



A presentation on
Biomass  Pyrolysis



What is Biomass?

- Biomass is an energy source produced by natural materials like:



Wood fuel



Rubbish



Alcohol fuels



Crops



Landfill gas

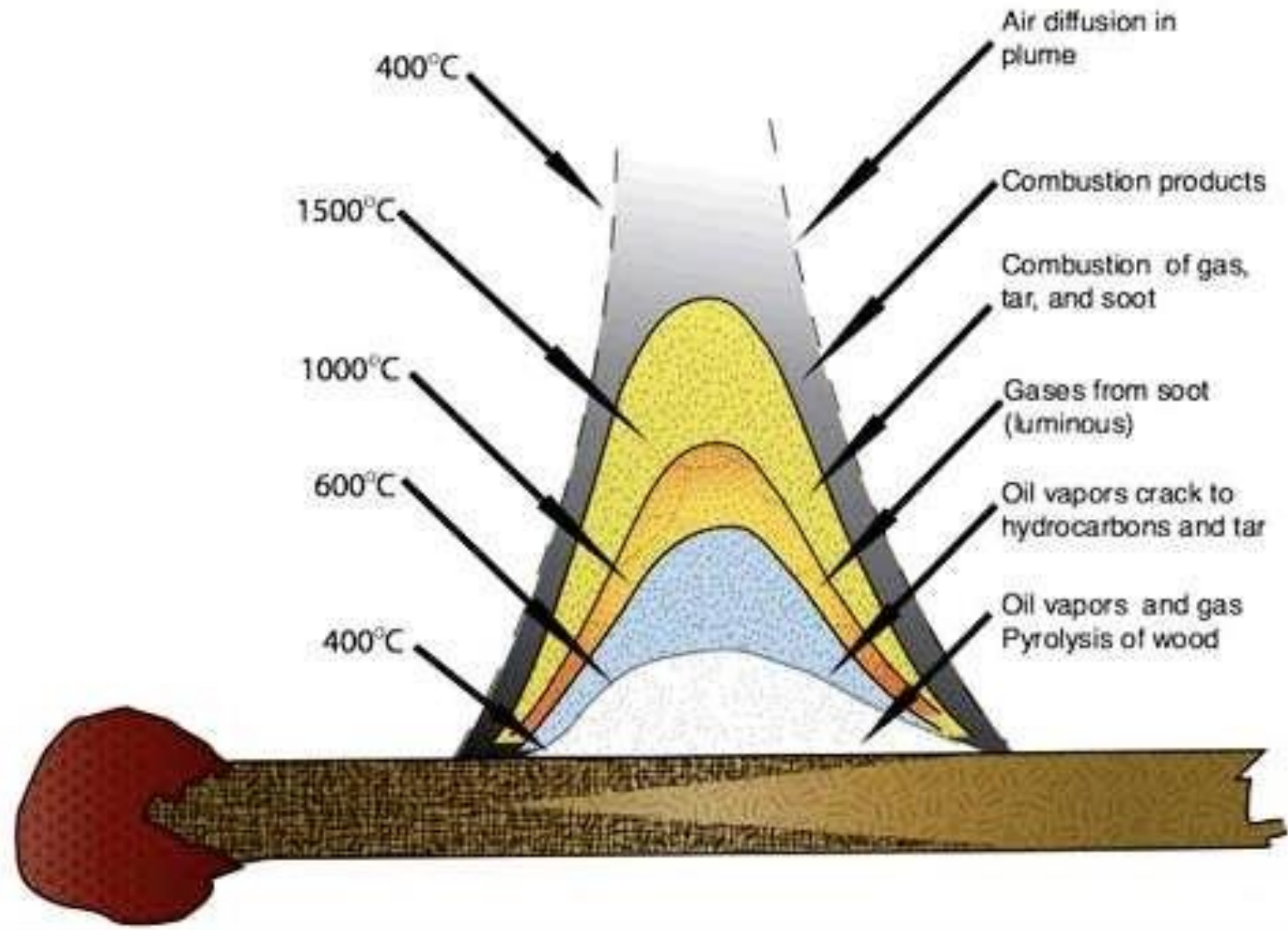
(Biological material derived from living, or recently living organisms.)

What is Pyrolysis?

