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.

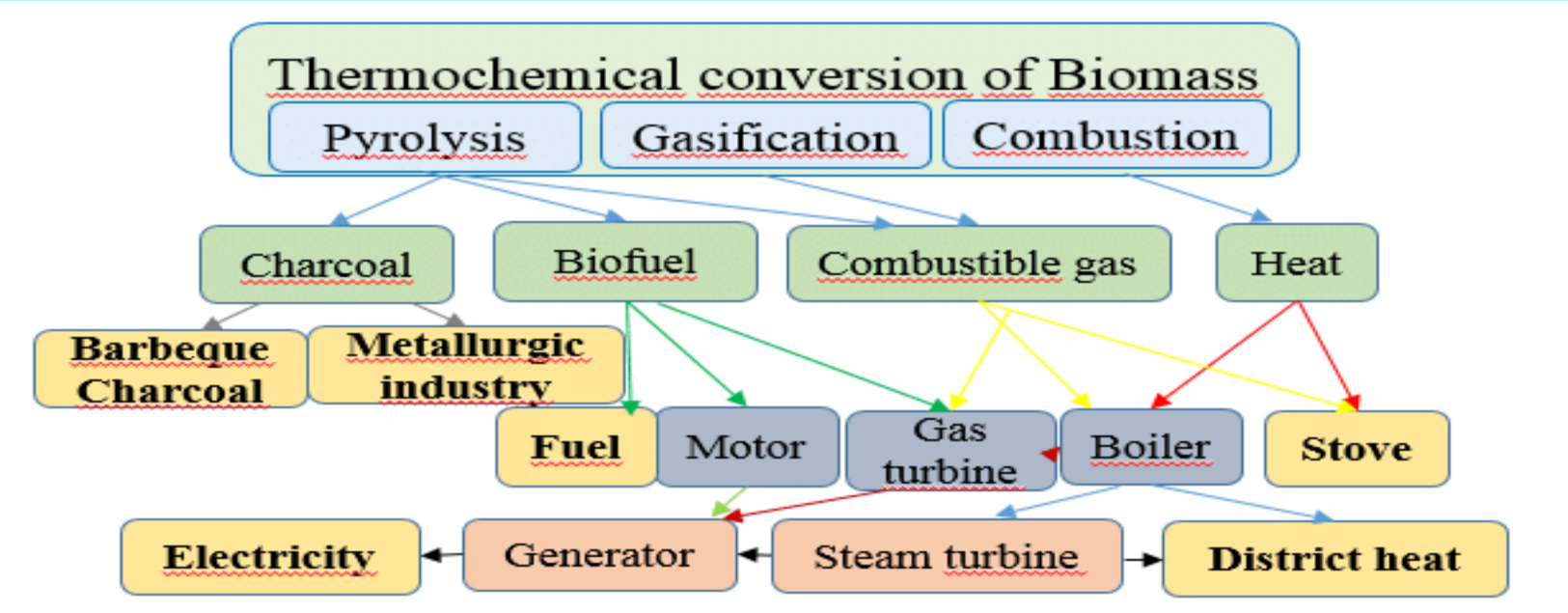
Lecture 3

- Thermo-Chemical Conversion
- PYROLYSIS
- Definition
- Products
- Bio-Char
- Bio-Oil
- Pyrolysis Types
- Pyrolysis Types Comparison
- Pyrolysis Reactors
- Pyrolysis Advantages
- Pyrolysis Limitations
- Waste Management Sector
- Comparison Thermo-Chemical Conversions

