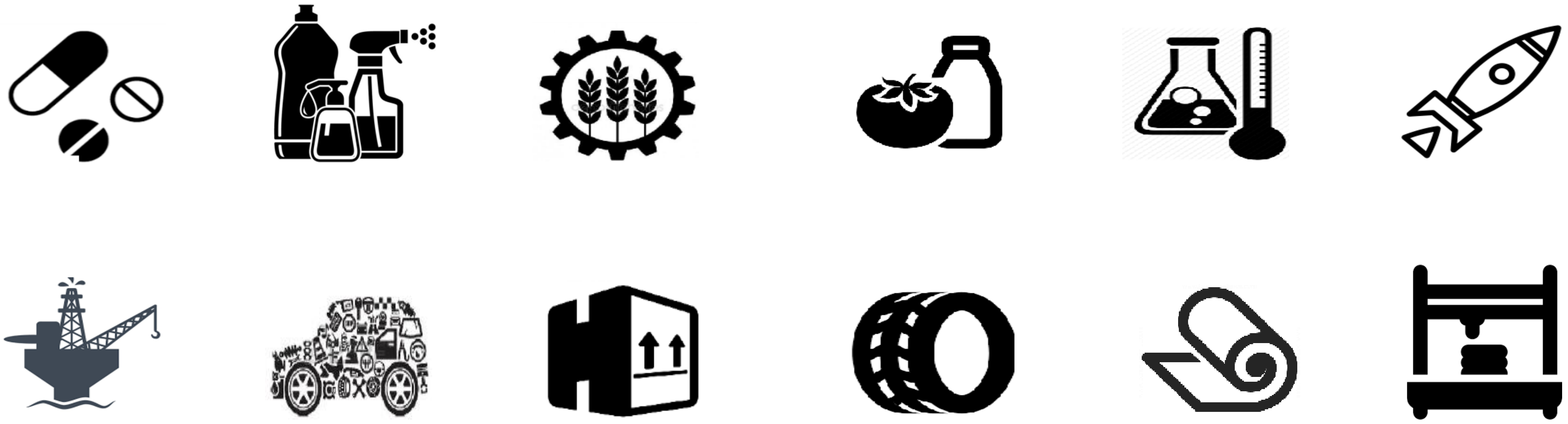
Eucalyptus Tree Wood Pyrolysis Project



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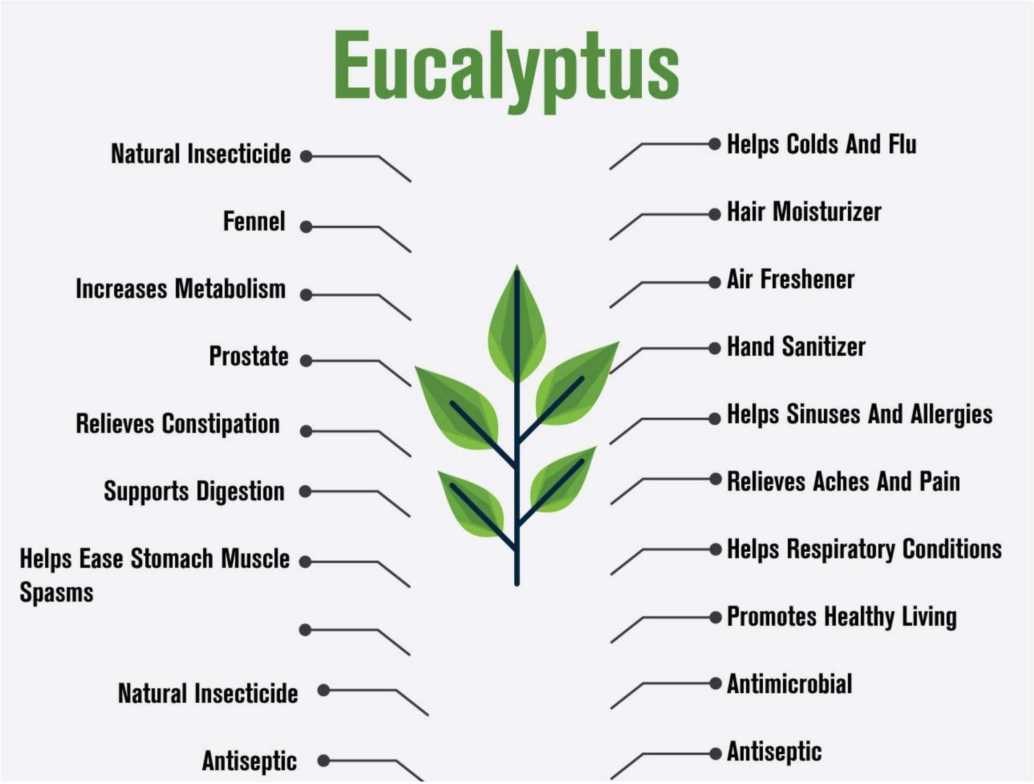
Introduction…

