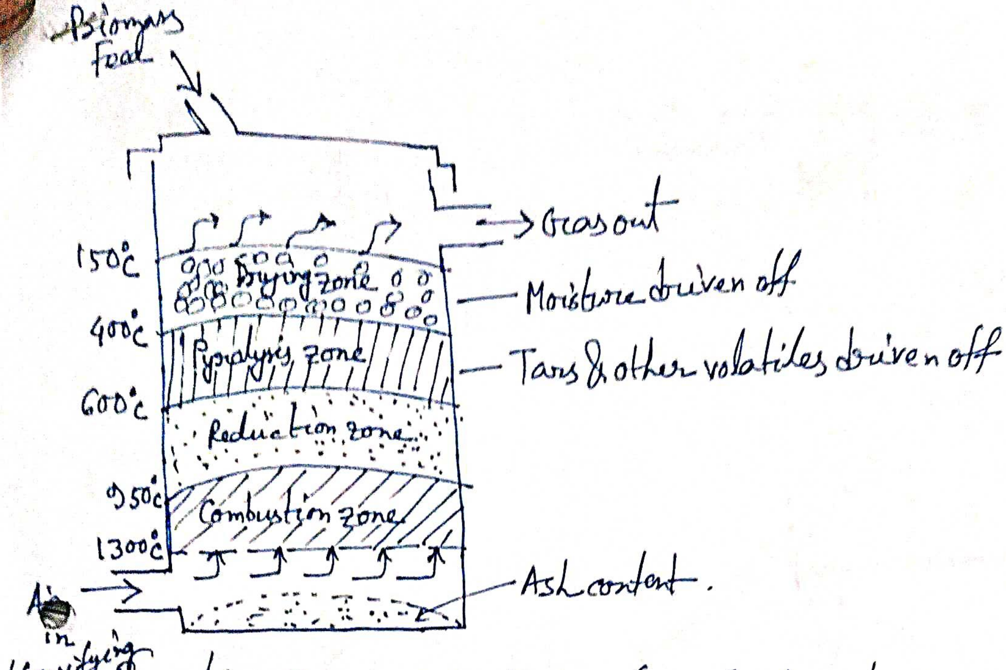
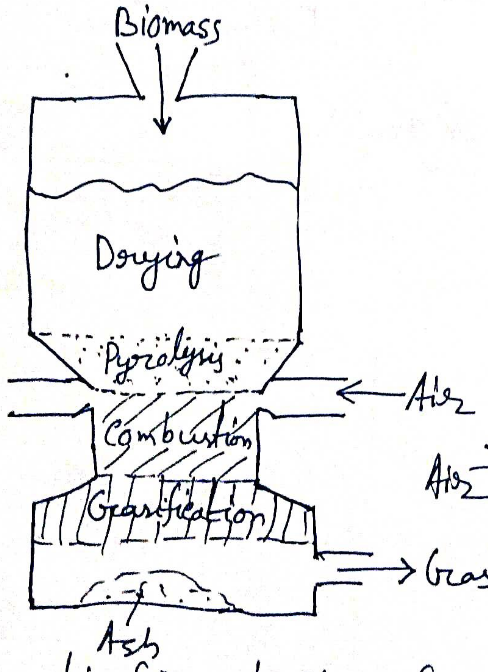
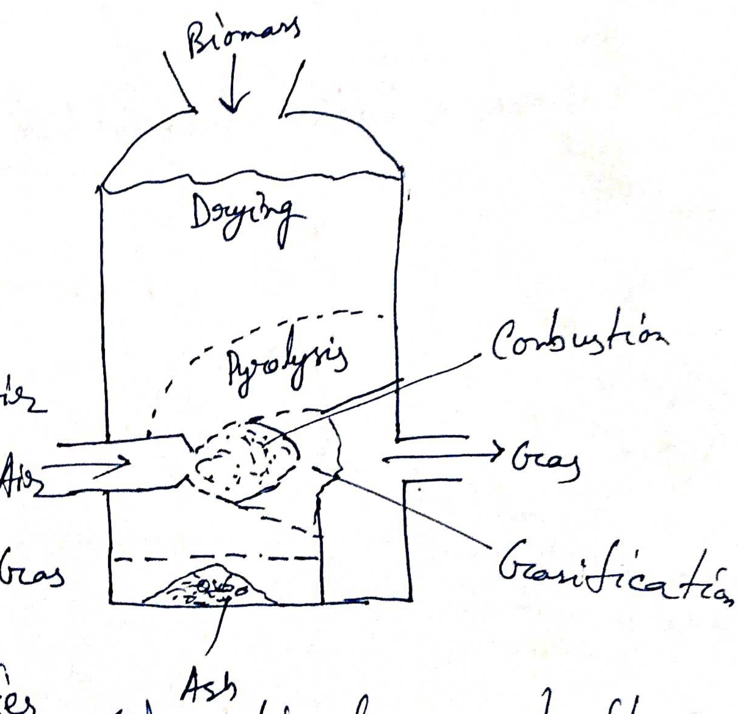


