Unit 3:- Biomass Energy

Syllabus…Unit 3

- Energy from Biomass, Thermo-Chemical, Bio-Chemical Conversion to fuels. Bio-gas and its applications

Books …

- Gilbert M. Masters, *Renewable and Efficient Electrical Power Systems*, Wiley - IEEE

Press, August 2004.

- Godfrey Boyle, *Renewable Energy*, Third edition, Oxford University Press, 2012.
- Chetan Singh Solanki, *Solar Photovoltaics-Fundamentals, Technologies and Applications*, PHI Third Edition, 2015.

Supplementary Reading:

- D.P.Kothari, K.C.Singal, Rakesh Rajan, *Renewable Energy Sources and Emerging Technologies*, PHI Second Edition, 2011.

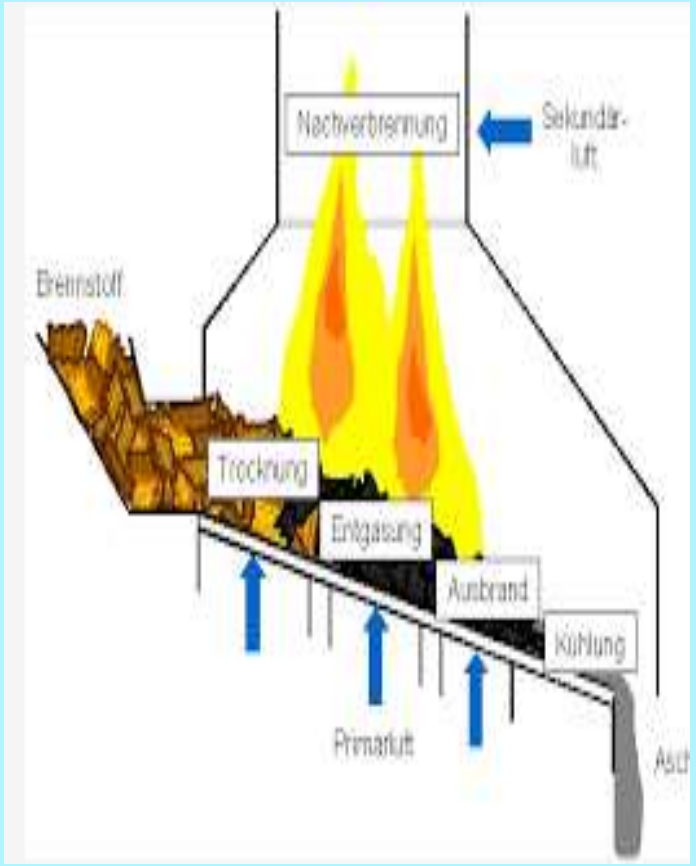
Lecture 2

- Direct Combustion
- Thermo-Chemical Conversion
- Gasification
- Syngas (Synthesis Gas)
- Landfilling
- Incineration
- Gasification Vs Incineration
- Gasification in Thermal Power Plant
- Gasification Chamber
- Gasification Reactions
- Syngas & Producer Gas
- Producer Gas
- Gasifier Efficiency
- Example

Biomass Energy Conversion……

Direct Combustion

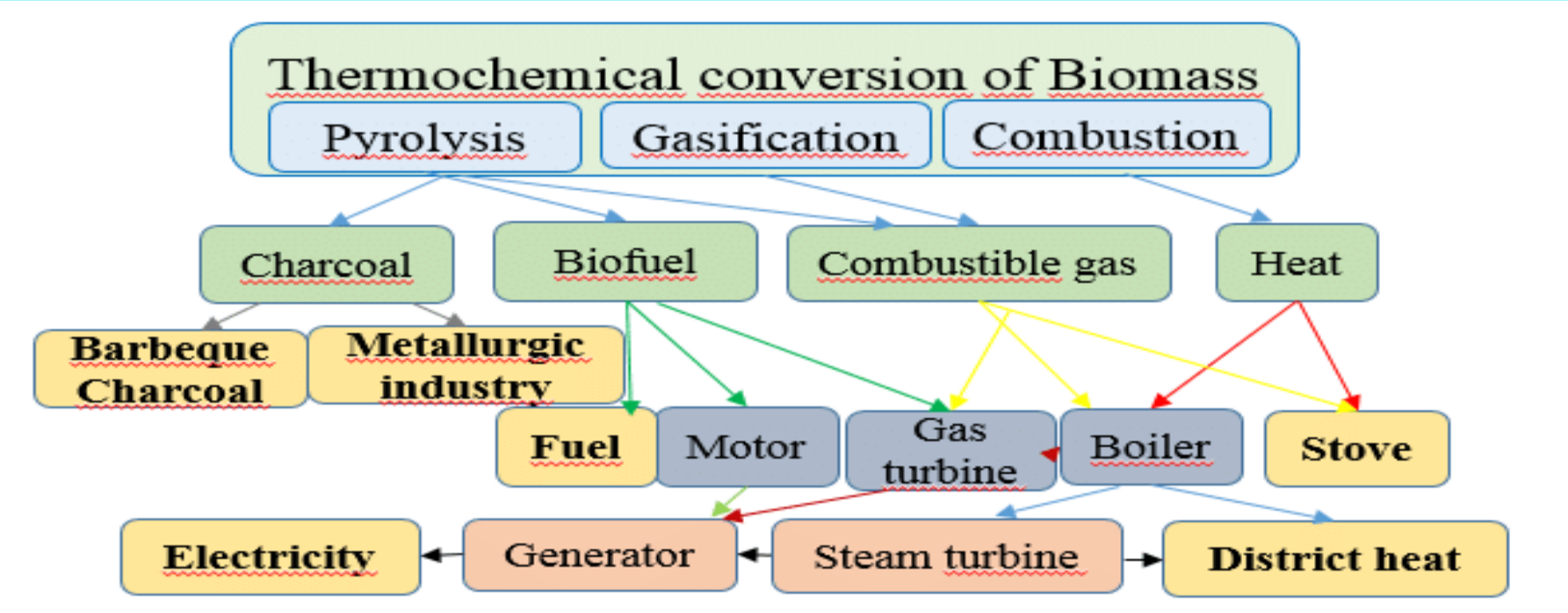
Combustion: the process by which flammable materials are burned in the presence of air or oxygen to release heat. It is the simplest method by which biomass can be used for energy. In its rudimentary form, combustion is used for space heating (i.e. a fire for warmth) but can also be used to heat steam for electricity generation.