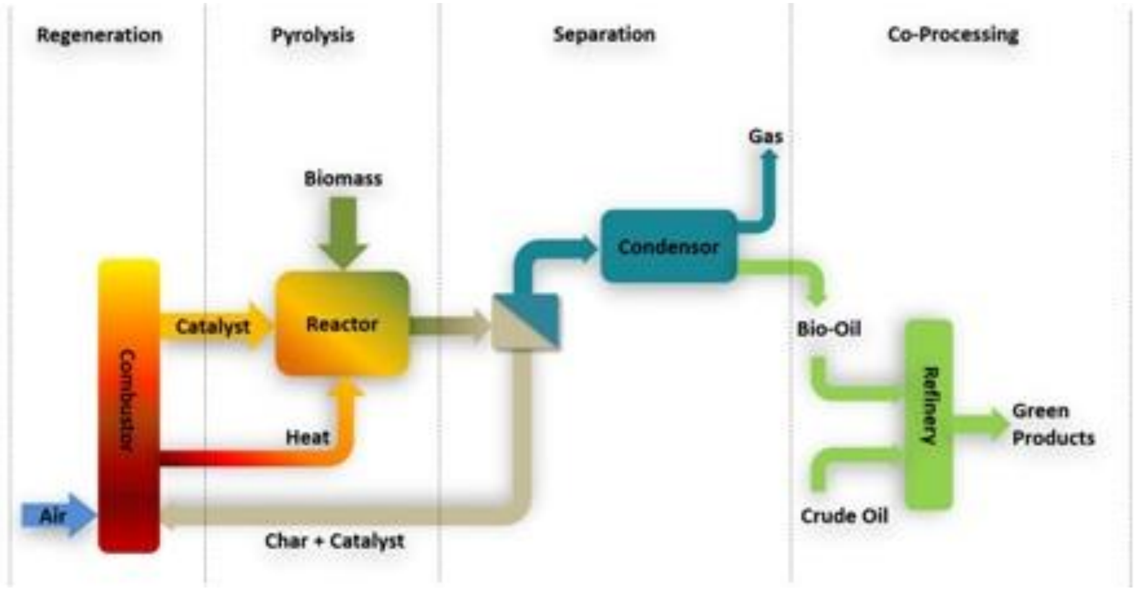
- Eucalyptus is a diverse genus of trees (rarely shrubs). It is a part of the myrtle family (Myrtaceae), which is a family of dicotyledon plants, that is, flowering plants. The seed of this family of plants typically contains two embryonic leaves or cotyledons.

- Eucalyptus species constitute a major reservoir for a wide range of secondary metabolites many of which have been found to harbor a diverse range of biological activities. A number of constituents isolated from Eucalyptus trees have been shown to have antibacterial, antifungal, antioxidant and repellent activities.

- Eucalyptus trees are used primarily for their wood, and they also provide other products, including oil, which is used for a variety of industrial and pharmaceutical purposes. Most species of eucalyptus trees produce some essential oil, but only about 20 have commercially viable concentrations of oil in their leaves. Several hundred species of Eucalyptus have been found to contain volatile oil.



Pyrolysis of Eucalyptus Wood:



- Pyrolysis is rapidly developing biomass thermal conversion technology and has been garnering much attention worldwide due to its high efficiency and good eco-friendly performance characteristics.

- Pyrolysis technology provides an opportunity for the conversion of biomass energy sources that are typically available and reliable from forest plantations, both renewable and natural can be used in several productive segments.

- In this method solid biomass material is heated in specially designed chamber which is called as pyrolysis reactor. In pyrolysis reactor, heating is carried out in closed environment which is almost oxygen free.