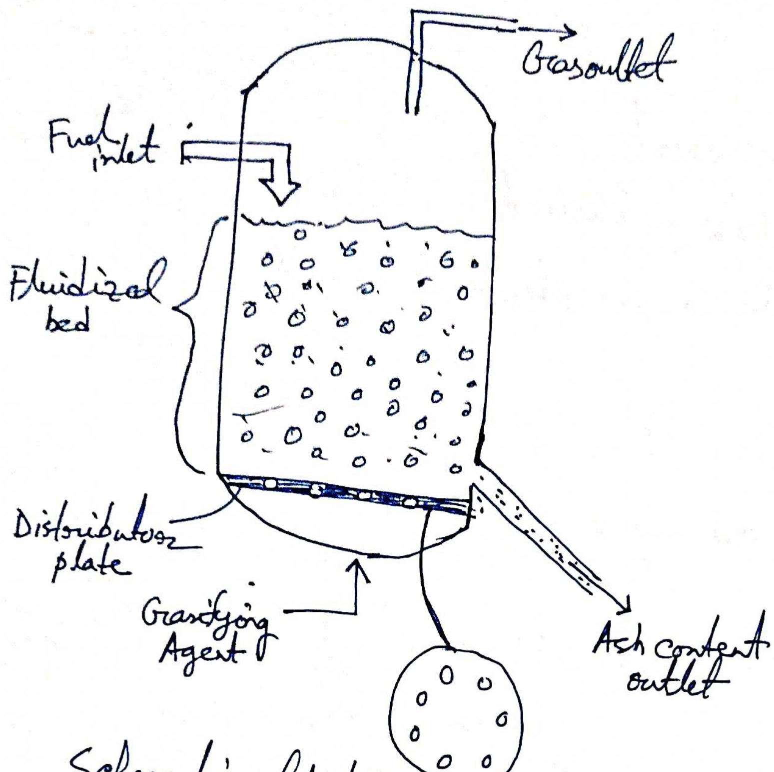
Reaction Zones in Updraft Gasifier (schematic)