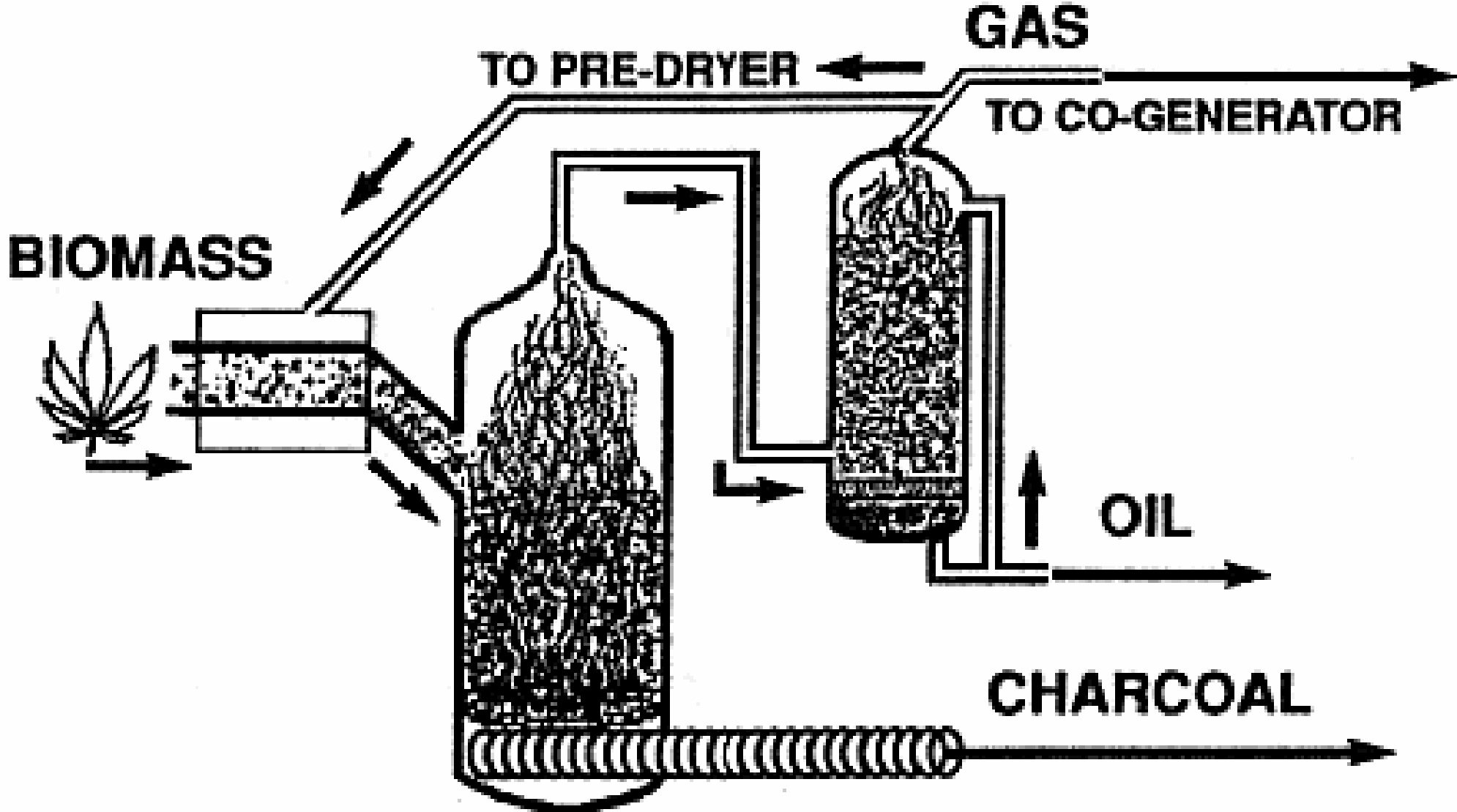
(Greek-derived: *pyro* "fire" and *lysis* "separating")

- thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen (or any halogen).
- involves the simultaneous change of chemical composition and physical phase, and is irreversible.
- usually the first chemical reaction that occurs in the burning of many solid organic fuels, like wood, cloth, and paper, and also of some kinds of plastic.
- products of biomass pyrolysis include biochar, bio-oil and gases including methane, hydrogen, carbon monoxide, and carbon dioxide