- Thermal decomposition of organic components in the biomass stream starts at 350°C–550°C and goes up to 700°C–800°C in the absence of air/oxygen. Process is very depend on the moisture content of the feedstock, which should be around 10%.

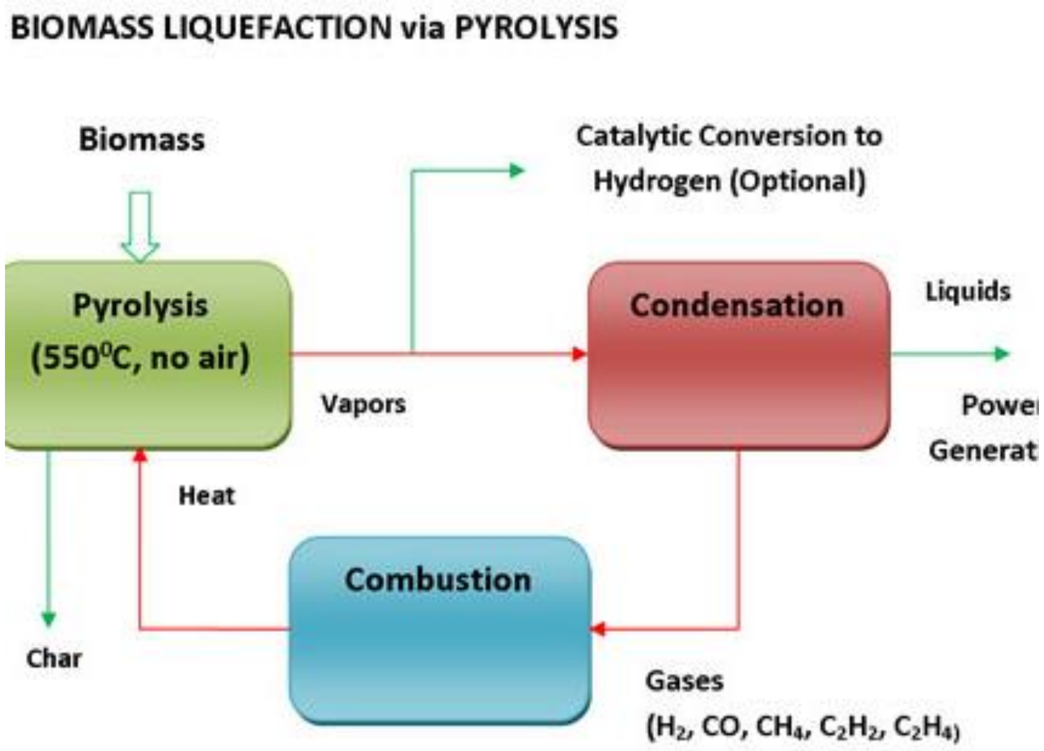
- The main products obtained from pyrolysis of Eucalyptus wood biomass are a high calorific value gas (synthesis gas or syngas), a biofuel (bio oil or pyrolysis oil) and a solid residue (char).

Conversion of Biomass…

- Pyrolysis of biomass is the heating of solid biomass in an inert atmosphere to produce gaseous products (mainly CO_2, H_2, CO, CH_4, C_2H_2, C_2H_4, C_2H_6, benzene, etc.), liquid products (tars, high molecular hydrocarbons and water) and solid products (char). By changing the rate of heating and the final temperature it is possible to modify the proportions of the gas, liquid and solid product.

- The method of wood conversion to charcoal by slow pyrolysis (slow heating rate) has been practiced for many years. This requires relatively slow reactions at low temperatures to maximize solid char yield. High heating rate is used to maximize either gas or liquid products according to the temperature employed.

- Although synthetic diesel fuel cannot yet be produced directly by pyrolysis of organic materials, there is a way to produce similar liquid (bio-oil) that can be used as a fuel, after the removal of valuable bio-chemicals that can be used as food additives or pharmaceuticals. Higher efficiency is achieved by the flash pyrolysis, in which finely divided feedstock is quickly heated to between 350 and 500 °C (660 and 930 °F)



Process characteristics and technology requirements…

Although pyrolysis of biomass has achieved commercial status, there are still many aspects of the process which are largely empirical and require further study to improve reliability, performance, product consistency, product characteristics and scale-up.