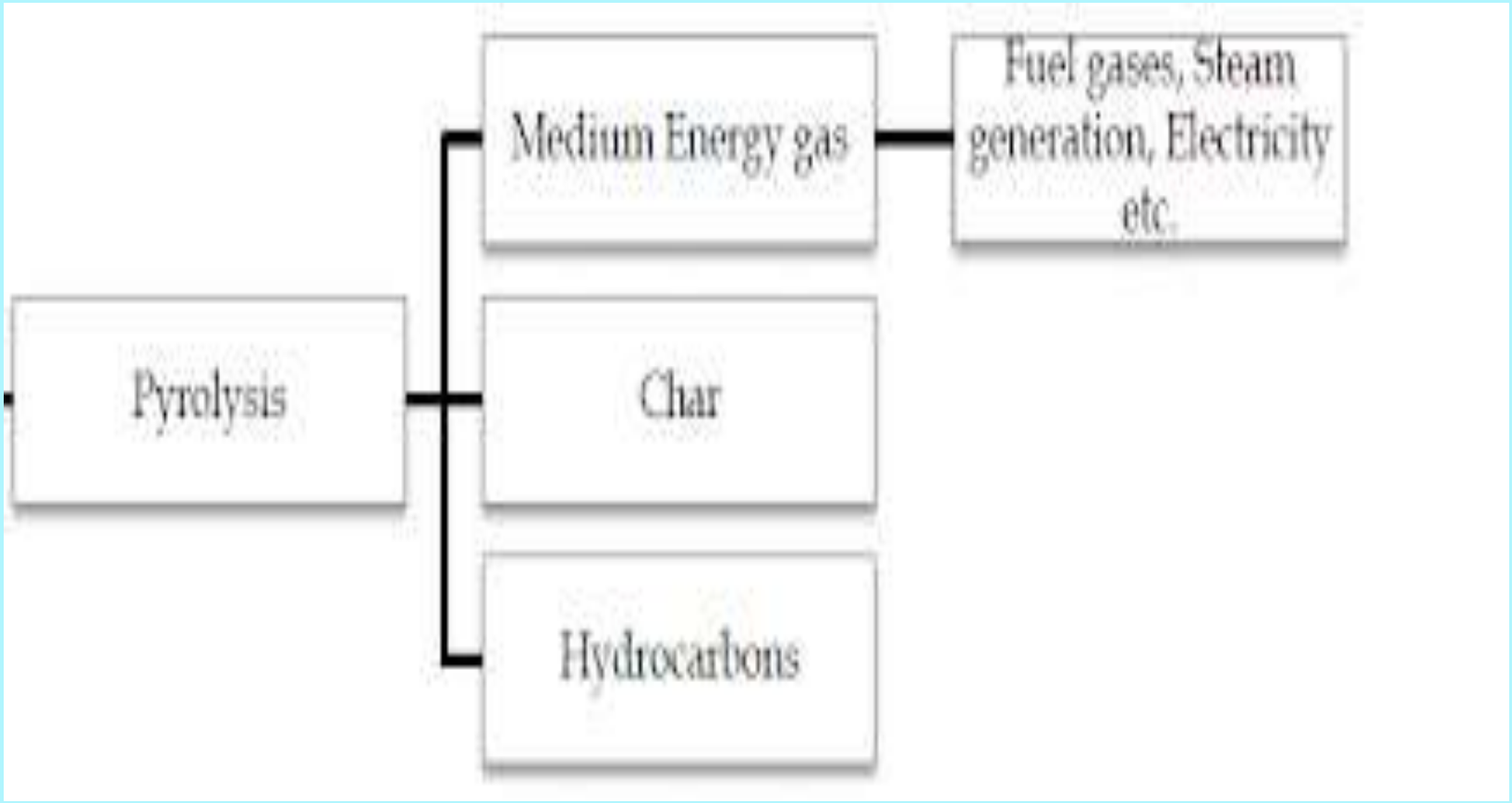
Biomass Energy Conversion……

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**



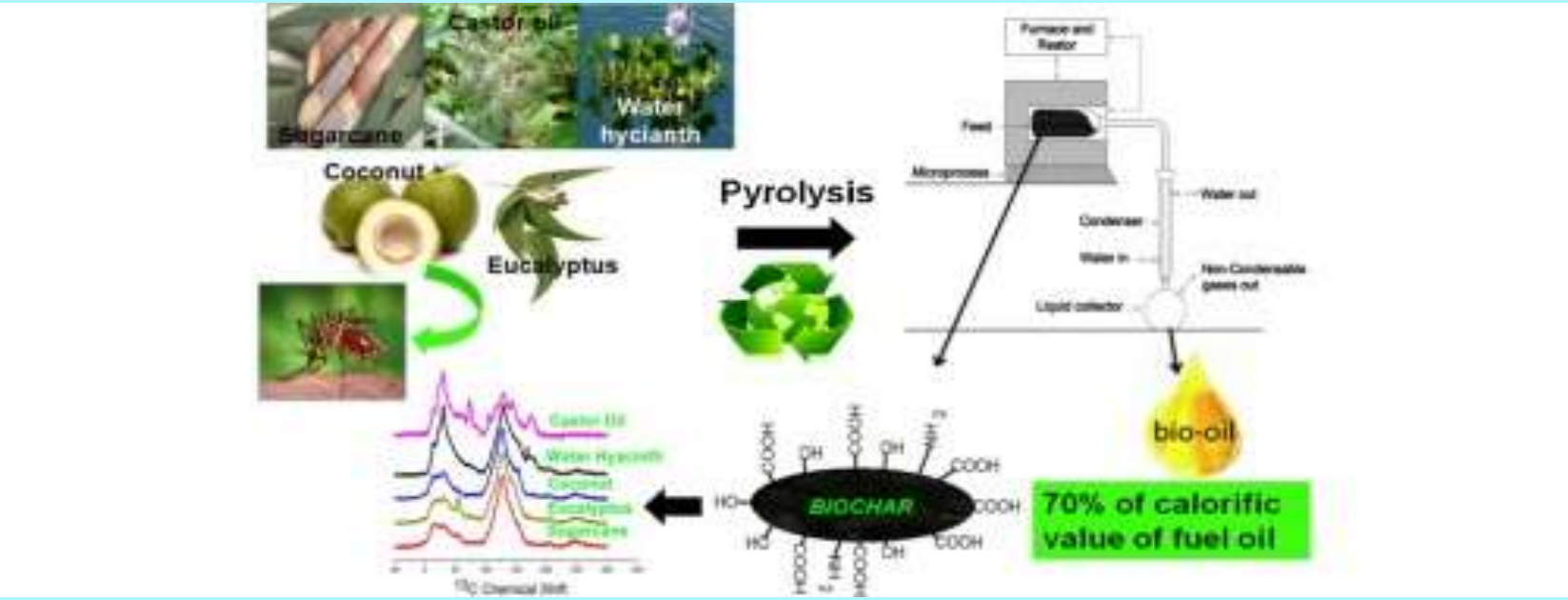
PYROLYSIS……


Pyrolysis
Medium Energy gas
Char
Hydrocarbons
Fuel gases, Steam generation, Electricity etc.

PYROLYSIS……

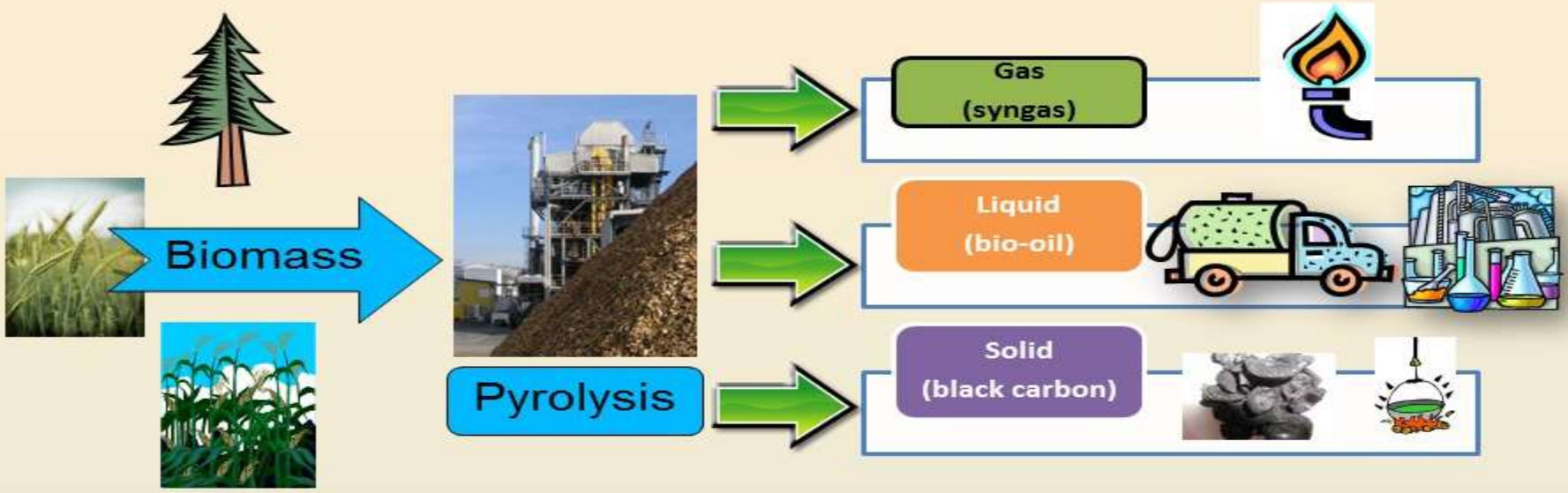
Definition *:Pyrolysis is the process of heating organic material at high temperatures in the absence of oxygen.*

