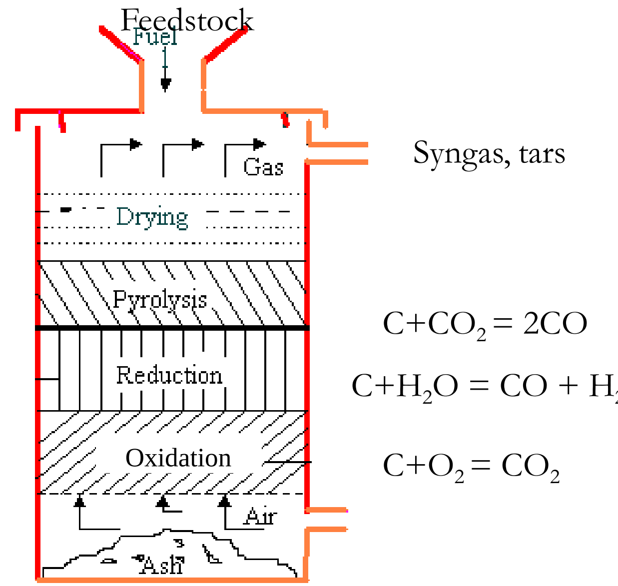
c. Large size (50 – 300 kW)

d. very large (above 300 kW)

Fixed Bed Gasifier – Updraft

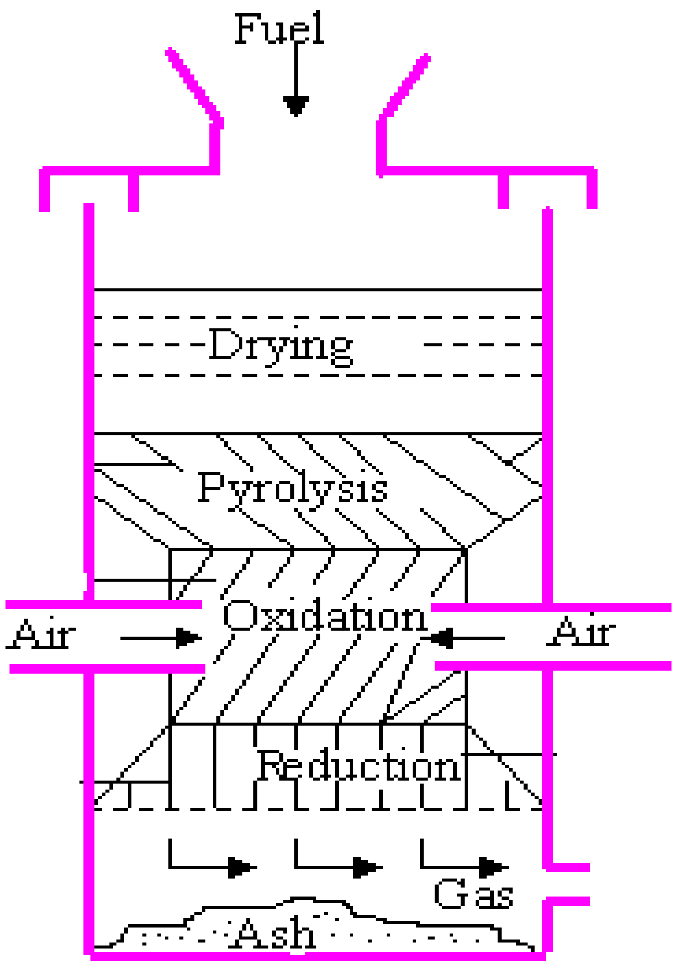
- Feedstock is pre-dried before it gets to gasification zone
- Can handle high moisture biomass
- Heat source is oxidation of char
- Operates at low temperatures
- High amount of tar in syngas