- Reactor configuration: Pyrolysis, perhaps more than any other conversion technology, has received considerable creativity and innovation in devising reactor systems that provide the essential ingredients of high heating rates, moderate temperatures and short vapor product residence times for liquids.

- Heat transfer: There are two important requirements for heat transfer in a pyrolysis reactor:
  1. to the reactor heat transfer medium (solid reactor wall in ablative reactors, gas and solid in fluid and transport bed reactors, gas in entrained flow reactors)
  2. from the heat transfer medium to the pyrolyzing biomass.

- Heat supply: The high heat transfer rate that is necessary to heat the sufficiently quickly imposes a major design requirement on achieving the high heat fluxes required to match the high heating rates and endothermic pyrolysis reactions.

- Feed preparation: The heat transfer rate requirements described above impose particle size limitations on the feed for some reactors. Drying is usually required to less than 10 wt% water unless a naturally dry material such as straw is available.

- Temperature of reaction: It is necessary to distinguish between temperature of reaction and reactor temperature, i.e. for fast pyrolysis the lower limit on wood decomposition is approximately 435C for obtaining acceptable liquid yields of at least 50% with low reaction times.

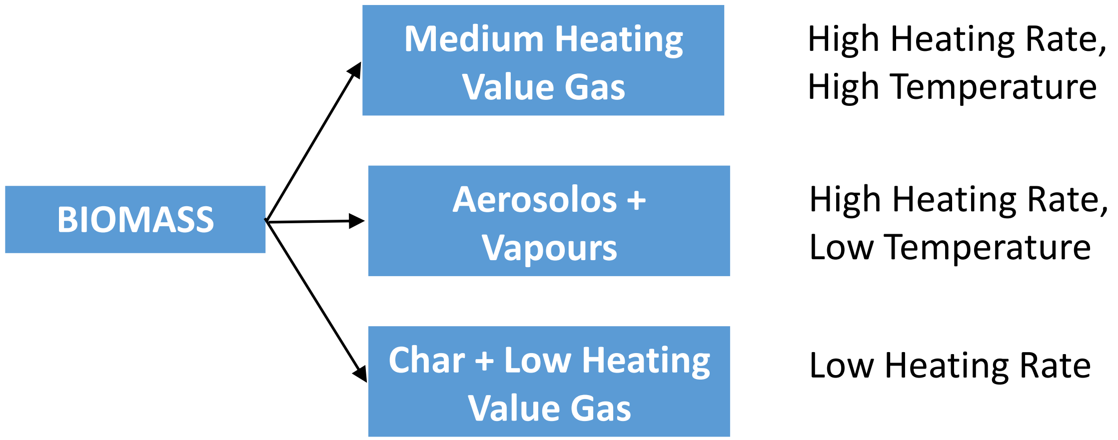
- Vapor residence time: The average molecular weight decreases with the degree of secondary reaction, i.e. increasing residence time and temperature. For chemicals, it is considered necessary to ``freeze'' the process at the appropriate time-temperature point in the envelope to maximize yield.

- Secondary vapor cracking: Long vapor residence times and high temperatures (>500C) cause secondary cracking of primary products reducing yields of specific products and organic liquids. Lower temperatures (<400C) lead to condensation reactions and the subsequent formation of lower molecular weight liquids which can also react.

- Liquids collection: The product vapors are not true vapors but rather a mist or fume and are typically present in an inert gas at relatively low concentrations which increases cooling and condensation problems. Larger scale processing usually employs some type of quenching or contact with cooled liquid product which is effective. Careful design is needed to avoid blockage from differential condensation of heavy ends.

- Char separation: Some char is inevitably carried over from cyclones and collects in the liquid. This aspect of char reduction and/or removal will be increasingly important as more demanding applications are introduced which require lower char tolerances in terms of particle size and total quantity. Possible solutions include hot gas filtration in a ceramic cloth bag house filter.

- Ash separation: The alkali metals from biomass ash are present in the char in relatively high concentrations and cannot be readily separated except by hot gas filtration.



Methods of Pyrolysis..

Pyrolysis methods can be ranked for feasibility by using many categories; these include: scale-up ability, status (commercial, demonstration, laboratory, pilot...), bio-oil yield, complexity, feed parameter specifications (moisture content, size...), and reactor size; even gas quality and inert gas requirements.