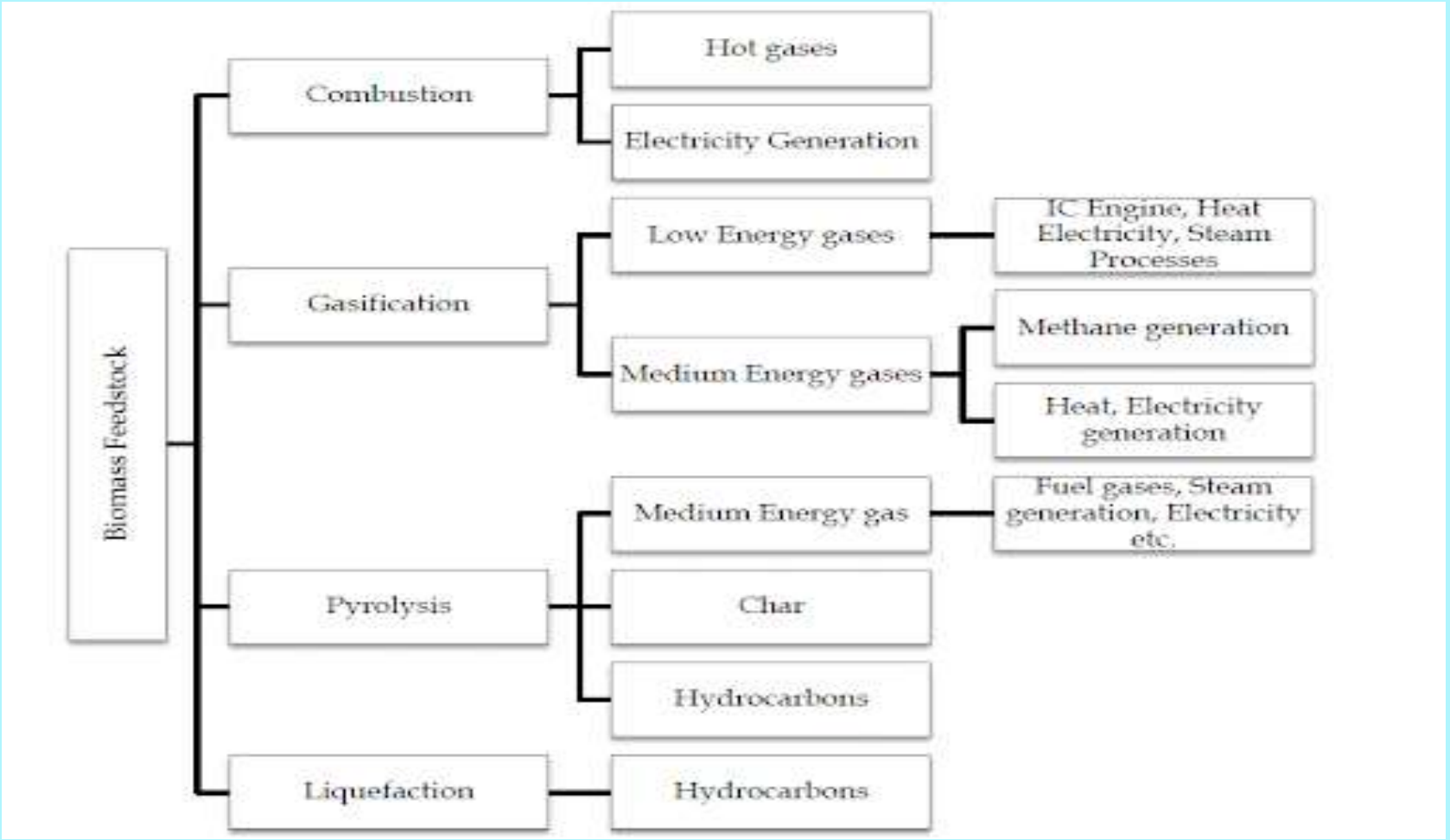
Biomass Energy Conversion……

Thermo-Chemical Conversion

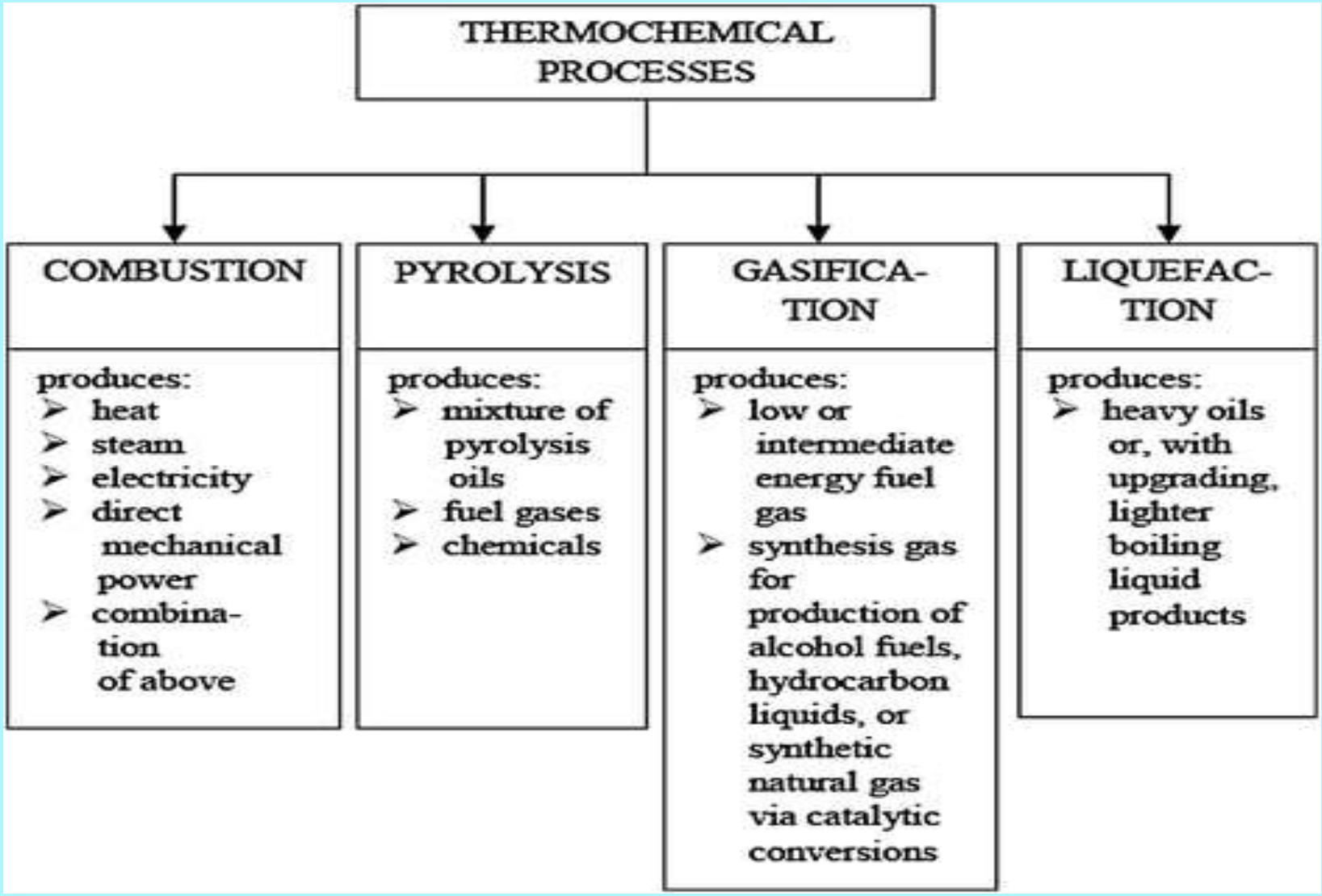
- **In this reaction organic biomass is converted in to more valuable and convenient form of products as gaseous and liquid fuels, residue and Bi-products**



Thermochemical Conversion……



Thermochemical Conversion……



Gasification……

Definition *:Gasification is a process that converts organic or fossil fuel based material into syngas and carbon dioxide.*