It is the heating of biomass in a closed vessel at temperatures in the range 500^{o}C-900^{o}C in absence of O2/air or with steam. It produces solid, liquid and gases.



PYROLYSIS……

Pyrolysis is the process of heating organic material at high temperatures in the absence of oxygen. Since no oxygen is present, the organic material does not combust. Instead, the chemical compounds (i.e. cellulose, hemicellulose and lignin) that make up the material decompose into combustible gases and charcoal.



PYROLYSIS Products……

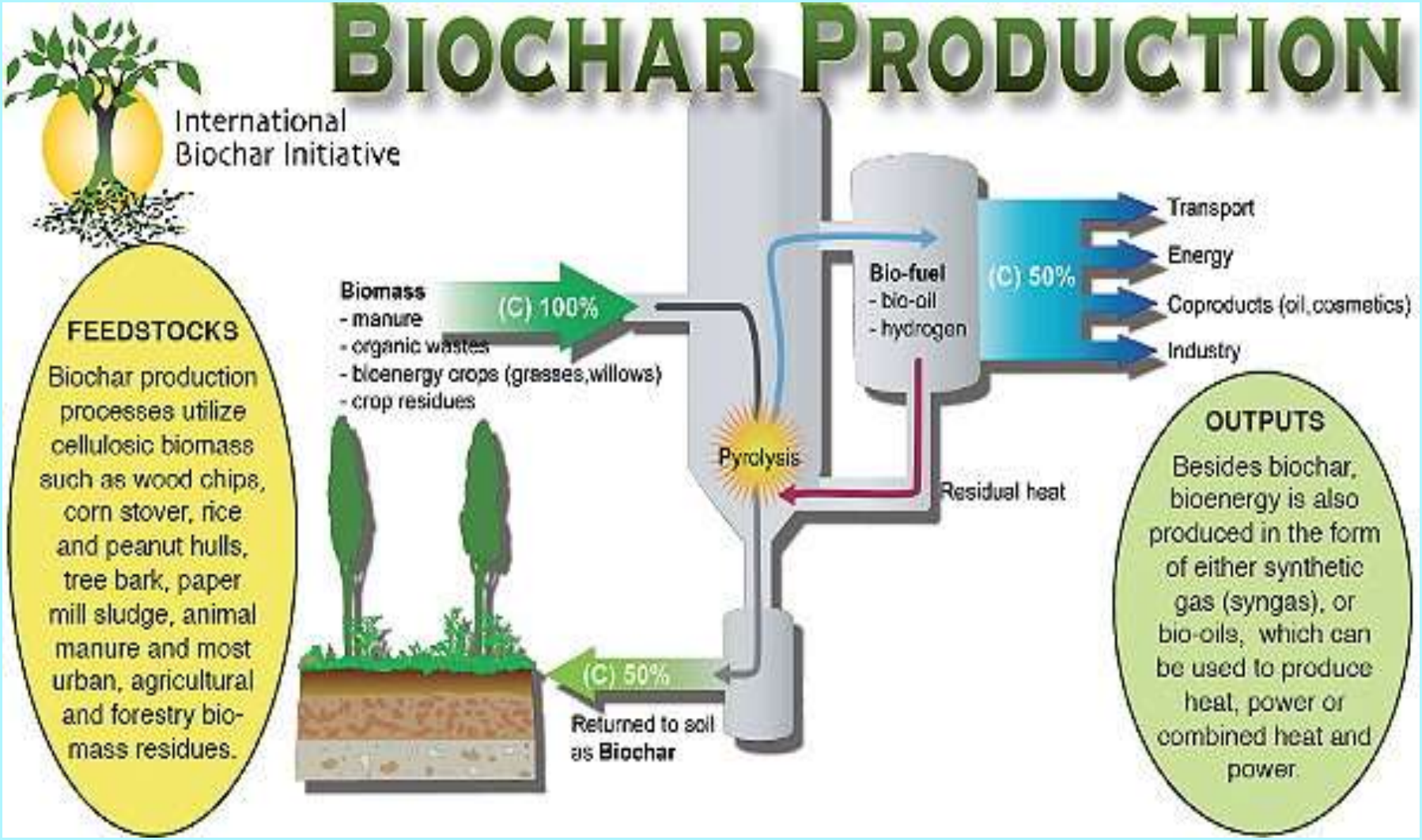
Pyrolysis of biomass produces three products - a liquid, a gas and a solid:

Bio-oil: comes from the combustible gases of the process, which are condensed, into a liquid. Bio-oil can be used as a low grade diesel oil.