The chart here shows different characteristics of pyrolysis; the methods of pyrolysis can be thought in terms of availability for scale-up, complexity, etc. As one can imagine, certain methods are more advantageous than others. Feed flow rates for different scale up ranges are also shown below.

Properties	Status	Bio-oil yield on dry biomass	Complexity	Feed Size Specification	Inert gas requirements	Specific Reactor Size	Scale up	Gas Quality
Fluid Bed	Commercial	75 wt. %	Medium	High	High	Medium	Easy	Low
CFB & Transported bed	Commercial	75 wt. %	High	High	High	Medium	Easy	Low
Rotating cone	Demonstration	70 wt. %	High	High	Low	Low	Medium	High
Entrained flow	Laboratory	60 wt. %	Medium	High	High	Medium	Difficult	Low
Ablative	Laboratory	75 wt. %	High	Low	Low	Low	Difficult	High
Screw or Auger	Pilot	60 wt. %	Medium	Medium	Low	Low	Medium	High
Vacuum	None	60 wt. %	High	Low	Low	High	Difficult	Medium

Favourable Features
Moderate Features
Unfavourable Features

Commercial	2 t/h -20 t/h
Demonstration	200-2000 kg/h
Pilot	20-200 kg/h
Laboratory	1-20 kg/h

Syngas: energy-rich gas for power applications..

Syngas from pyrolysis

- High temperature pyrolysis process carried in the absence of oxygen results in production of calorific syngas at exceptional heating values, up to even 36 MJ/Nm3.

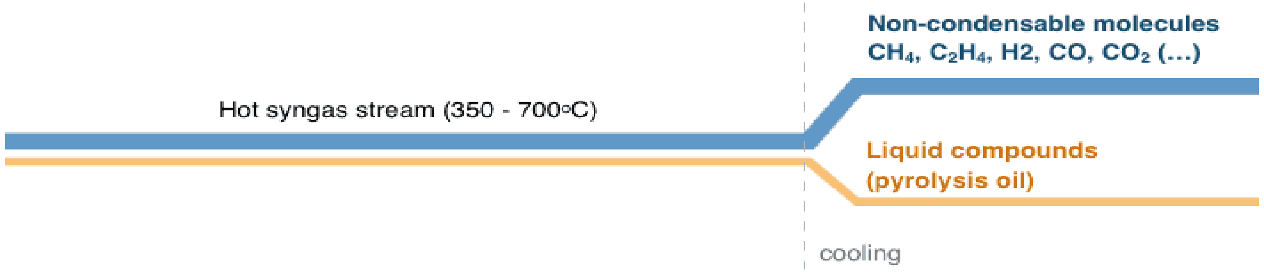
- Generated synthetic gas leaving the Biogreen reactor is a hot mixture of condensable and non-condensable phases. The composition of such blend depends on source material (feedstock) and pyrolysis operating conditions. Gases from pyrolysis typically contain significant quantities of methane, hydrogen, carbon monoxide, and dioxide, as well as higher hydrocarbons that build their calorific value and make them important fuel for the chemical and energy industries.

- In the hot state, synthetic gas contains condensable and permanent gases and can be considered as an alternative, or renewable energy source, and as a fuel for high temperature syngas burners.

Power Generation from Syngas

- The main application of produced syngas is typically the generation of power and heat. This can be realized either in stand-alone combined heat and power (CHP) plants or through co-firing of the product gas in large-scale power plants.

- Syngas from pyrolysis is a combustible gas and can be used for the production of power in many types of equipment, from steam cycles through gas engines and turbines. While the usages in boilers for steam cycles typically do not require extensive gas treatment before the power generation, the gas engines request a higher degree of purification and preparation. The stability and consistency of fuel provided to the internal combustion engine is one of the key factors of process. It is ensured by feedstock stability and the precisely controlled treatment conditions in Biogreen pyrolysis unit.