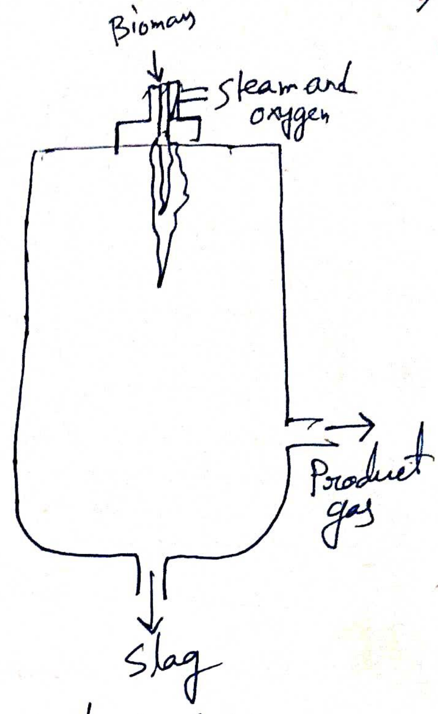
Schematic of Downdraft Gasifier



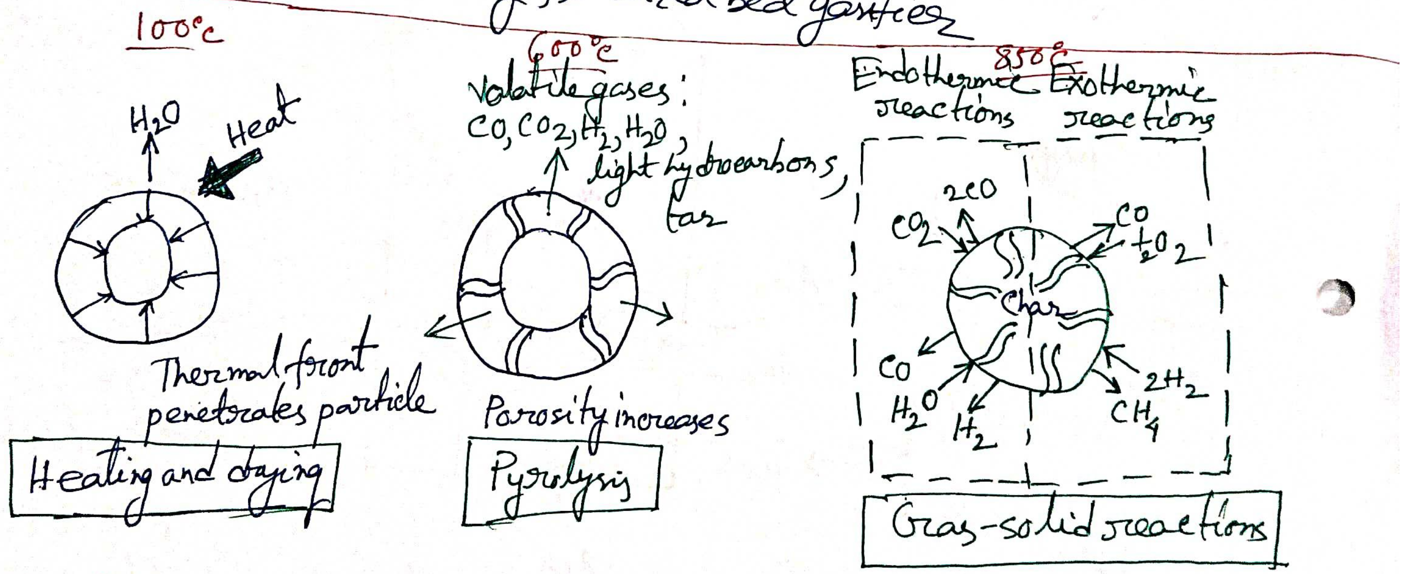
Schematic of a crossdraft Gasifier



Schematic of bubbling fluidized bed gasifier



Entrained flow gasifier



$$CO + H_2O \rightarrow CO_2 + H_2$$
$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

Gas-phase reactions

Processes of Thermal gasification

Gasification air requirements

$$C_aH_bO_cN_dS_e + fO_2 + 3.76fN_2 \rightarrow aCO_2 + \frac{b}{2}H_2O + eSO_2 + \left(3.76f + \frac{d}{2}\right)N_2$$

For full combustion, the moles of oxygen required are f:

$$f = a + \frac{b}{4} + e - \frac{c}{2}$$

For example, the moles of oxygen required to fully combust coal are

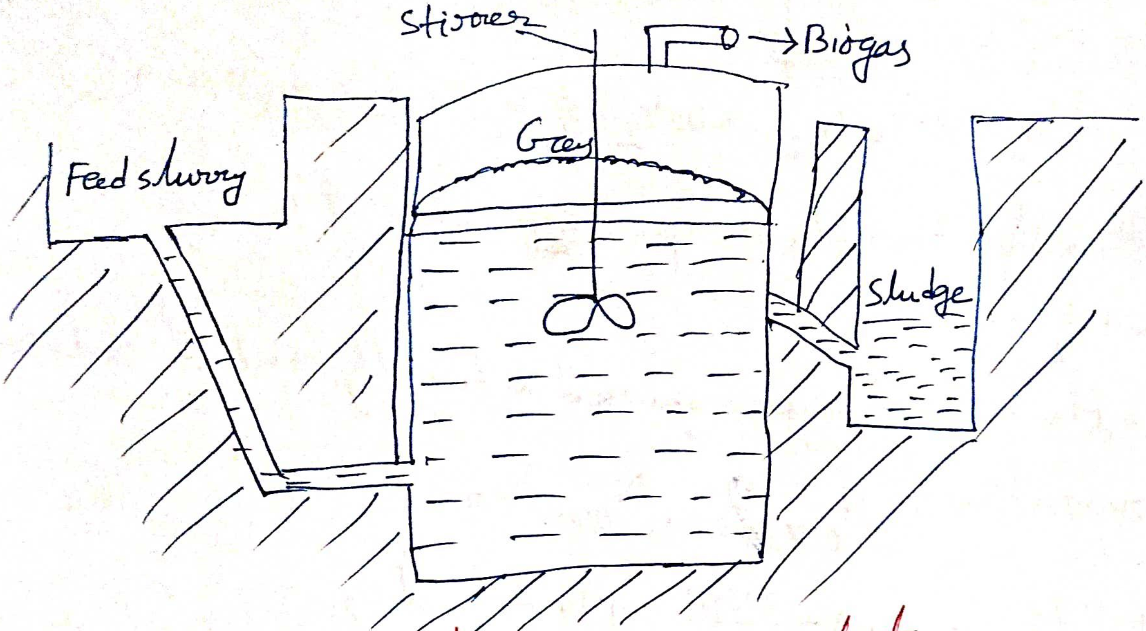
Coal composition $= CH_{0.739}O_{0.091}N_{0.014}S_{0.003}$

$$f = 1 + \frac{0.739}{4} + 0.003 - \frac{0.091}{2} = 1.14 \text{ moles of } O_2$$