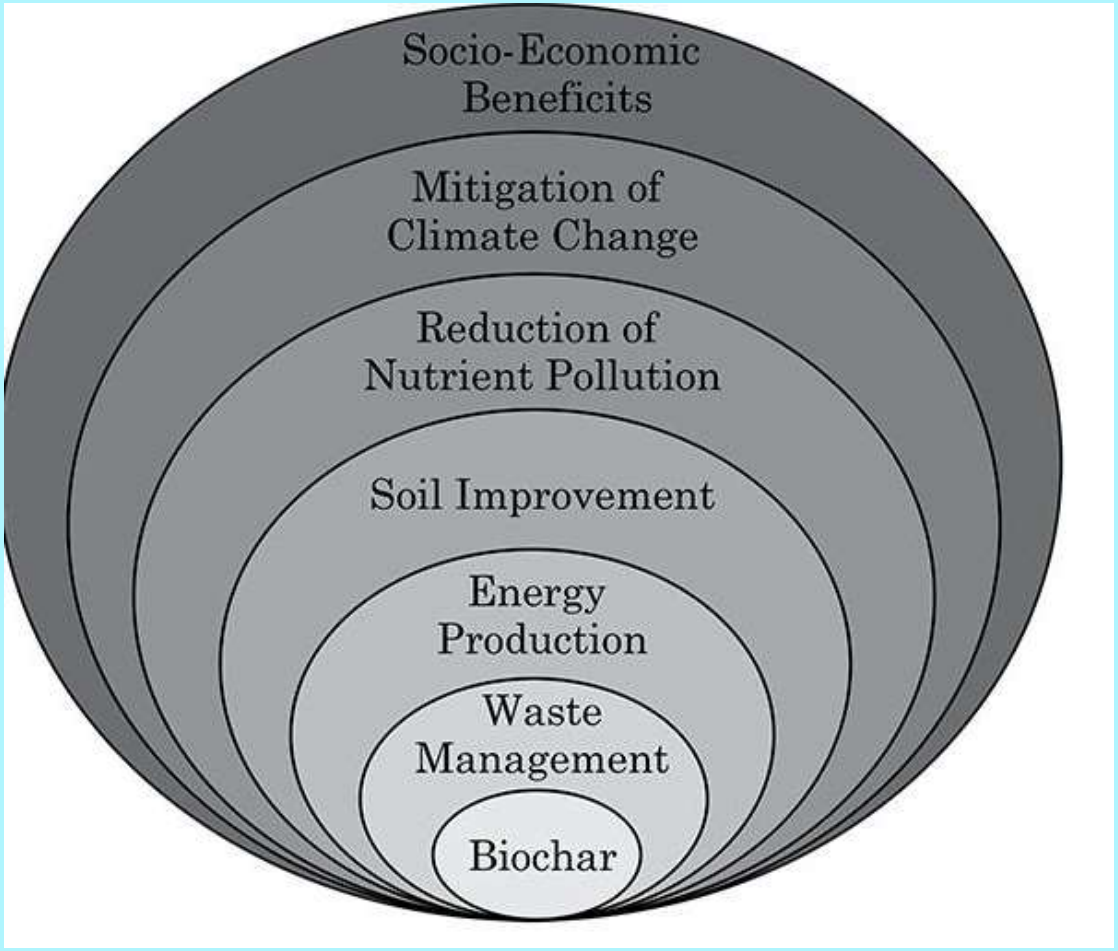
Bio-char: is the solid material that is created in the process. Bio-char is being promoted for its potential to improve soil properties and fertility as well as sequester carbon.

Syngas: are the permanent gases (CO2, CO, H2, light hydrocarbons) that remain after the pyrolysis process is complete. Syngas can be used in place of natural gas or converted with catalysts to ethanol.