–Must be cleaned prior to downstream use



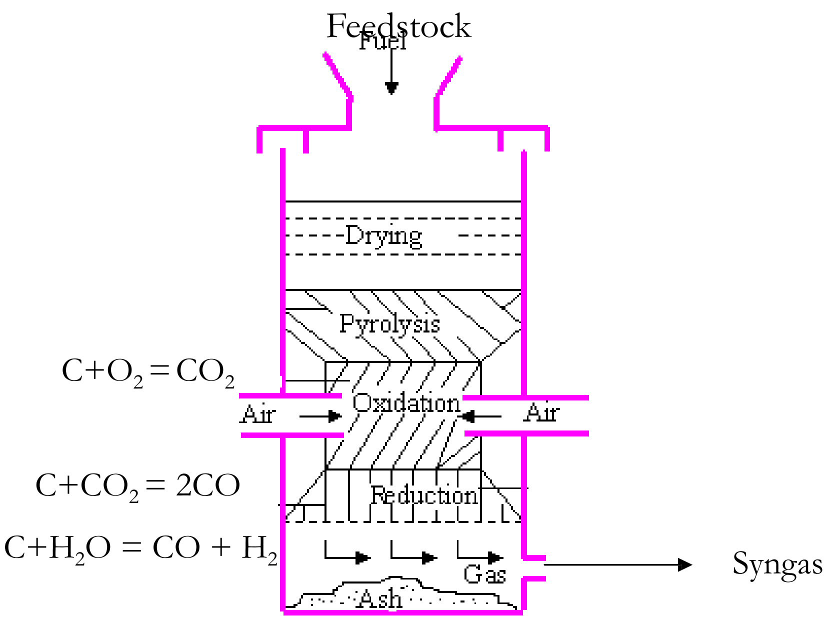
Types of Gasifiers

- Downdraft Gasifier



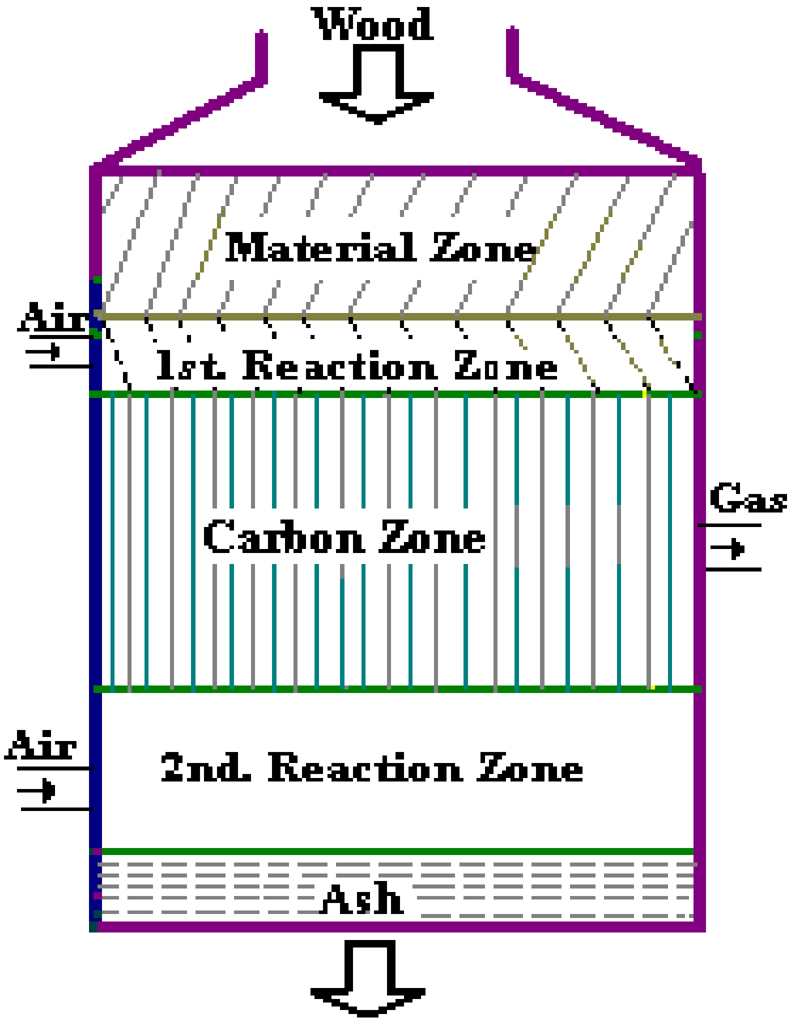
Fixed Bed Gasifier – Downdraft

- Needs low moisture (<20%) and low ash
- Fines are a problem
- Heat source is oxidation of volatile gases
- Operates at high temperatures
- Low tars in syngas