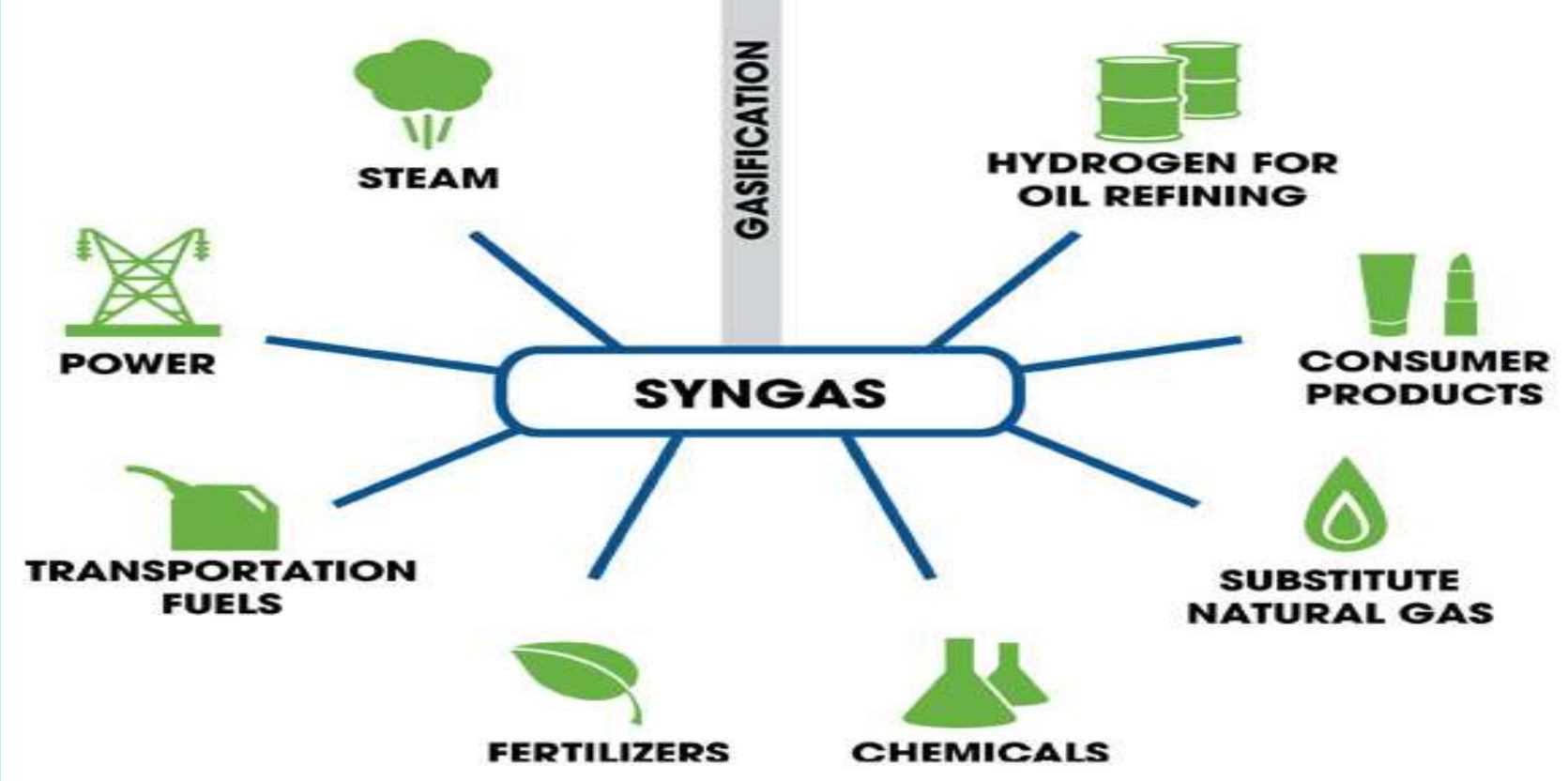
It is the conversion of biomass into a combustible gas mixture referred to as Producer Gas ($CO+H^2+CH^4$) or Syngas. The gasification process uses heat, pressure and partial combustion to create syngas, which can then be used in place of natural gas.

Combustion	vs.	Gasification
$C + O \rightarrow CO_2$		$C + \frac{1}{2} O_2 \rightarrow CO$
		$C + CO_2 \rightarrow 2CO$
		$C + H_2O \rightarrow CO + H_2$
A flame is present		Syngas is produced

Gasification……

- Gasification does not involve combustion, but instead uses little or no oxygen or air in a closed reactor to convert carbon-based materials directly into a synthesis gas, or syngas.
- The gasification process breaks these carbon-containing materials down to the molecular level, so impurities like nitrogen, sulphur, and mercury can be easily removed and sold as valuable industrial commodities.