Pyrolysis, Gasification and Combustion in a Flaming Match



PYROLYTIC REACTOR



Feedstock for Pyrolysis

- **Moisture content of feedstock:** A wide range of biomass feedstock can be used in pyrolysis processes, process is very dependent on the moisture content of the feedstock, which should be around 10%.
 - At higher moisture contents, high levels of water are produced and at lower levels there is a risk that the process only produces dust instead of oil.
 - High-moisture waste streams, such as sludge and meat processing wastes, require drying before subjecting to pyrolysis.
- **Particle size of feedstock:** most of the pyrolysis technologies can only process small particles to a maximum of 2 mm keeping in view the need for rapid heat transfer through the particle and hence demand for small particle size means that the feedstock has to be size-reduced before being used for pyrolysis.

Types of Pyrolysis

Pyrolysis

Slow Pyrolysis

- takes several hours to complete
- results in biochar as the main product

Flash Pyrolysis

- achieve up to 75% of bio-oil yield.
- rapid de-volatilization in an inert atmosphere,
- high heating rate of the particles,
- High reaction temperatures between 450 °C and 1000 °C.
- **Limitations:**
- poor thermal stability and corrosiveness of the oil,
- solids in the oil

Fast Pyrolysis

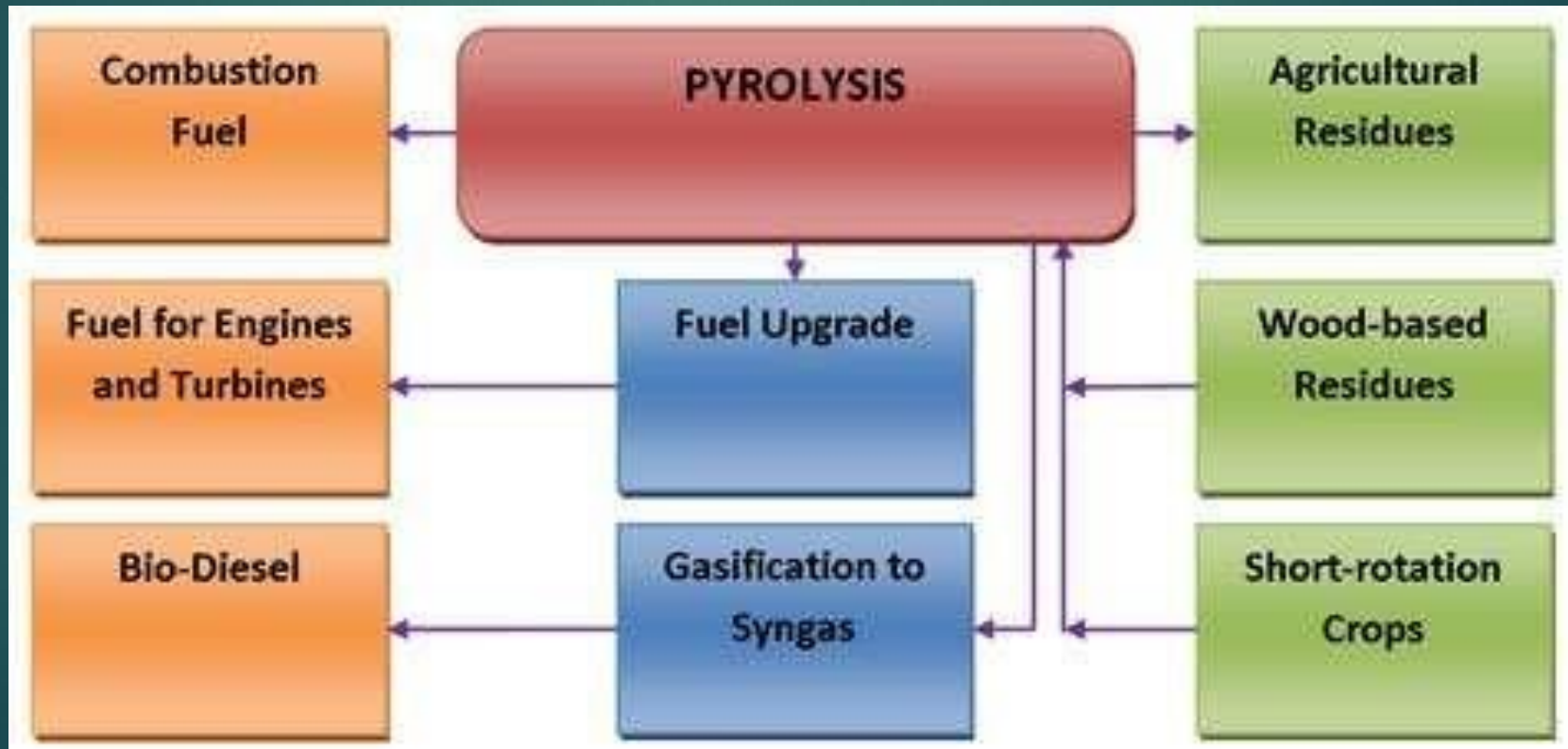
- takes seconds for complete pyrolysis.
- yields 60% bio-oil
- In addition, it gives 20% biochar and 20% syngas.