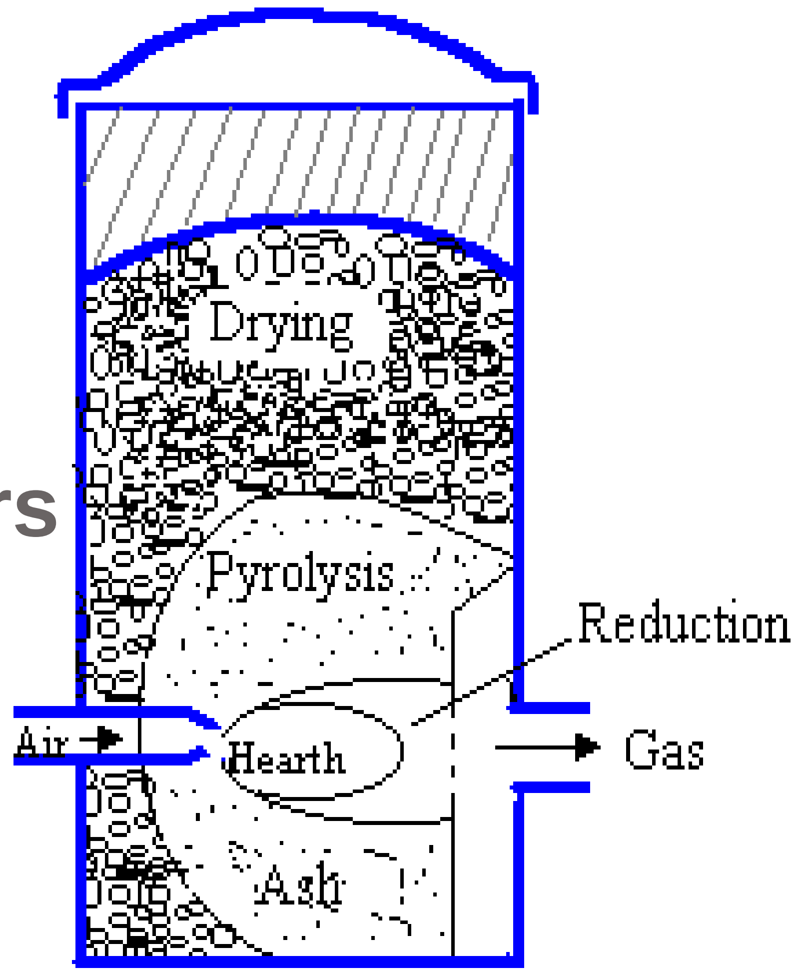
Types of Gasifiers

- Twin-fire Gasifier



Types of Gasifiers

- **Crossdraft gas producers**

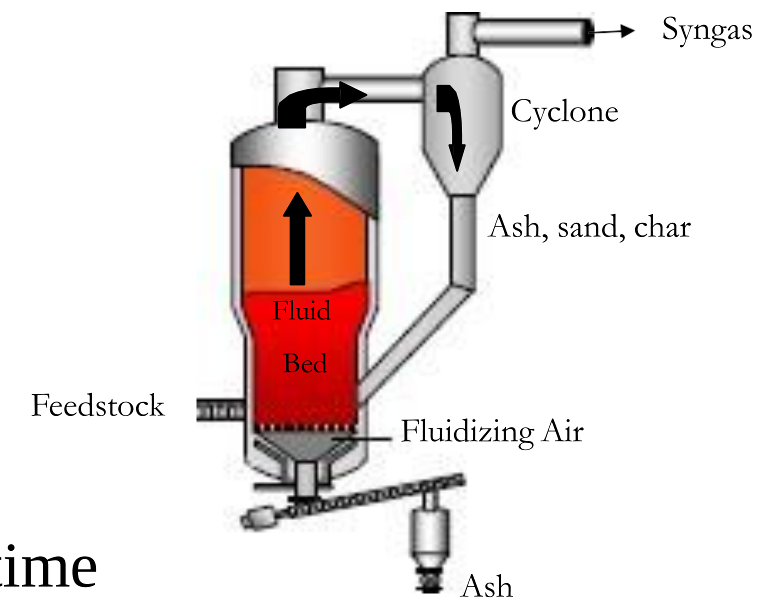


Advantages and Disadvantages

Sr. No.	Gasifier Type	Advantage	Disadvantage
1	Updraft	➢ Small pressure drop ➢ Good thermal energy efficiency due to the low temperature of the gas leaving the chamber ➢ Little tendency towards slag ➢ Handle high moisture and inorganic content	➢ Poor reaction capability with heavy gas load ➢ Syngas can contain high levels of tars and hydrocarbons. ➢ Furthermore, updraft gasifiers have a feed size limit, and slagging potential.
2	Downdraft	➢ Flexible adaptation of gas production to load. ➢ Low sensitivity to charcoal dust and tar content of fuel. ➢ It produces a relatively cleaner gas with very low tar formation.	➢ Design tends to be tall. ➢ Not feasible for very small part. ➢ Requires low moisture and ash feedstock, can only use feedstocks within a limited particle size range (between 1-30 cm)
3	Cross draft	➢ Short design height ➢ very fast response time to load ➢ flexible gas production	➢ Very high sensitivity to slag formation ➢ High pressure drop