Gasification……



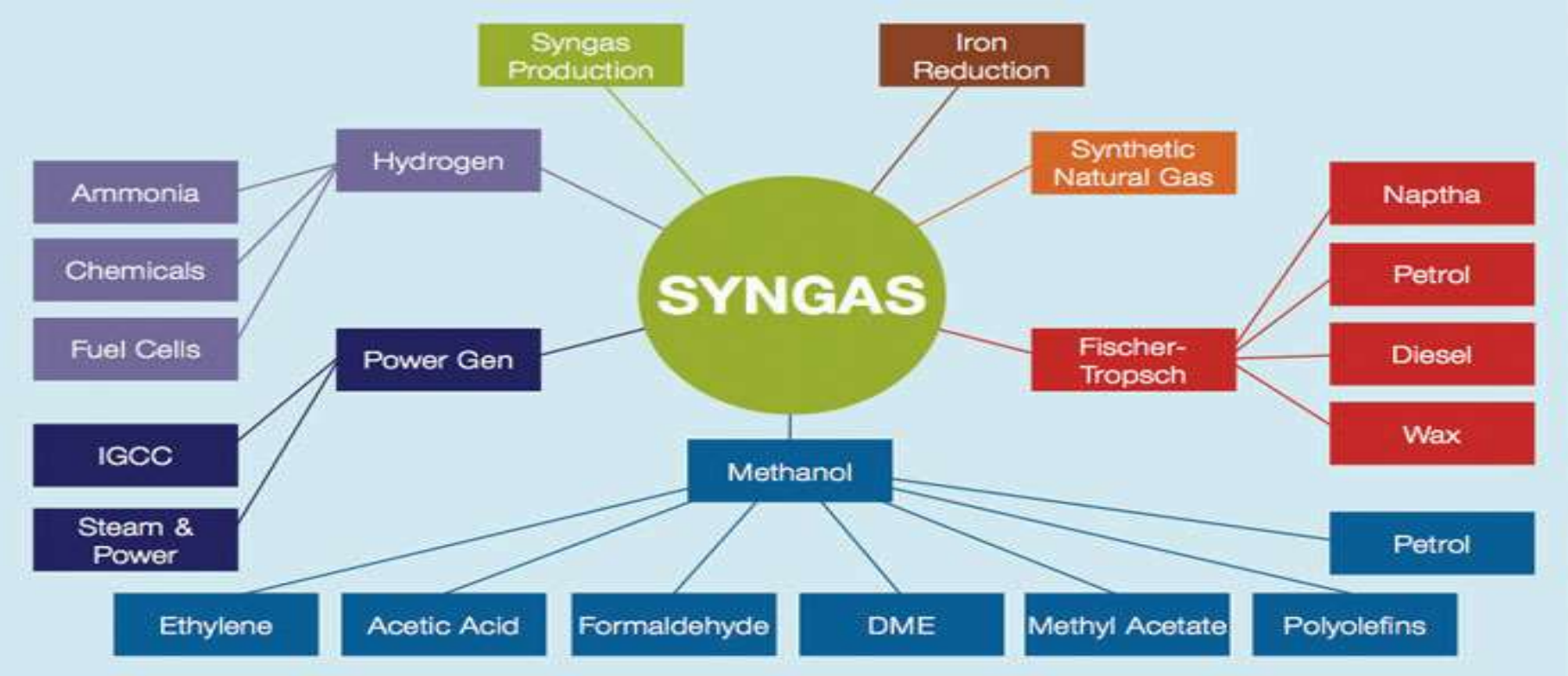
Gasification is a technology that creates synthesis gas which in turn can be used to produce electricity and other valuable products, such as chemicals, fuels, and fertilizers.

Syngas…

Syngas, or synthesis gas, is a fuel gas mixture consisting primarily of **hydrogen**, **carbon monoxide**, and very often some **carbon dioxide**. The name comes from its use as intermediates in creating synthetic **natural gas** (SNG) and for producing **ammonia** or **methanol**.

Historically, syngas has been used as a replacement for gasoline, when gasoline supply has been limited; for example, wood gas was used to power cars in Europe during WWII however, Syngas has less than half the energy density of natural gas.

Syngas…



Syngas is the primary product of the gasification plants, marketable products obtained from syngas include chemicals (45%), liquid fuels (28%), gaseous fuels (8%), and electric power (19%)[2]