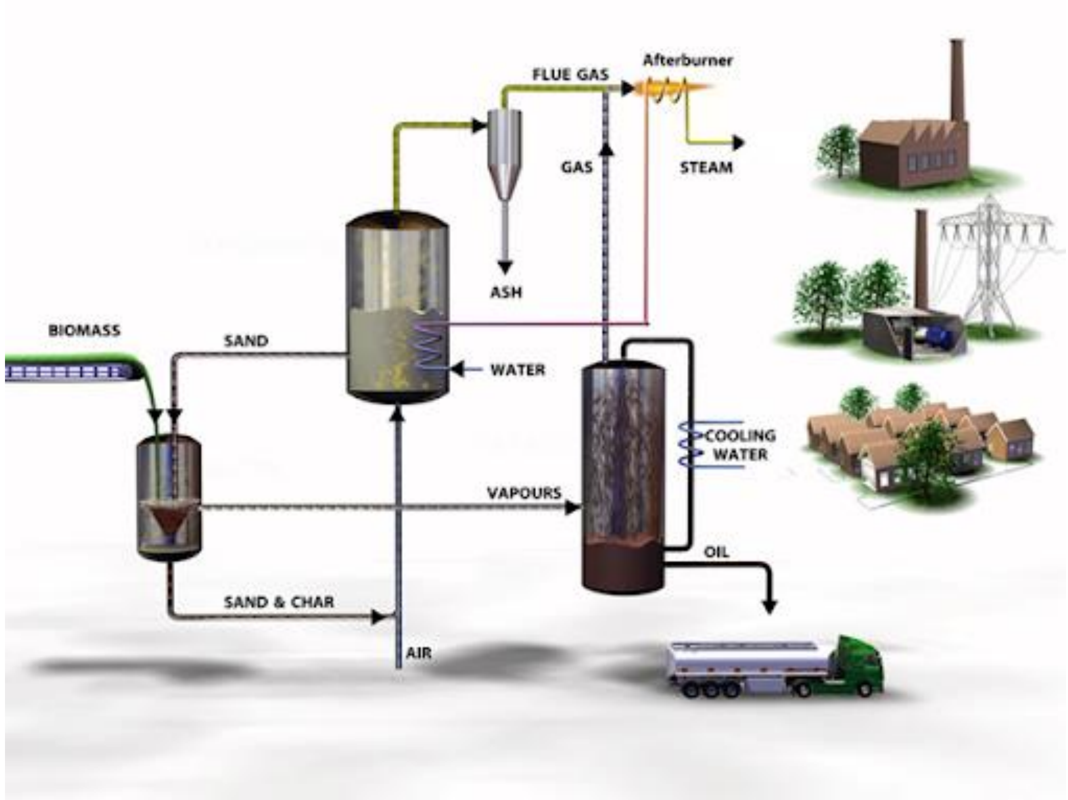
Syngas Utilization Routes

1. Directions of **hot syngas** utilization:

- heat production for drying or industrial purposes
- industrial steam or thermal oil production
- replacement of conventional fuel in the existing boilers
- electricity generation via ORC turbine
- electricity generation via steam turbine

2. Directions of **ambient temperature syngas** utilization:

- electricity generation via internal combustion engine
- electricity generation via gas turbine
- methane to grid production
- hydrogen production
- fuel cells utilization
- other special applications



Biochar Production:

- There are many different ways to make biochar, but all of them involve heating biomass with little or no oxygen to drive off volatile gasses, leaving carbon behind. This simple process is called thermal decomposition usually from pyrolysis or gasification.

- Biochar technology is more than just the equipment needed to produce biochar. Biochar technology necessarily includes entire integrated systems that can contain various components that may or may not be part of any particular system.

In general, however, biochar systems should include the following elements:

- Collection, transport and processing of biomass feedstocks
- Characterization and testing of biochar
- Production and utilization of energy co-products: gas, oil or heat
- Biochar transport and handling for soil application
- Monitoring of biochar applications for carbon accounting
- Life Cycle Assessment and full system monitoring for sustainability assessment

Post Process to Enhance Bio-char Properties

The effectiveness of the biochar can be altered by post-processing the biochar.

Techniques can include:

- Treat with phosphoric acid to enhance functional groups, reduce pH and make a slow-release phosphate fertilizer,
- Treat the biomass with alkali (e.g. potassium hydroxide) to increase pH and increase K content
- Infuse with organic or inorganic nitrogen compounds e.g. urine to enhance N content
- Mix with nutrient-rich organic material eg manure. May need to heat, to sterilize and dry the mixture to eliminate biohazard and facilitate handling
- Add minerals e.g. rock phosphate, gypsum, dolomite, iron oxides, lime to address specific soil constraints
- Add chemicals e.g. urea, diammonium phosphate to make a compound fertilizer
- Granulate or pelletize to aid handling and biochar application
- Add steam or oxygen. (Note that this is not creating activated carbon, which occurs in the reactor.)