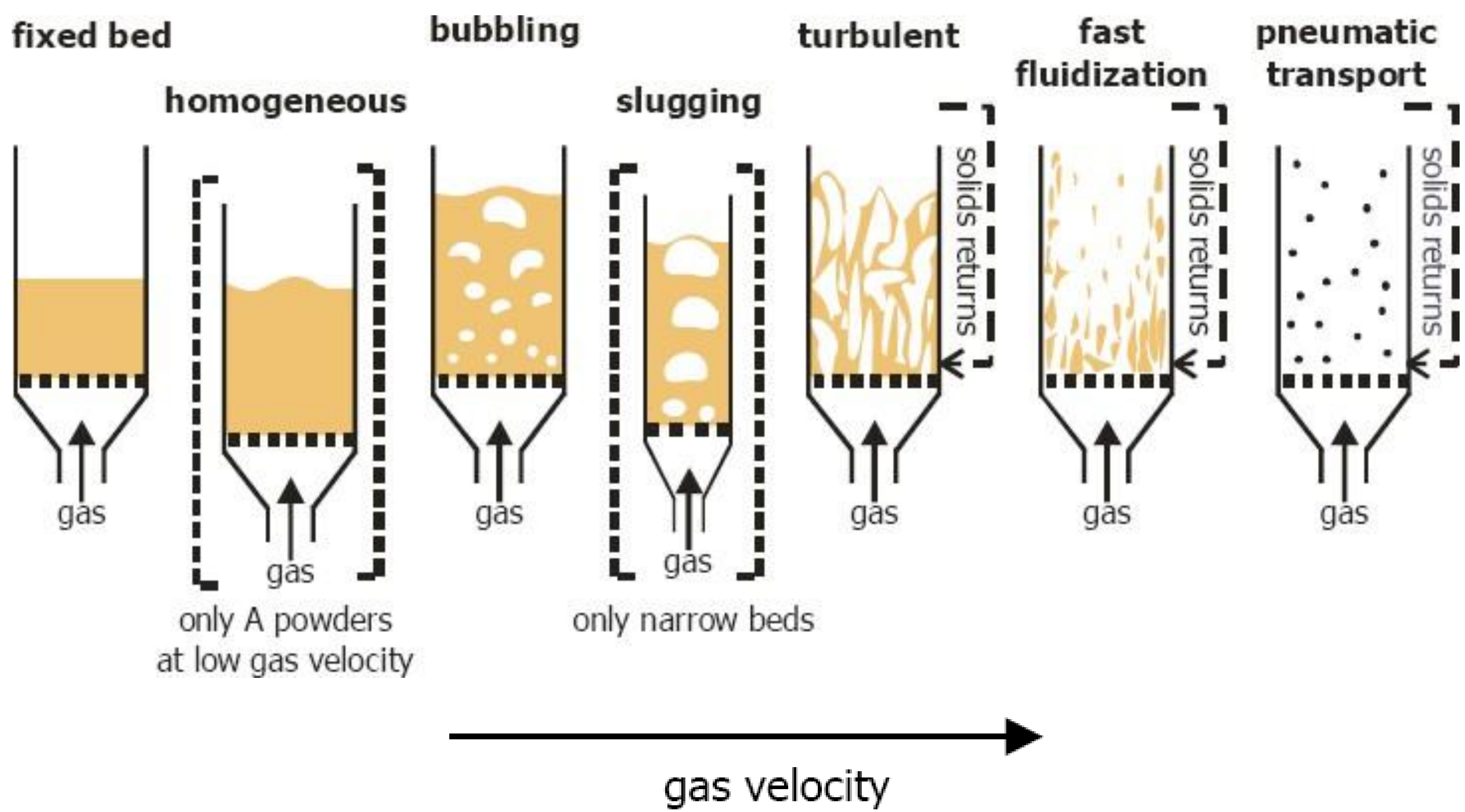
Fluid Bed Gasifiers

- Good for low reactivity feedstocks
- Good for fines
- Air/sand bed mixture is fluidized
- Moderate temperatures
- Provides high turbulence and residence time
- High carbon conversion
- Syngas/ash/sand mixture exits to cyclone
  – Ash/sand mixture is returned to bed
- Low tars in syngas