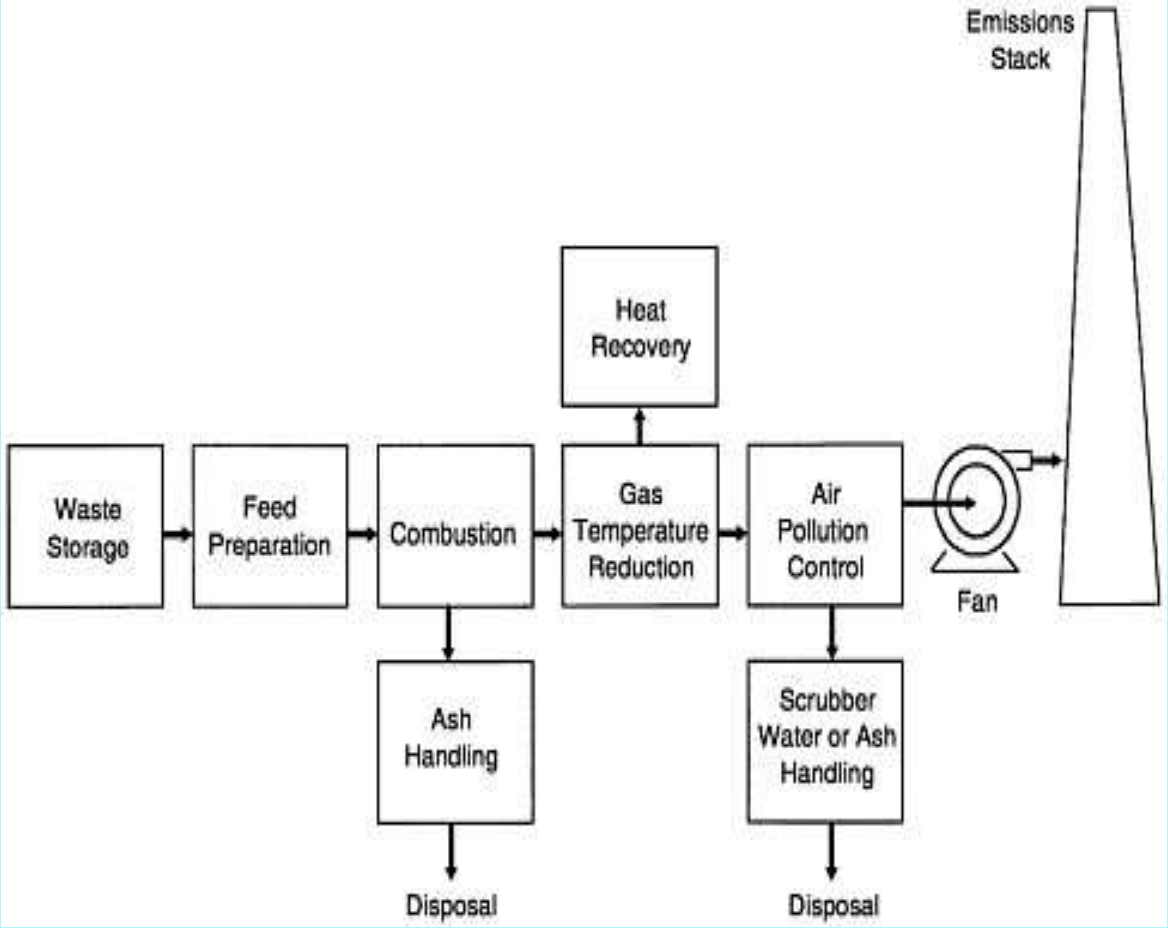
Gasification……

- Gasification has been reliably used on a commercial scale for more than 75 years in the refining, fertilizer, and chemical industries, and for more than 35 years in the electric power industry.
- Gasification produces electricity with significantly reduced environmental impacts compared to conventional technologies. Compared to the old coal-burning plants, gasification can capture carbon dioxide much more efficiently and at a lower cost.
- There are concerns over gasification of waste such as the undermining of zero waste programs. Such as Incineration and landfilling problems.

Landfilling……

In Gasification Municipal solid waste is converted in to Syngas, It is eliminating the need for landfilling.

Incineration……



Gasification also eliminates the need for incineration

Gasification Vs Incineration ……

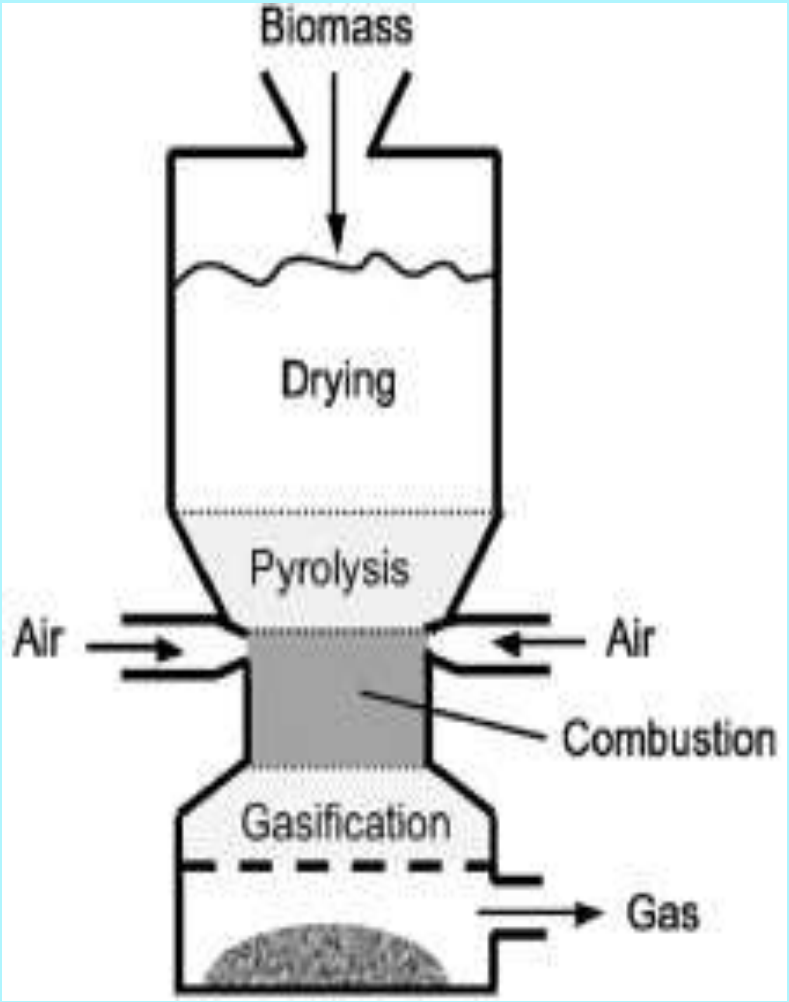
- Gasification is not incineration.
- Incineration is the burning of fuels in an oxygen-rich environment, where the waste material combusts and produces heat and carbon dioxide, along with a variety of other pollutants.
- Gasification is the conversion of wastes into their simplest molecules.
- The process works by having carbon monoxide, hydrogen and methane form a syngas which then can be used for generating electricity or producing valuable products that can be cleaned of pollutants before being used, unlike incineration.
- The oxygen-deficient atmosphere in a gasifier does not provide the surroundings needed for dioxins and furans to form or reform.
- When the syngas is primarily used as a fuel for making heat, it can be cleaned as necessary before combustion which cannot occur in incineration.

Gasification in Thermal Power Plant……

A coal gasification power plant : First, the coal gases are fired in a gas turbine to generate electricity. The hot exhaust of the gas turbine, and some of the heat generated in the gasification process, are then used to generate steam. This dual source of electric power, called a *"combined cycle"*. The fuel efficiency of a coal gasification power plant in this type of combined cycle can be boosted to 50 percent or more.