Bio-Char……

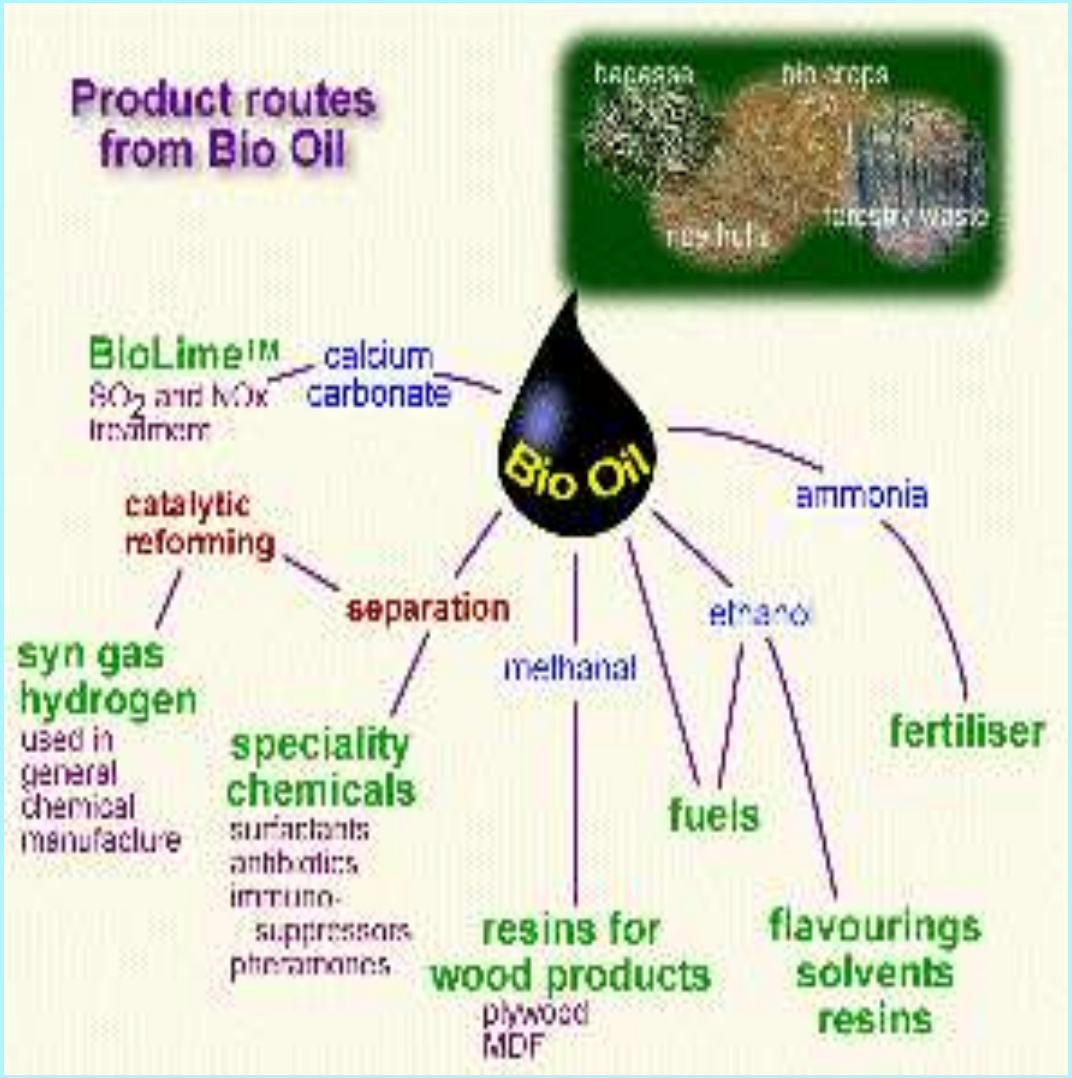

BIOCHAR PRODUCTION
International Biochar Initiative
FEEDSTOCKS
Biochar production processes utilize cellulosic biomass such as wood chips, corn stover, rice and peanut hulls, tree bark, paper mill sludge, animal manure and most urban, agricultural and forestry biomass residues.
Biomass
- manure
- organic wastes
- bioenergy crops (grasses,willows)
- crop residues
(C) 100%
Bio-fuel
- bio-oil
- hydrogen
(C) 50%
Transport
Energy
Coproducts (oil,cosmetics)
Industry
Pyrolysis
Residual heat
(C) 50%
Returned to soil as Biochar
OUTPUTS
Besides biochar, bioenergy is also produced in the form of either synthetic gas (syngas), or bio-oils, which can be used to produce heat, power or combined heat and power.

Bio-Char……



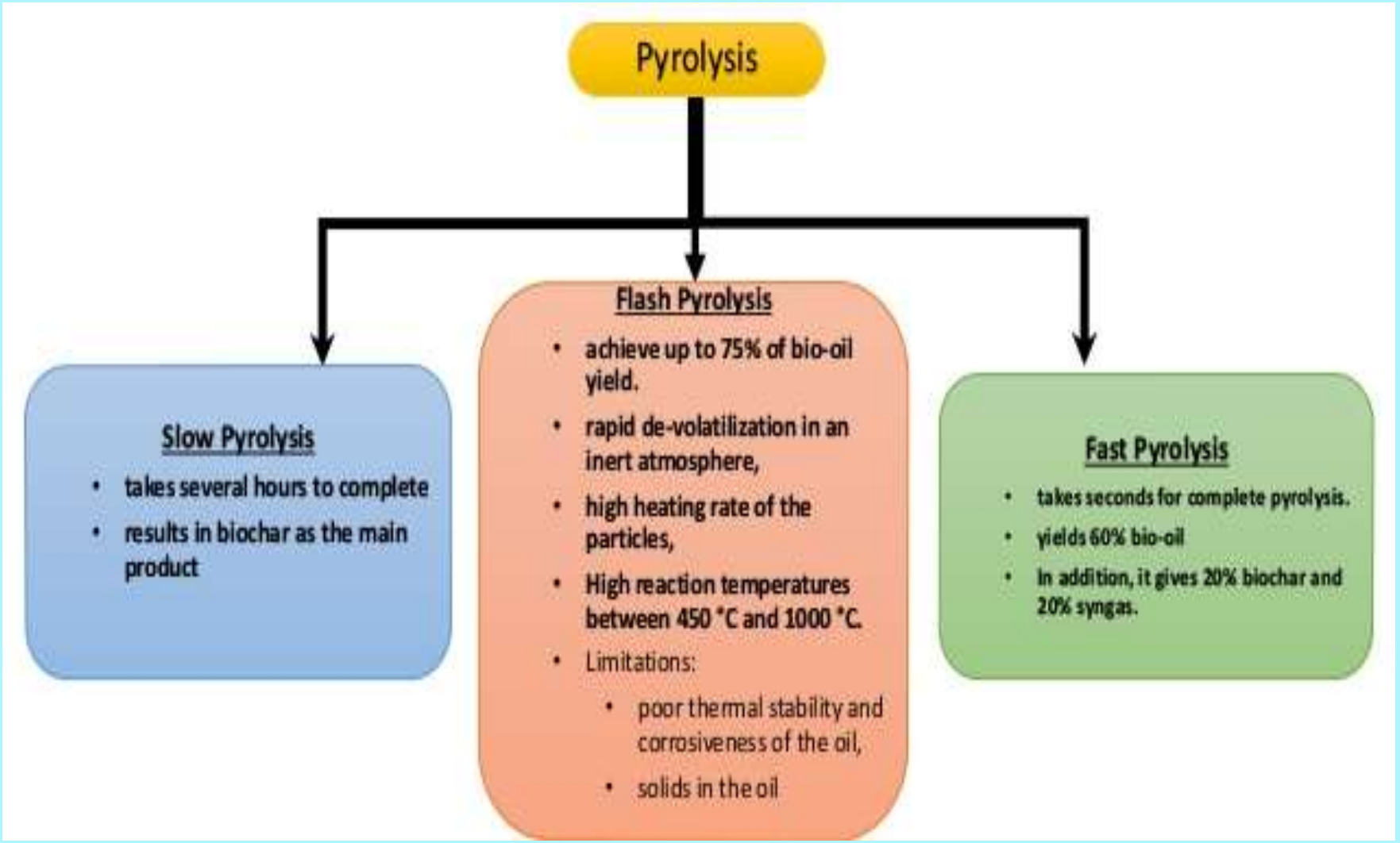
- As a solid Fuel in boiler
- Used further for the gasification process to obtain hydrogen rich gas
- Used directly as activated carbons
- Useful as a sorbent for air pollution control as well as for wastewater treatment.
- Serve as catalysts and catalyst supports

Bio-Oil……



- As a combustion fuel
- Used for power generation
- Can be used for production of chemicals and resins
- Can be used as a transportation fuel
- Suitable blend with diesel oil may be used as diesel engine fuels
- Easily stored and transported