- We can calculate stoichiometric oxygen requirement on a mass basis using

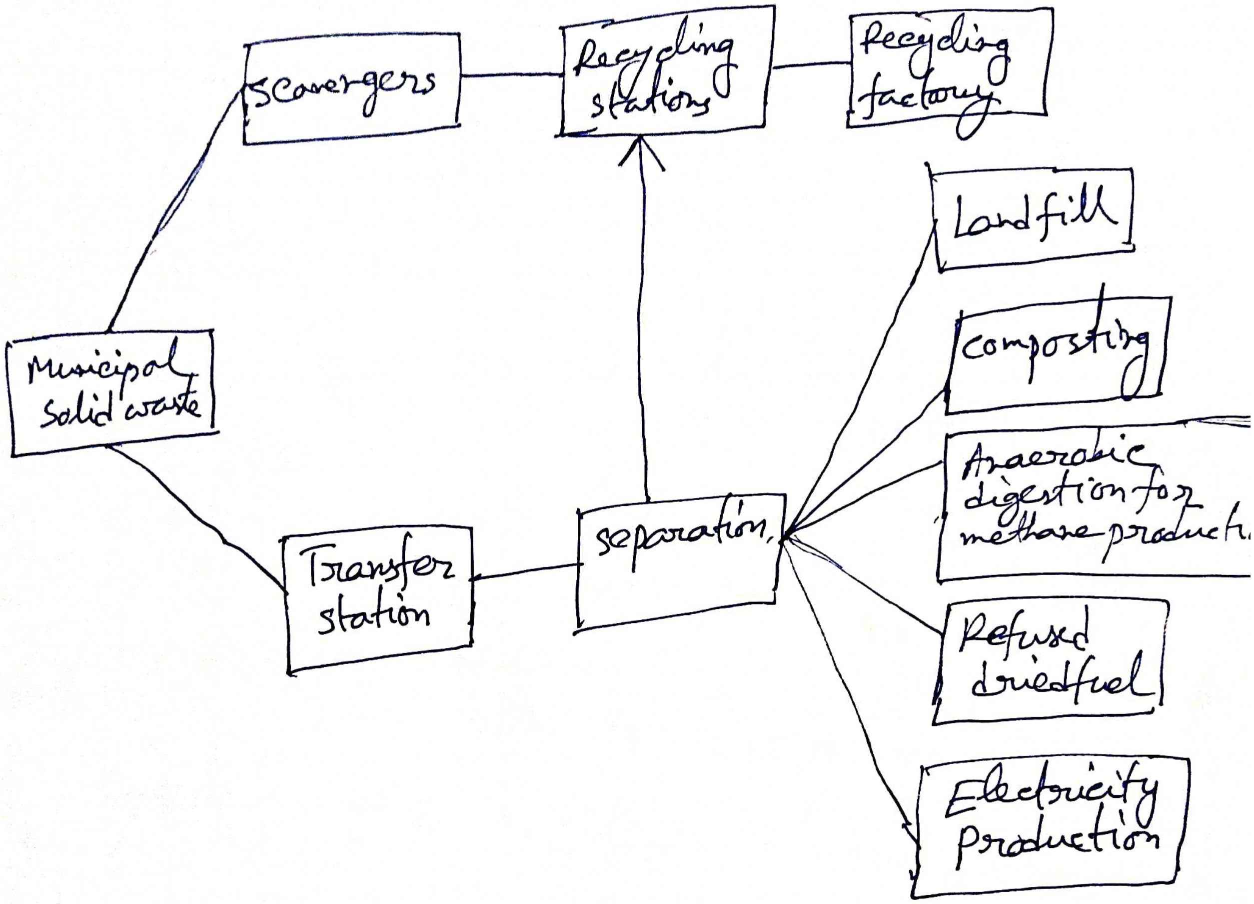
$$\frac{1.14 \text{ moles of } O_2}{\text{mole of Coal}} \; \frac{32.0 \text{ g of } O_2}{\text{mole of } O_2} \; \frac{\text{mole of Coal}}{14.49 \text{ g of coal}} = 2.52 \frac{\text{g of } O_2}{\text{g of Coal}}$$