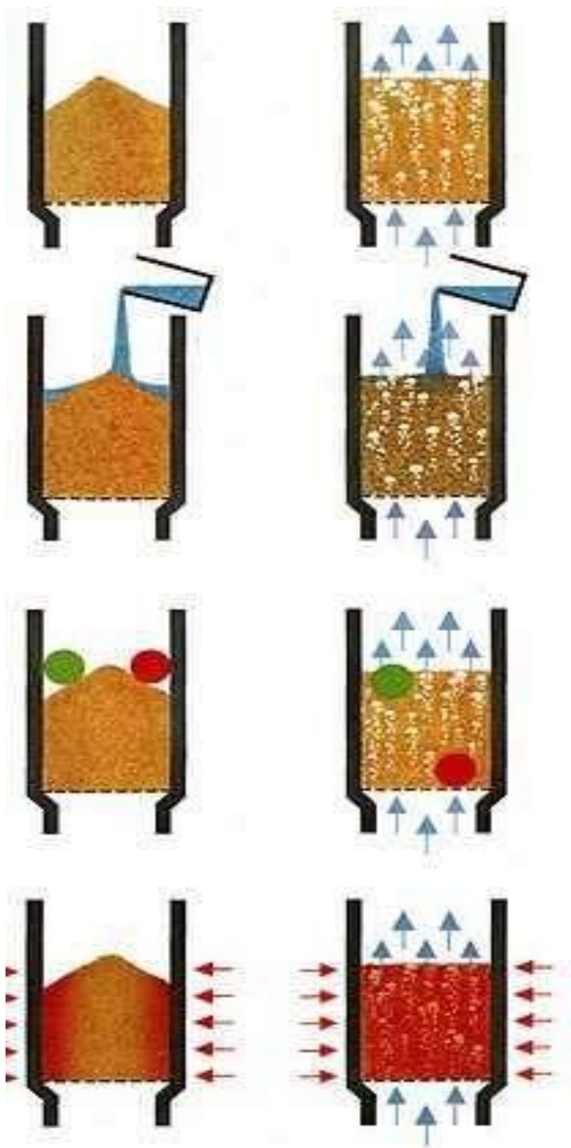
Flow Regimes in Fluidized Beds

J. Ruud van Ommen, 2003



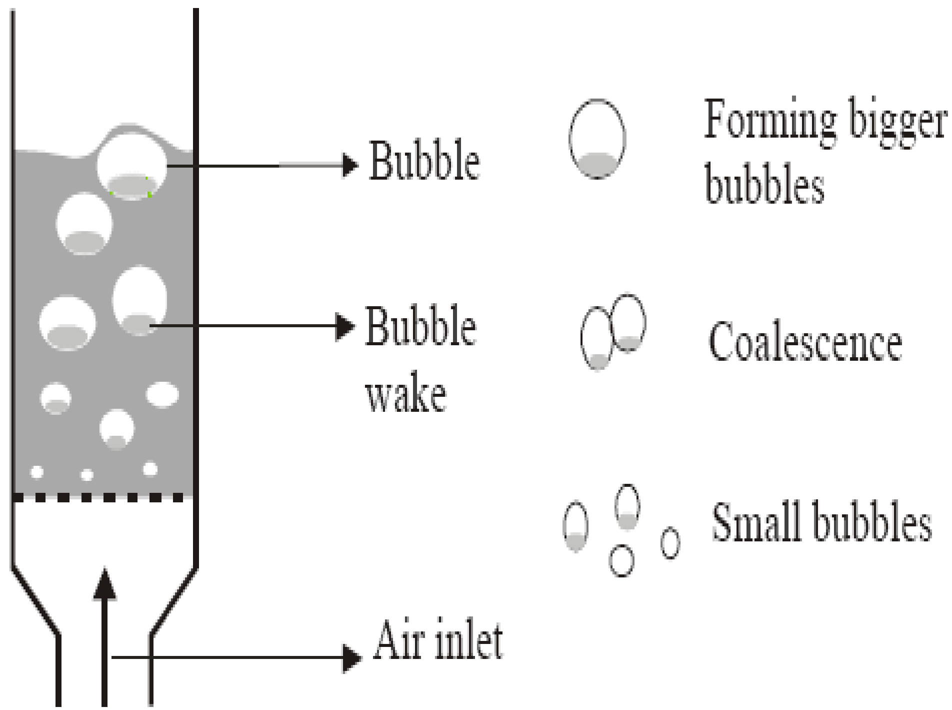
MECHANISM **Fluidisation of solids**

- Sand particles resting on a mesh (left) become fluidised when air is blown through (right) and take on the appearance and some of the properties of a boiling fluid.
- Granular solids remain in layers when one is poured on to another (left), but rapid mixing occurs on fluidisation (right).
- A bed of stationary particles supports objects whatever their density (left). On fluidisation, an object of lower density (the green ball) floats while the higher density (red ball) sinks.
- In a bed of stationary particles (left), heat is transferred slowly and there are big differences in temperature. In a fluidised bed (right), rapid mixing ensures uniformity of temperature.



Bubbling Fluidization

- ✓ This type of fluidization has been called 'aggregative fluidization', and under these conditions, the bed appears to be divided into two phases, the bubble phase and the emulsion phase.
- ✓ The bubbles appear to be very similar to gas bubbles formed in a liquid and they behave in a similar manner. The bubbles coalesce as they rise through the bed.



Turbulent Fluidization

Turbulent regime has the following features:-

✓High solid hold-ups (typically 25-35 % by volume).

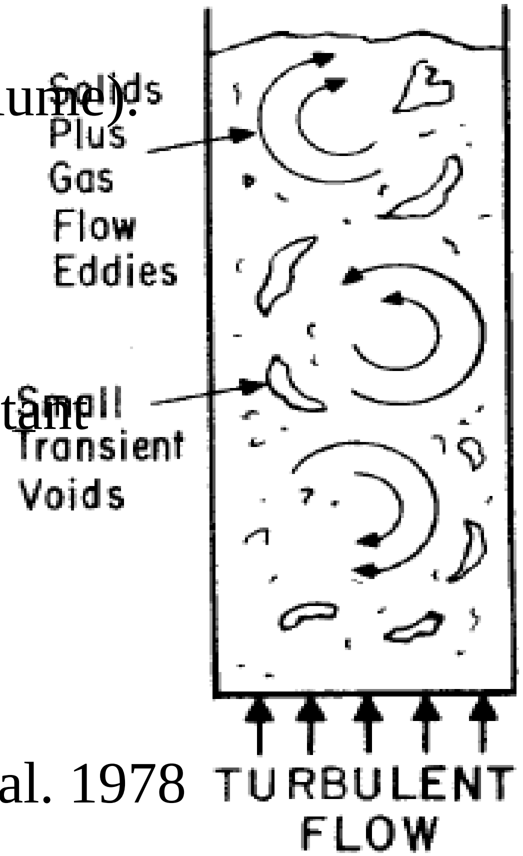
✓Limited axial mixing of gas.