PYROLYSIS Types……



PYROLYSIS Types……

Process	Conditions	Products		
		Liquid	Char	Gas
Fast pyrolysis	Moderate temperature, short residence time	**75%** Water 25 %	12%	13%
Slow pyrolysis (carbonization)	Low temperature, long residence time	30% Water 75 %	**35%**	35%
High temperature pyrolysis	High temperature	5% Tars 5 %	10%	**85%**

PYROLYSIS Types……

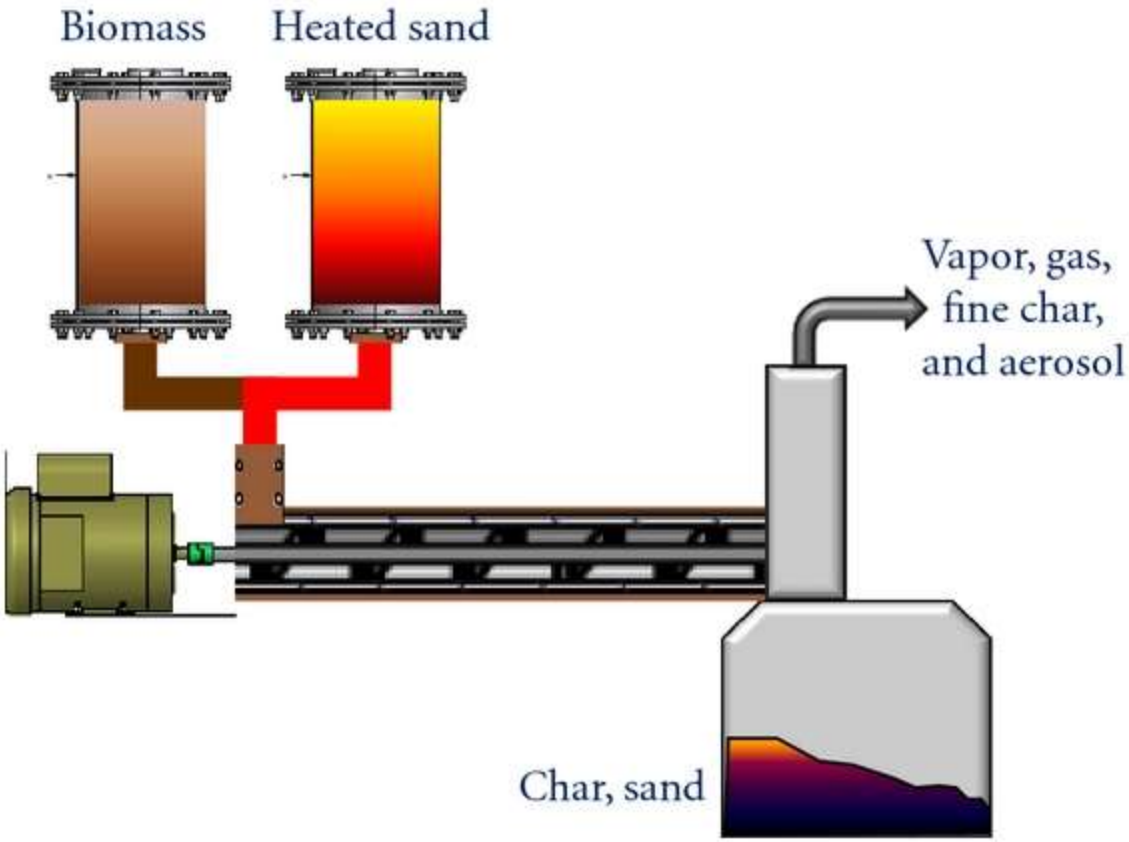
- Fast Pyrolysis optimizes bio-oil production by increasing the rate of pyrolysis temperature to 1000°C/second.
- This process yields approximately 60-70% bio-oil, 15-25% bio-char, and 10-15% syngas.
- In contrast, Slow Pyrolysis uses slower heating rates and bio-char is the major end product.
- In both process, the system is self-sustaining by harnessing the syngas to drive the reaction.

PYROLYSIS Types……

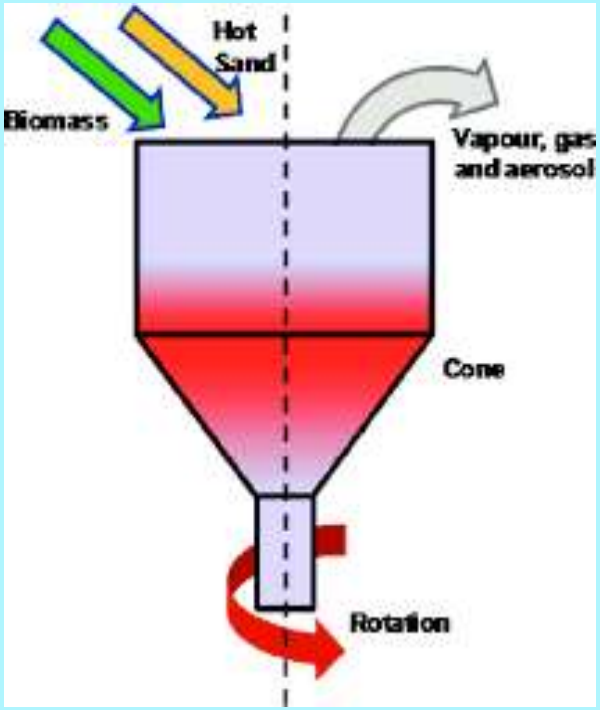
Classification of pyrolysis methods with differences in temperature, residence time, heating rate, and major products. The major products are listed in decreasing importance.