Gasification Chamber……

- A conversion efficiency of gasification is 60-70%
- The produced gas has low calorific value 1000-1200 Kcal/Nm^3
- When used in DG set as dual fuel it can save 65-85% fuel.
- Gasification occurs at 1000 °C in Gasifier.
- Process carried out by supply of less air (partial combustion) less than stoichiometric requirements.

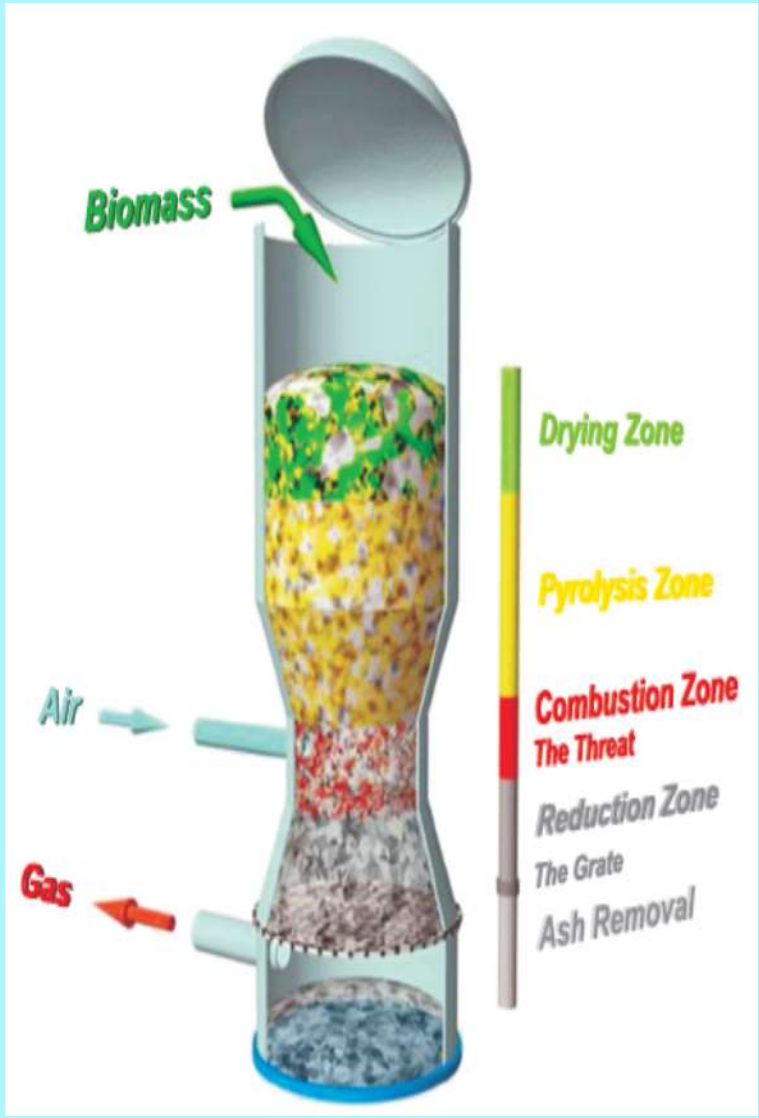


Gasification Reactions……

A gasification system consists of four main stages:

- ✓ Feeding of feedstock
- ✓ Gasifier reactions where gasification takes place
- ✓ Cleaning of resultant gas
- ✓ Utilization of cleaned gas.

Biomass gasifier (Figure is a thermo chemical converter / reactor where various physical and chemical reactions take place. Biomass is passed through various zones – Drying/ Distillation Zone, Pyrolysis Zone, Combustion Zone & Reduction Zone. When the biomass is passed through all the above zones, it gets converted into a high quality combustible gas called Producer Gas.



Gasification Reactions……

The following reactions take place in the biomass gasification.

$C + O_2 = CO_2$

$H_2 + 1/2\ O_2 = H_2O$ **Exothermic Reaction**

When these gases passes through bed of biomass converted charcoal in the reduction zone, the following main reactions takes place:

$C + CO_2 = 2CO$

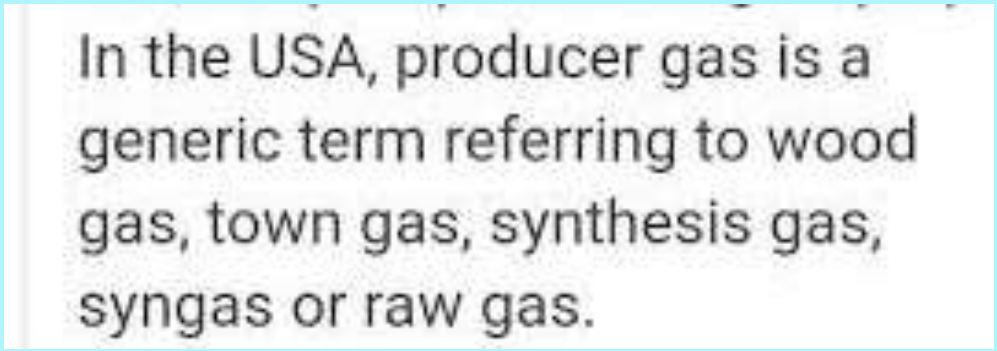
$C + H_2O = CO + H_2$ **Reduction Reaction**