* in case of gasification, mass of air flow rate varies generally in between (20% - 40%) of stoichiometric air.



Continuous type biogas plant

A flow chart of a municipal solid waste treatment system



Biogas Plant

(Sorensen, RE)

Animal manure → ~~Form~~ Biological / or Biochemical conversion (Anaerobic digestions)
Biodegradable Kitchen waste

↓

Methane gas.

Anaerobic digestion

↓ step 1 (not necessarily confined to anaerobic environments)

complex biomass materials is decomposed by a heterogeneous set of microorganisms

[cellulose ⟷ glucose]
hydrolysis using enzymes provided by microorganisms.

[proteins ⟶ amino acids, lipids → long chain fatty acids

* most of the biomass is now water-soluble and in a simpler chemical form

↓ step 2

removing hydrogen atoms from the biomass material (dehydrogenation)

e.g. glucose → acetic acid
removing carboxyl group of amino acid
long chain fatty acids ⟶ short chain acids → acetic acid

* these reactions are fermentation reactions accomplished by a range of acidophilic bacteria

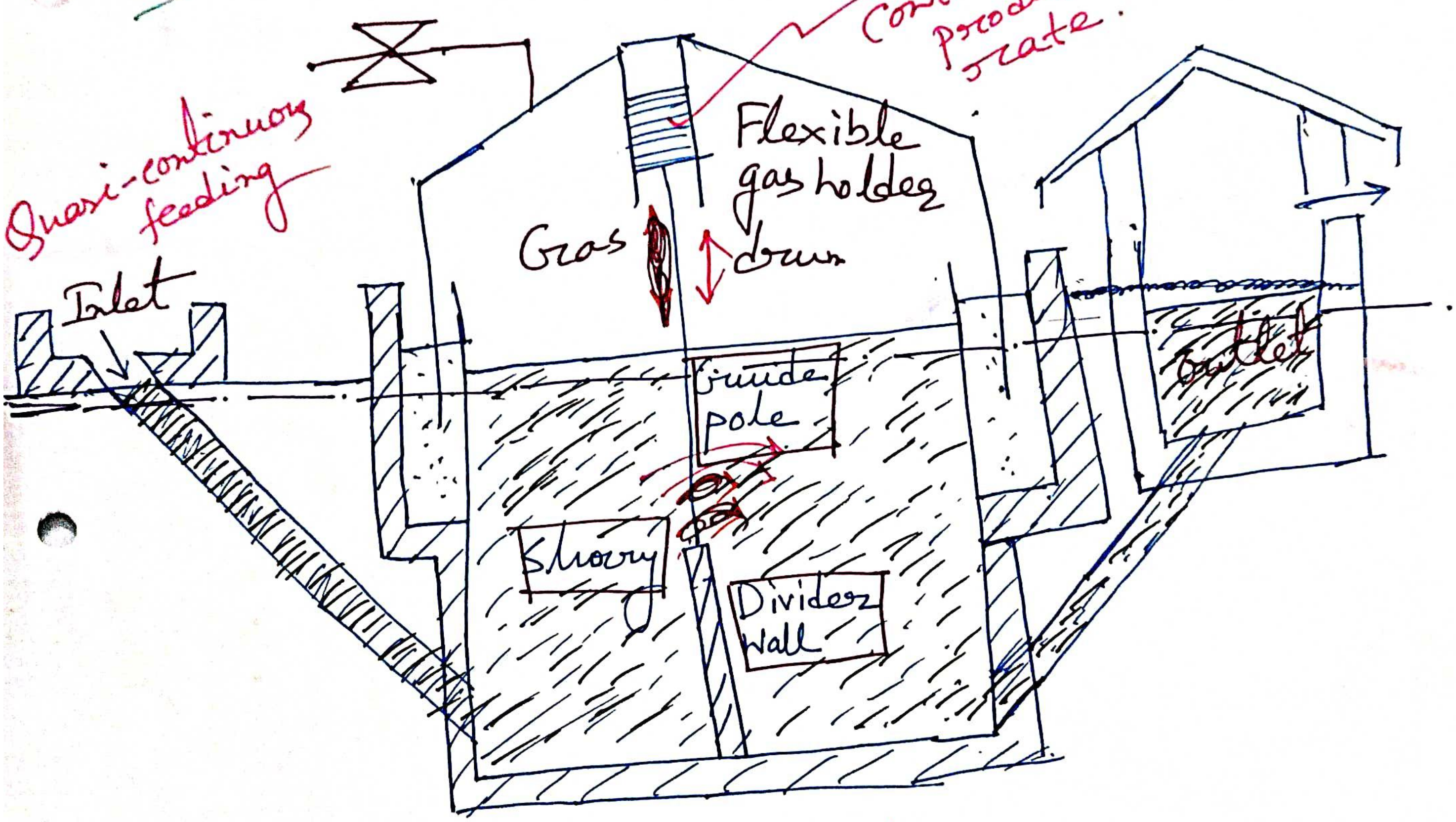
step 3

Second set of fermentation reactions performed by methanogenic bacteria

acetic acid ⟶ methane, CO_2
(methanogenic bacteria)

* These bacteria require a strictly anaerobic (oxygen free) environment

L. Breitenmoser et al. (2019)



Floating drum digester (KVIC model)
Khadi and Village Industries Commission.

separation of the AD acidogenesis and methanogenesis process due to their longitudinal design.

N ratio C/N < 30 is preferable for digestion.

Sewage sludge — 13 : 1

Cow dung — 25 : 1

Cow urine — 0.8 : 1

Pig droppings — 20 : 1

Pig urine — 6 : 1

Chicken manure — 25 : 1

kitchen refuse — 6-10 : 1

Saw dust — 200-500 : 1

Straw — 60-200 : 1

Bagasse — 150 : 1

Seaweed — 80 : 1

Alfalfa hay — 18 : 1

Grass clippings — 12 : 1

Potato tops — 25 : 1

Silage liquor — 11 : 1

Slaughterhouse waste — 3-4 : 1

Clover — 2.7 : 1

Lucerne — 2 : 1.

(Sorensen, RE)

Composition of biogas (J.G. Speight / Synthetic Fuels Handbook)

Biogas typically refers to a (biofuel) gas produced by the anaerobic digestion or fermentation of organic matter including manure, sewage sludge, municipal solid waste, biodegradable waste, or any other biodegradable feed stock, under anaerobic conditions.

Constituent	%
CH_4	50-75
CO_2	25-50
N_2	0-10
H_2	0-1
H_2S	0-3
O_2	0-2