Method	Temperature (°C)	Residence Time	Heating rate (°C/s)	Major products
Conventional/slow pyrolysis	Med-high 400-500	Long 5-30 min	Low 10	Gases Char Bio-oil (tar)
Fast pyrolysis	Med-high 400-650	Short 0.5-2 s	High 100	Bio-oil (thinner) Gases Char
Ultra-fast/flash pyrolysis	High 700-1000	Very short < 0.5 s	Very high >500	Gases Bio-oil

PYROLYSIS Reactor …



Screw Pyrolysis Reactor



Rotating Cone Reactor

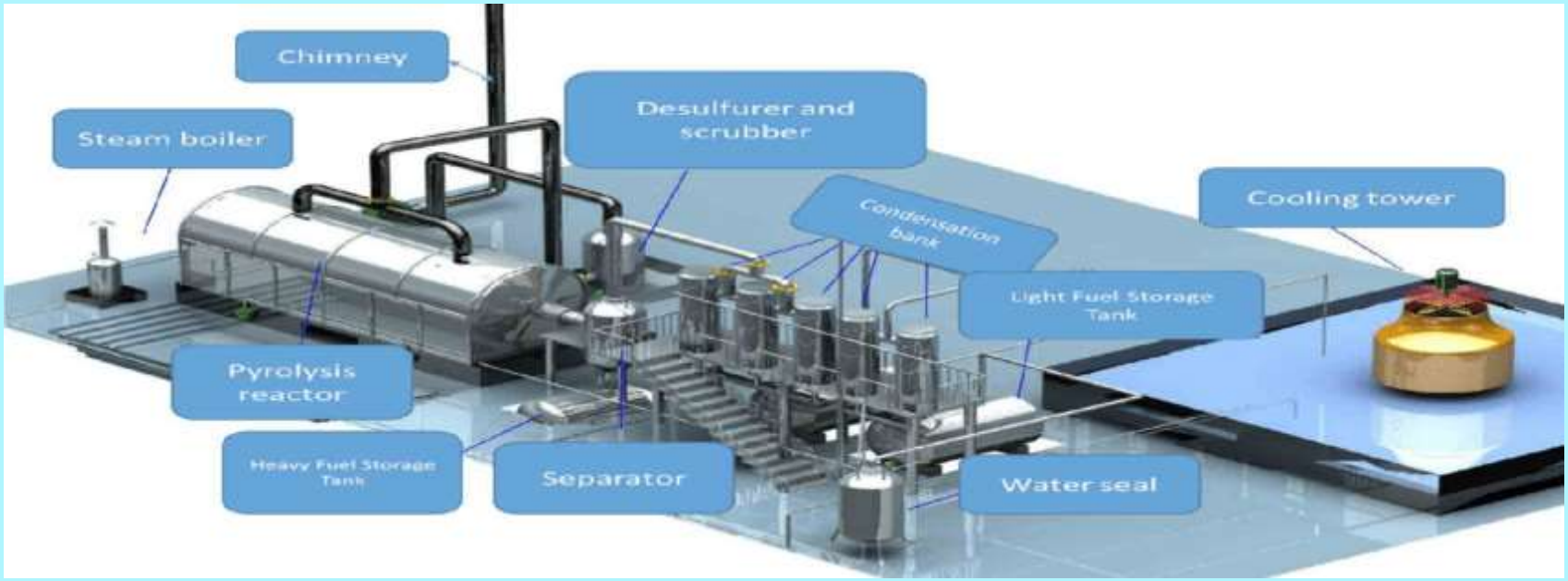
Pyrolysis Advantages ……

Advantage…

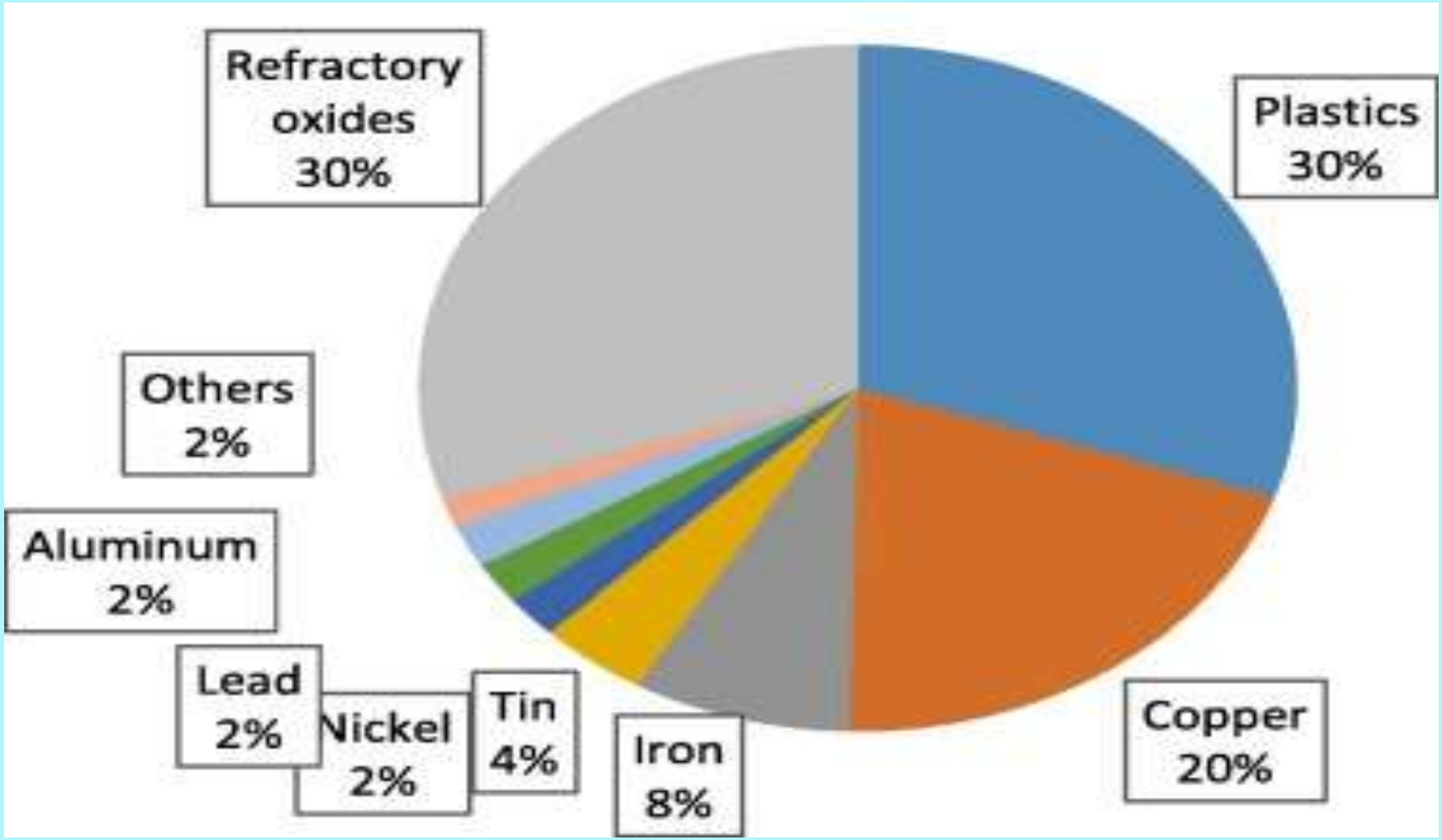
- Pyrolysis presents an opportunity to manufacture low-carbon liquid fuels and decrease the emissions of the industry.
- Pyrolysis can be carbon negative if the bio-char produced is buried into the soil and used for crop enhancement instead of combustion
- The fuels produced are considered second generation fuels since the feed stocks are from renewable sources, like waste and biomass. As a result, they are less carbon-intensive than fossil fuels
- These fuels are also compatible with our existing transportation infrastructure which eliminates the need to introduce costly new infrastructure