$CO_2 + H_2 = CO + H_2O$ **Water Gas Reaction**

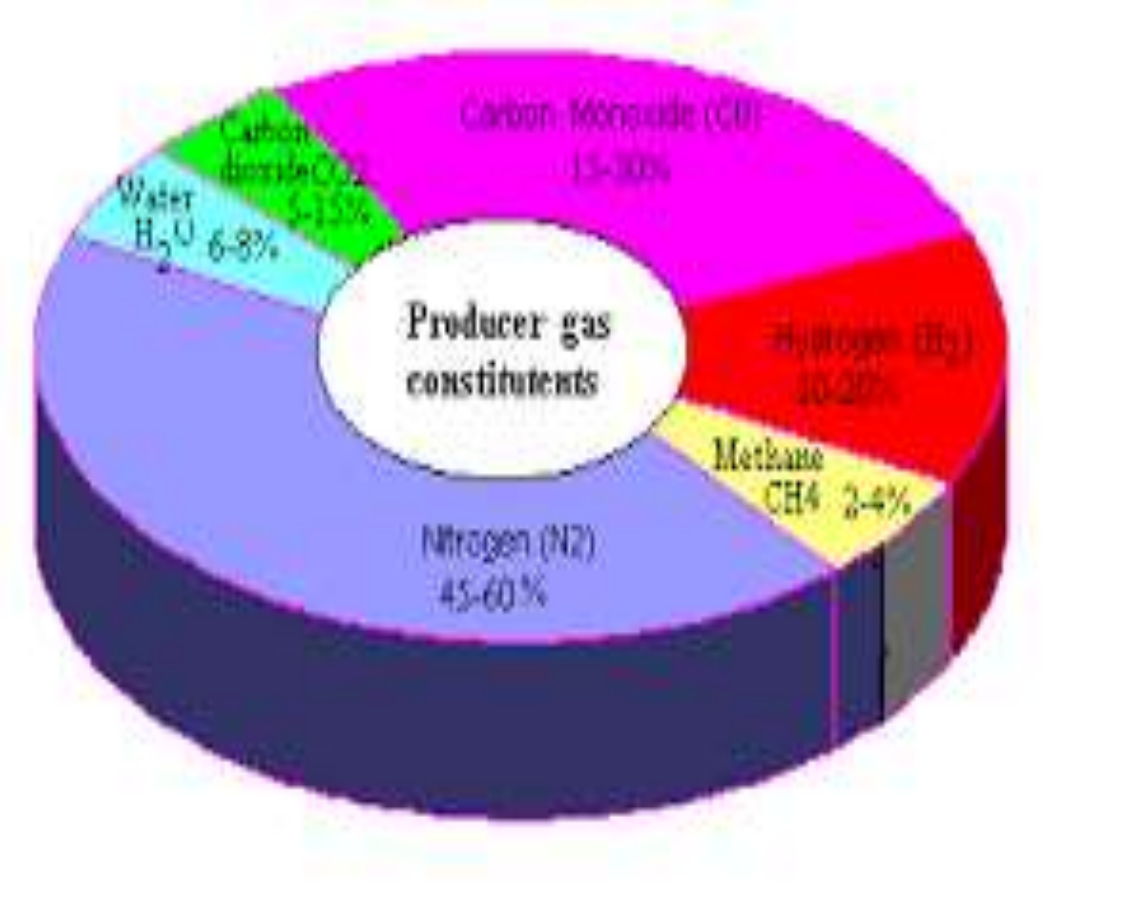
$C + 2H_2 = CH_4$ **Methanation Reaction**

Syngas and Producer gas……

Syngas is a mixture of Carbon Monoxide and Hydrogen which is the product of steam or oxygen gasification of organic material such as biomass. ... If the gasification product contains significant amount of non-combustible **gases** such as nitrogen and carbon dioxide, the term used for such mixtures is '**Producer Gas**'.



Producer Gases ……



$CO = 19 \pm 3\ \%$

$H_2 = 18 \pm 2\%$

$N_2 = 50 \pm 2\%$

$CH_4 = 03 \pm 1\%$

$CO_2 = 10 \pm 3\%$

Gasifier Efficiency ……

Average conversion efficiency of a gasifier is given by the following formula:

$$\eta_{Gas} = \frac{\text{Calorific value of gas/kg of fuel}}{\text{Avg. calorific value of 1 kg of fuel}}$$

Spark ignition engines running on producer gas on an average produces 0.55-0.75 kWh of energy from 1 kg of biomass. Compression ignition (diesel) engines cannot run completely on producer gas. Thus to produce 1 kWh of energy they consume 1 kg of biomass and 0.07 litres of diesel. Consequently they effect 80-85% diesel saving.

Example……

Example:

1 kg of wood produces 2.5 m^3 of gas with average calorific value of 1000 kcal/Nm^3. Average calorific value of wood (dry) is 3500 kcal/kg.

Hence

$$\eta \text{ Gas} = \frac{2.5 \text{ } (m^3/\text{kg of wood}) \text{ x } 1000 \text{ kcal}/m^3)}{3500 \text{ kcal/kg of wood}} = 71\%$$

Thank You