✓Suitable for exothermic and fast reactions.

✓Good gas-solid contact and hence, favors reactant conversion.

✓high gas flow-rates operation and good for isothermal operation.

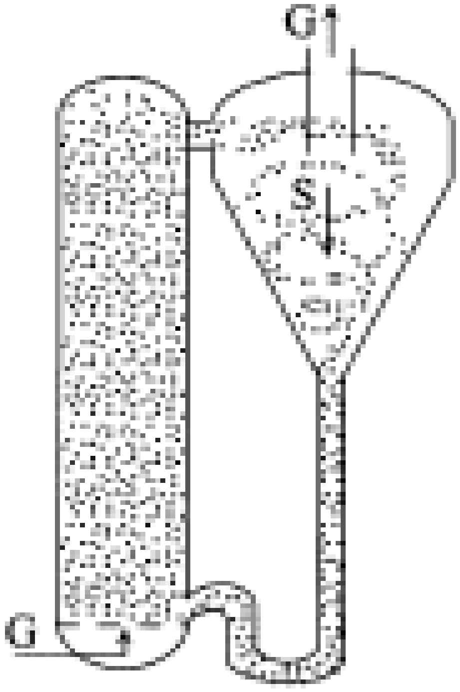
✓Favorable bed to surface heat transfer.



Canada et al. 1978

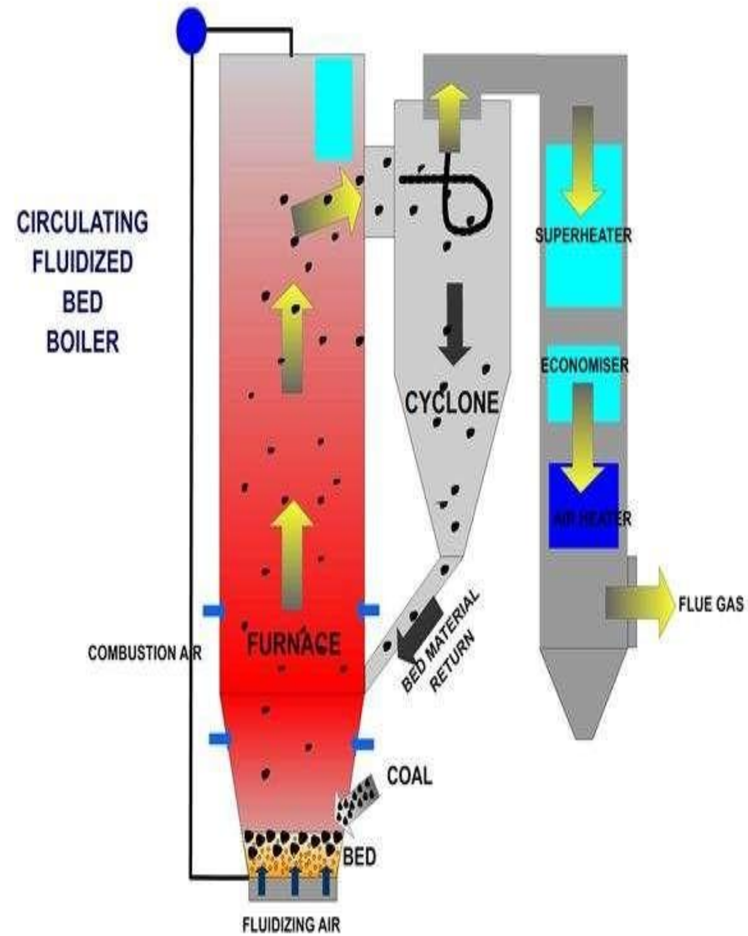
Fast Fluidized Bed

- ✓ The fast fluidization occurs as a result of continuing increasing in operating velocity beyond that required at turbulent fluidization, a critical velocity, commonly called the transport velocity (Utr), will be reached where a significant particle entrainment occurs.
- ✓ The CFB has significant industrial applications because of its efficiency, operational flexibility, and overall profitability (Berruti *et al.*, 1995).