Bio-Oil Production:

- The calorific value of the bio-oil from pyrolysis of different agricultural residues varies about 20 MJ/kg which is approximately equal to that of the petroleum fuel and therefore can be considered to be a promising fuel oil.

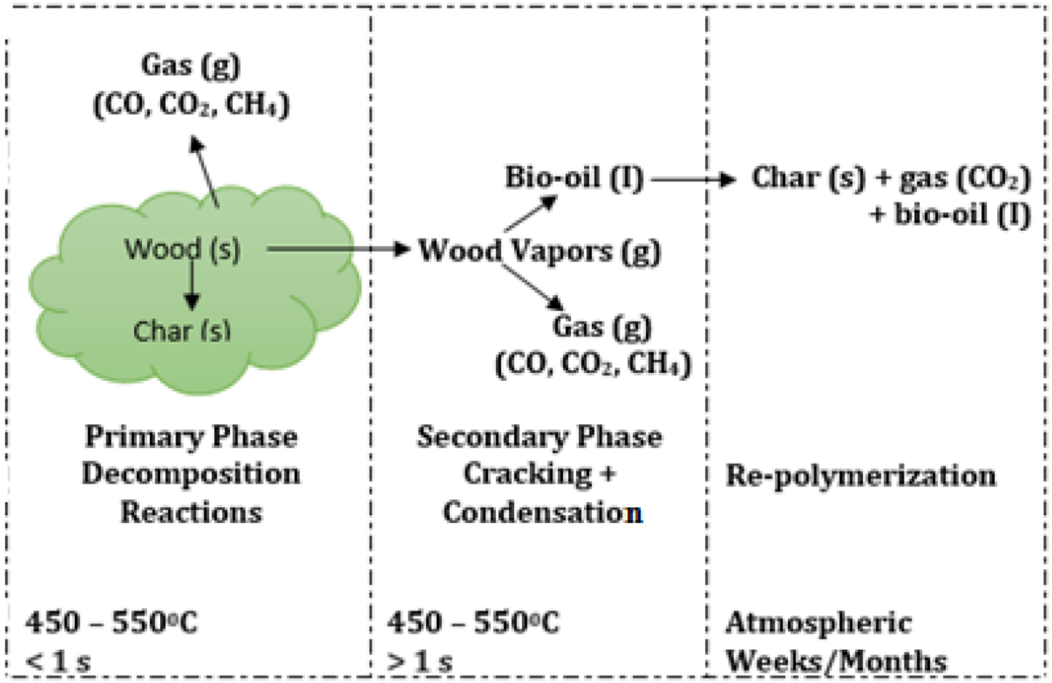
- The biomass in fast pyrolysis is heated often in the range of 425–500°C at very high heating rate (300–500°C/min) results in very short residence time (typically < 2 s) followed by rapid quenching of the pyrolysis vapors and aerosols to give bio-oils. Fast pyrolysis process produce 60–75% of liquid bio-oil, 15–25% of solid char, and 10–20% of non-condensable gases, depending on the feedstock used.

- No waste is generated in this process because the bio-oil can be used as a fuel oil substitute.

Directions of **Pyrolysis Oil** Utilization:

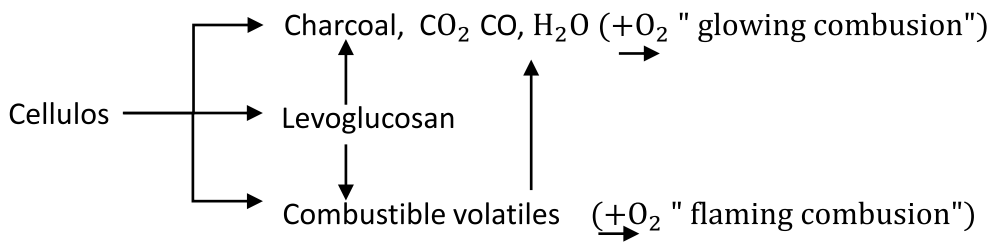
- Source of bio-molecules
- Fuel for further refining
- Food aromas (liquid smoke)
- Pesticides and plant enhancers (wood vinegar)

Factors affecting Biomass Pyrolysis:



- The amount and quality of the solid residue and the composition of the volatile fraction are strongly dependent both on the physical and chemical characteristics of the feed and on the process conditions.