Pyrolysis Limitations ……

- Pyrolysis does have higher costs associated with the machinery and heating.
- It is dependent on a supply of cheap biomass.
- The quality of the bio-oil is also low grade and cannot be used in all applications where fossil fuels are used.



Waste Management Sector……

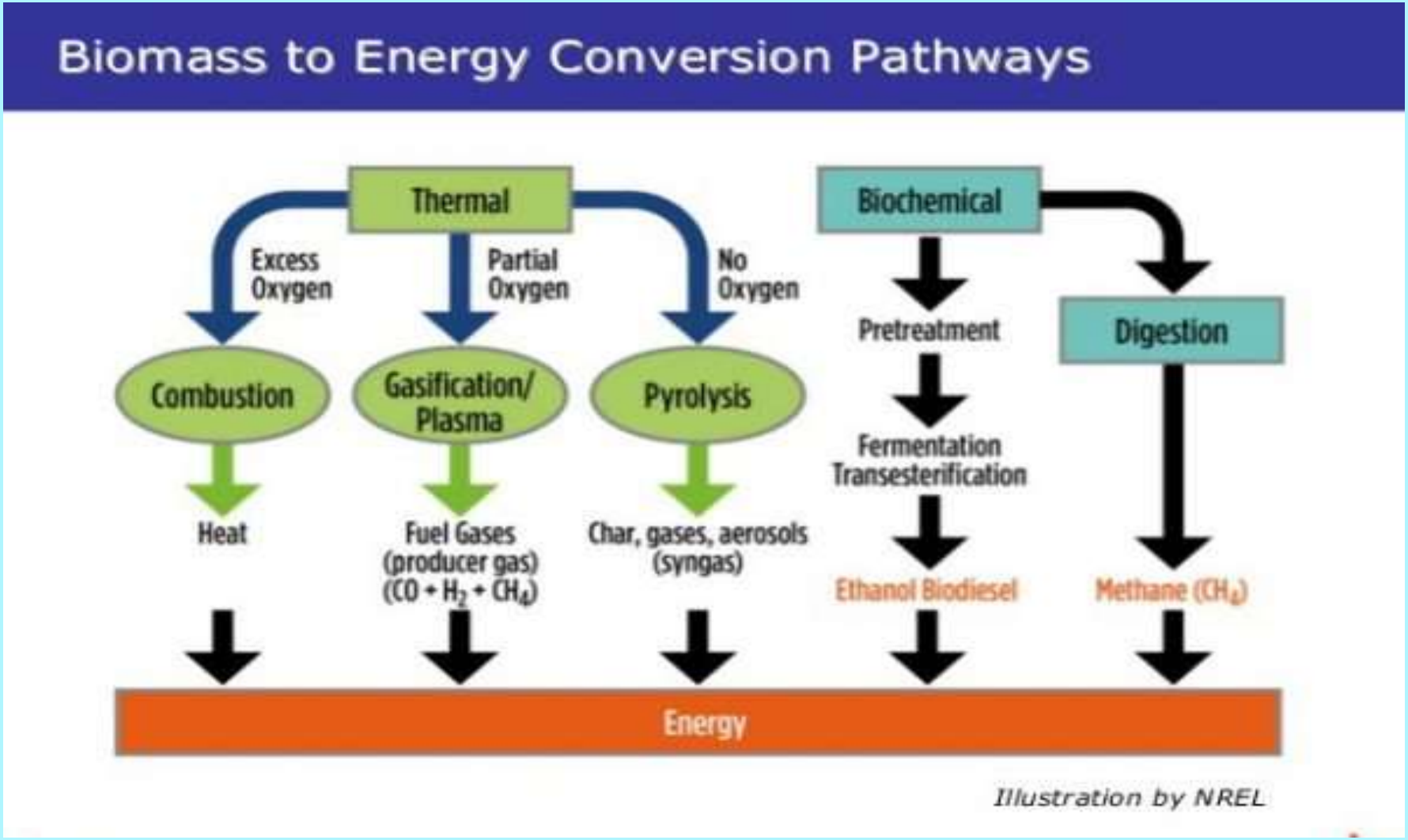


Potential of pyrolysis processes in the waste management sector

Comparison……

	Combustion	Gasification	Pyrolysis
Oxidizing Agent	Greater than stoichiometric supply of oxygen*	Less than stoichiometric oxygen* or steam as the oxidizing agent	Absence of oxygen or steam
Typical Temperature Range with Biomass Fuels	800°C to 1200°C (1450°F to 2200°F)	800°C to 1200°C (1450°F to 2200°F	350°C to 600°C (660°F to 1100°F)
Principle Products	Heat	Heat and Combustible gas	Heat, Combustible liquid and Combustible gas
Principle Components of Gas	CO_2 and H_2O	CO and H_2	CO and H_2

Biomass Energy next ……



Thank You