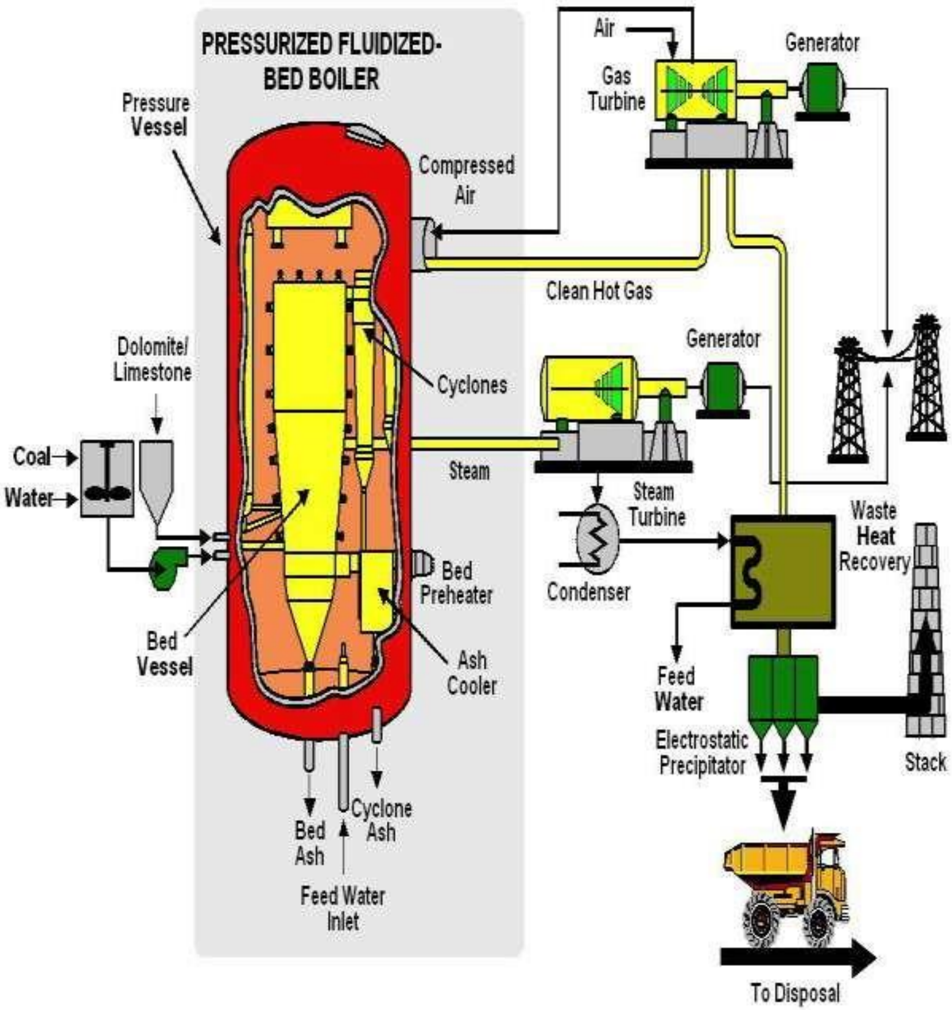
Circulating Fluidised Bed Combustion (CFBC)

- Taller boiler structure
- Coal is crushed to a size of 6 –12 mm dependin
  on the rank of coal.
- The fluidising velocity in circulating beds range
  from
  3.7 to 9 m/sec.
- Combustion efficiency as high as 99.5%.
- The combustion takes place at 840-900ºC, and t
  fine particles (<450 microns) are elutriated out o
  the furnace with flue gas velocity of 4-6 m/s.
- The particles are then collected by the solids
  separators and circulated back into the furnace.
- There are no steam generation tubes immersed i
  the bed.



Pressurised Fluid Bed Combustion

- Combined cycle i.e Rankine & Brayton cycle using steam & gas turbine.
- Operating temp. & pressure is 860°C & 16-18 bars.
- The fuel is fed along with the sorbent and maintained in fluidised condition in the pr combustion chamber.
- The pressurized flue gases are cleaned off expanded into a gas turbine.
- In addition, the excess air requirements of are met by the gas turbine compressor.
- Power generated by steam cycle and thc generated by gas turbine which is of the 80:20