Essential features of a fast pyrolysis process:

- Very high heating and heat transfer rates, which require a finely ground feed.
- Thermodynamically stable and easily achievable process.
- Product is obtained in less than 1 sec.
- Quenching (rapid cooling) of the pyrolysis vapours to give the bio-oil product.

Products

- Depending on the thermal environment and the final temperature, pyrolysis will yield:
 - mainly biochar at low temperatures, less than 450 °C, when the heating rate is quite slow,
 - mainly gases at high temperatures, greater than 800 °C, with rapid heating rates.
 - at an intermediate temperature and under relatively high heating rates, the main product is bio-oil.



Bio-oil (Pyrolysis Oil)

- dark brown liquid
- has a similar composition to biomass.
- much higher density than woody materials which reduces storage and transport costs.

Advantages:

- particularly attractive for co-firing because it can be more readily handled and burned than solid fuel and is cheaper to transport and store
- can offer major advantages over solid biomass and gasification due to the ease of handling, storage and combustion in an existing power station when special start-up procedures are not necessary.
- In addition, bio-oil is also a vital source for a wide range of organic compounds and speciality chemicals.

Disadvantage:

- not suitable for direct use in standard internal combustion engines. Alternatively, the oil can be upgraded to either a special engine fuel or through gasification processes to a syngas and then bio-diesel.

Pyrolysis oil properties :

- Due to large amounts of oxygenated components present, the oil has a polar nature and does not mix readily with hydrocarbons.
- degradation products from the biomass constituents include organic acids (like formic and acetic acid), giving the oil its low pH.
- Water is an integral part of the single-phase chemical solution. The (hydrophilic) bio-oils have water contents of typically 15 - 35 wt.%.
- Typically, phase separation does occur when the water content is higher than about 30 to 45 %. Below an example of properties from typical wood-derived pyrolysis oil is given.

Property	Unit	Value
C	wt%	46
H	wt%	7
N	wt%	< 0.01
O (Balance)	wt%	47
Water content	wt%	25
Ash content	wt%	0.02
Solids content	wt%	0.04
Density	kg/m ³	1,170
LHV	MJ/kg	16
LHV	MJ/Ltr	19
pH	-	2.9
Kinematic viscosity (40 °C)	cSt	13

Typical industrial applications of pyrolysis oil as a fuel :

Pyrolysis oil is widely used as industrial fuel to substitute furnace oil or industrial diesel.