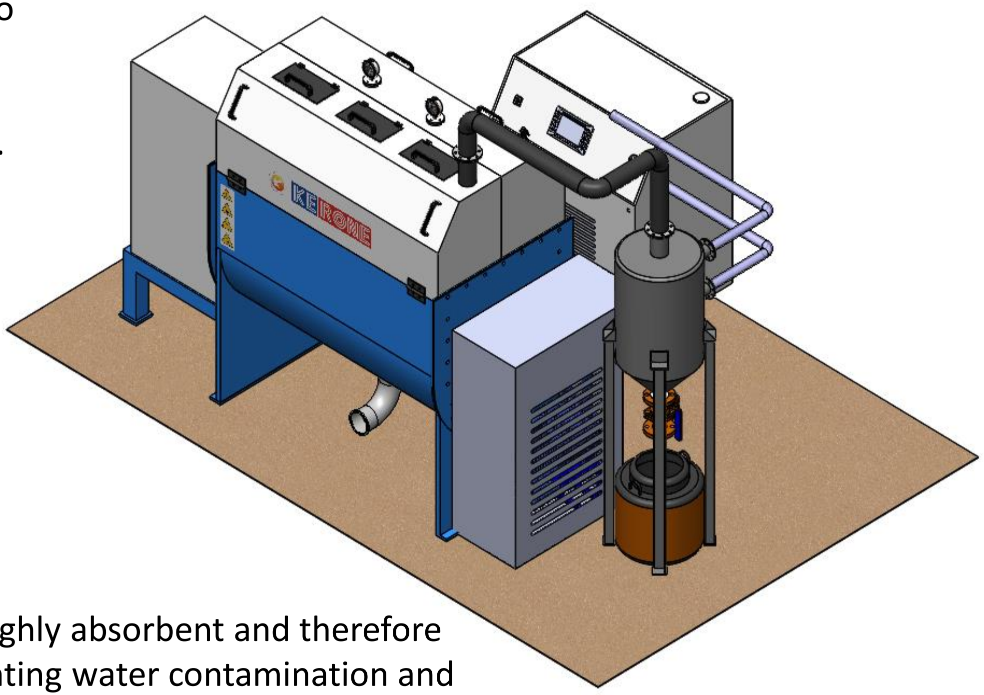
- Thermal decomposition of cellulosic materials proceeds through a complex series of chemical reactions, coupled with mass and heat transfer processes. The general set of pyrolysis reactions of cellulose has been: scheanatized by Shafizadeh (1968) as follows:
  The pyrolysis of biomass:



- Two general pyrolysis pathways must be recognized:
  one, involving dehydration and charring reactions, leads to the formation of charcoal, CO2 and H_2O ; the second involves depolymerization and volatilization, and leads to the formation of combustible volatiles. These competitive schemes help to explain the extreme sensitivity of the pyrolysis products distribution on the type of feedstock and process conditions.

Overview of Pyrolysis Process..

Pyrolysis processes can be categorized as slow or fast. Slow pyrolysis takes several hours to complete and results in biochar as the main product. On the other hand, fast pyrolysis yields 60% bio-oil and takes seconds for complete pyrolysis. In addition, it gives 20% biochar and 20% syngas. Fast pyrolysis is currently the most widely used pyrolysis system.



The essential features of a fast pyrolysis process are:

- Very high heating and heat transfer rates, which require a finely ground feed.
- Carefully controlled reaction temperature of around 500ºC in the vapor phase.
- Residence time of pyrolysis vapors in the reactor less than 1 sec.
- Quenching (rapid cooling) of the pyrolysis vapors to give the bio-oil product.

The essential features of a slow pyrolysis process are:

- A wide range of biomass feedstocks can be used in pyrolysis processes.
- The bio-char produced can be used on the farm as an excellent soil amender as it is highly absorbent and therefore increases the soil's ability to retain water, nutrients and agricultural chemicals, preventing water contamination and soil erosion.
- Biochar sequestration could make a big difference in the fossil fuel emissions worldwide and act as a major player in the global carbon market with its robust, clean and simple production technology.

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