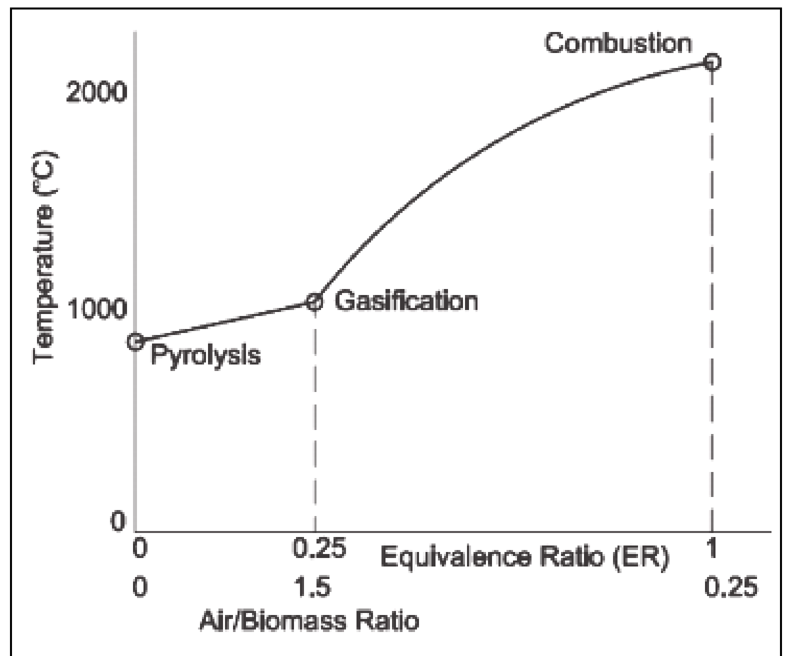


Factors Effects of gasification operation:

Air flow rate (equivalence ratio, ER or superficial velocity, SV)

- ***Equivalence ratio (ER)***: Ratio of air flow to the airflow required for stoichiometric combustion of the biomass, which indicates extent of partial combustion. With stoichiometric oxidation or complete combustion taking place at ER = 1. ER ratio varies between ranges of 0.10 to 0.30

$$ER = \frac{\dfrac{F_{oxidant}}{F_{biomass}}}{\dfrac{F_{oxidant,stochioometry}}{F_{biomass}}}$$



- ***Superficial velocity (SV)***: Ratio of air flow to the cross-sectional area of the gasifier which removes the influence of gasifier dimension by normalization. Hence, both ER and SV are directly proportional to the airflow. SV should be 0.63 for pyrolysis zone and 2.5 m/s for char zone. Yamazaki found that, in a downdraft gasifier, a higher SV of 0.7 m/s resulted in higher amount of tar as compared to a lower SV of 0.4 m/s.
- An excess degree of combustion, on the other hand, results in decreased energy content of the gas produced because a part of biomass energy is spent during combustion. Higher airflow also shortens the residence time which may decrease the extent of biomass conversion.

- **Steam flow rate (steam to biomass ratio, S/B)**
- Supplying steam as a gasifying agent increases the partial pressure of H_2O inside the gasification chamber which favors the water gas, water gas shift and methane reforming reactions, leading to increased H_2 production.
- The gasification temperature needs to be high enough (above 750–800 °C) for the steam reforming and water gas reactions to be favorable.
- Higher S/B also leads to higher biomass conversion efficiency.
- Reduction in tar also is observed at higher steam to biomass ratios, which is attributed to steam reforming of the tar with an increased partial pressure of steam.

CHP – heat and power from biomass
Machine assembly

Biomass drying
Flash dryer or
rotary dryer

Biomass grinding
to <2-3 mm
Hammer mill

Gasification and cleaning of Syngas
Universal gasifier
"Gasifired Vergassen GB 3G Series"

CHP unit
Container unit
or unit for
machine room

Advantages of FBC Gasifier

1. High Efficiency.

Combustion efficiency of over 95%

Overall operating efficiency is 84%

2. Fuel Flexibility.

3. Ability to Burn Low Grade Fuel.

4. Pollution Control.

SOx formation is minimised by addition of limestone for high sulphur coals.

$CaCO_3$ (solid) + SO_2 (gas) → $CaSO_3$ (solid) + CO_2 (gas) SO3 + CaCO3 = CaSO3 + CO3

Low combustion temperature eliminates NOx formation.

NOx formation takes place around1500° C

5. Easier Ash Removal – No Clinker Formation

6. Simple Operation, Quick Start-Up

7. No Slagging in the Furnace-No Soot Blowing

8. Provisions of Automatic Coal and Ash Handling System

9. Provision of Automatic Ignition System 10.High Reliability and

low maintenance costs.

Disadvantages of FBC Gasifier

1. The only disadvantage is that, a large amount of power will be required to lift up the silica surface. So motor of force draft fan will b twice bigger than that of other conventional system.

Referance

1 . http://mnre.gov.in/file-manager/annual-report/2014-2015/EN/Chapter%201/chapter_1.htm

2. MNRE, GOI ; CEA Statistics GEF National Workshop in India ,MNRE 3. https://en.wikipedia.org/wiki/File:Pyrolysis.svg

4.http://www.oil-gasportal.com/wp-content/uploads/2015/03/Immagine41.png

5.Case Studies on Small Scale Biomass Gasifier Based Decentralized Energy Generation Systems by G. Sridhar, H .V. Sridhar, Basawaraj, M. S. Sudarshan, H. I. Somsekhar, S. Dasappa, P. J. Paul

6.Non conventional energy sources by G.D. Rai


THESE BIOFUELS WORK GREAT... ESPECIALLY AFTER ADDING THIS GASOLINE ENGINE!
BioFuels
Renewable Energy Source
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Thank You