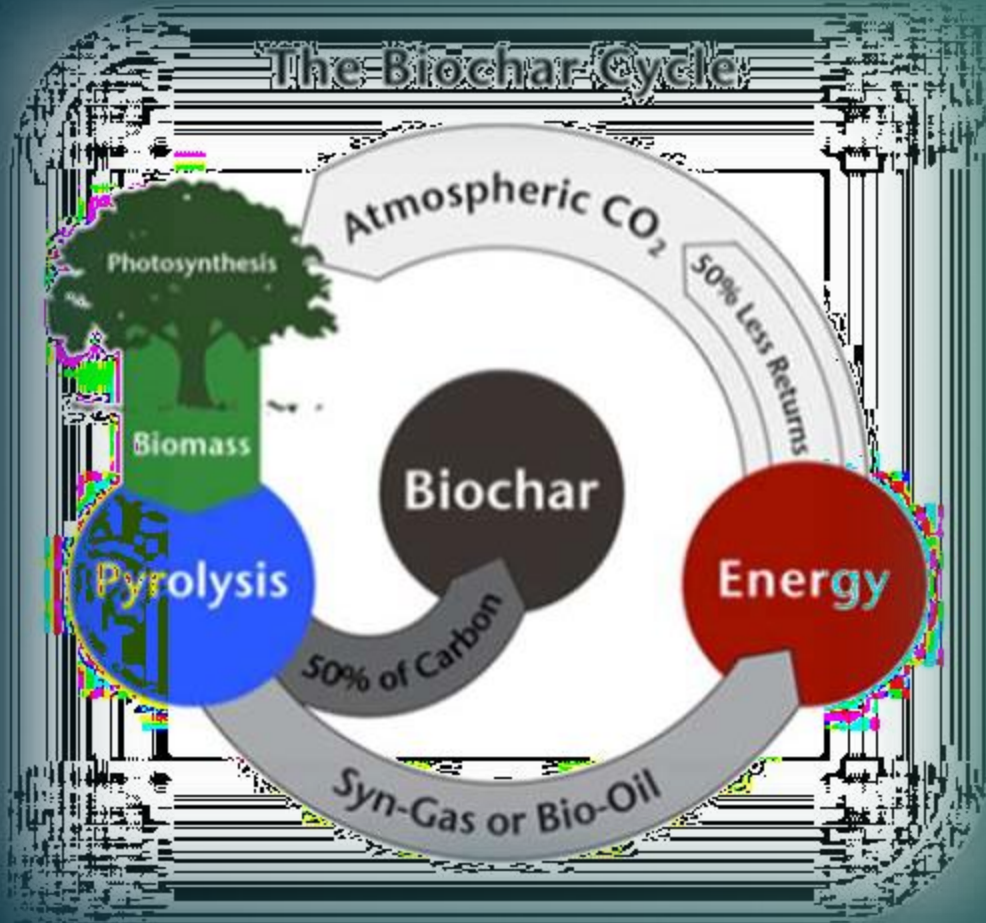
Other Uses:

- Boilers
- Furnaces
- Hot Water Generators
- Hot Air Generators
- Thermic Fluid Heater
- Electric Generators (mixed with 50% diesel)
- Diesel Pumps(mixed with 50% diesel)

Biochar

Importance of Biochar:

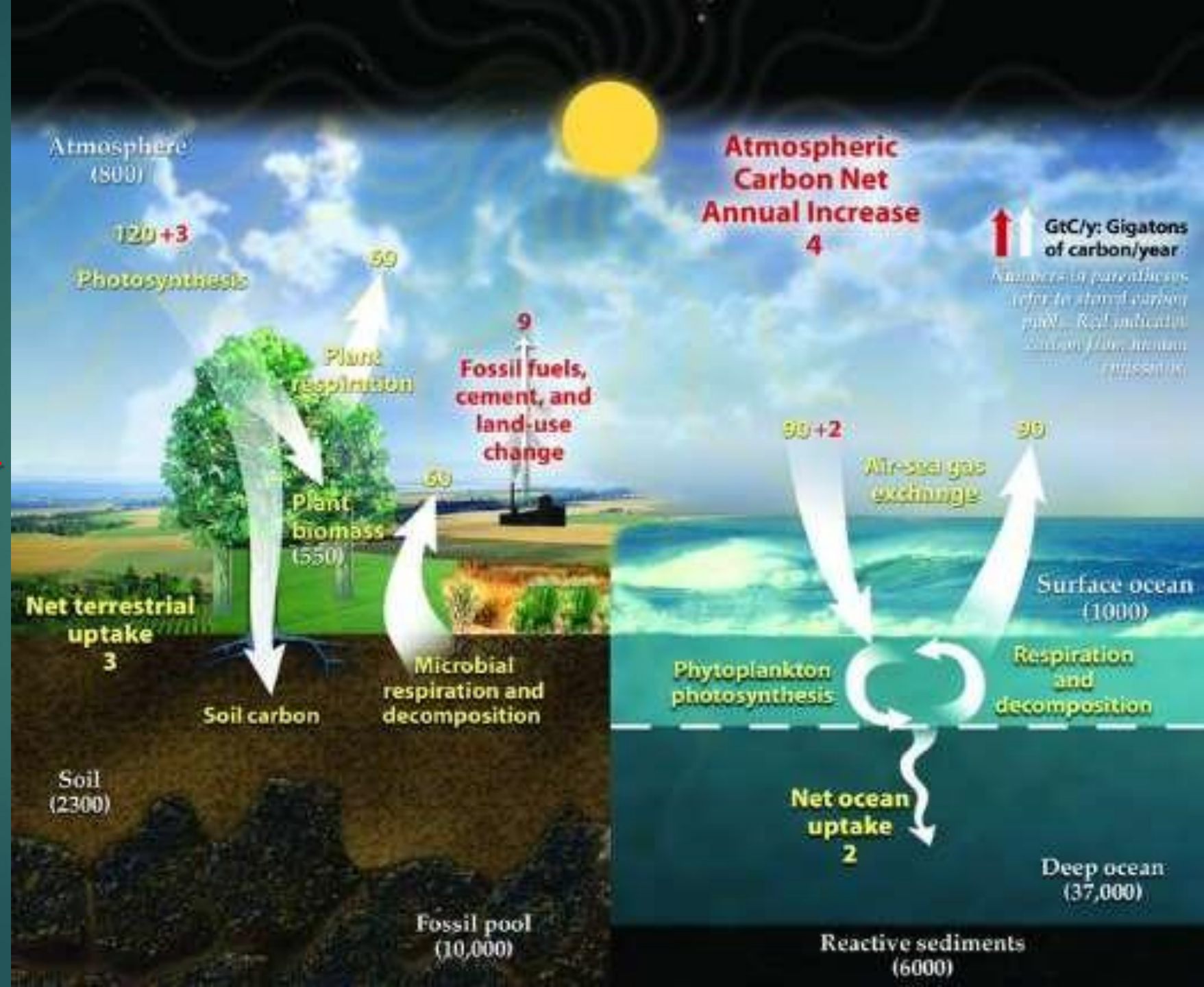
- The growing concerns about climate change have brought biochar into limelight. Combustion and decomposition of woody biomass and agricultural residues results in the emission of a large amount of carbon dioxide. Biochar can store this CO₂ in the soil leading to reduction in GHGs emission and enhancement of soil fertility.
- can increase the available nutrients for plant growth, water retention and reduce the amount of fertilizer by preventing the leaching of nutrients out of the soil.
- reduces methane and nitrous oxide emissions from soil, thus further reducing GHGs emissions.
- can be utilized in many applications as a replacement for other biomass energy systems.
- can be used as a soil amendment to increase plant growth yield.



Carbon Cycle

A net increase of 4 Giga-tones of atmospheric carbon/year

- No. in parentheses refer to stored carbon pools.
- Red indicates carbon from human emissions.



Organisation of Development Action and Maintenance (ODAM, Tamil Nadu), with support from the Siemenpuu Foundation in Finland, conducted a series of biochar field trials in Southern India using common feedstocks to produce the biochar. And used it for farming purposes.



Farmers using Biochar for farming



Mosses
(Scientific name: *Bryophyta*)
growing on a piece of biochar



A test shows growth of roots of Ladyfinger plant in *presence of biochar in the soil (Left)* and *in the absence of biochar in the soil (Right)*.

Syngas

- made up of carbon monoxide, and hydrogen (85%) with smaller amounts of carbon dioxide and methane.
- has a high calorific value so it can be used as a fuel to generate electricity or steam.
- may also be used as a basic chemical in the petrochemical industry.
- has less than half the energy density of [natural gas](#).

Industrial Practices of Biomass Pyrolysis

Cogeneration or combined heat and power (CHP)

- is the use of a heat engine or power station to *simultaneously generate electricity and useful heat* and is *thermodynamically efficient* use of fuel.
- in separate production of electricity, some energy must be discarded as waste heat, but in cogeneration this thermal energy is put to use.

Sugar industries in India:

- traditionally practicing cogeneration by using bagasse as a fuel, these industry can produce electricity and steam for their own requirements.
- It can also produce significant surplus electricity for sale to the grid using same quantity of bagasse. For example, if steam generation temperature/pressure is raised from 400°C/33 bar to 485°C/66 bar, more than 80 KWh of additional electricity can be produced for each ton of cane crushed. The sale of surplus power generated through optimum cogeneration would help a sugar mill to improve its viability, apart from adding to the power generation capacity of the country.

Environmental benefit

Life Cycle Analysis (LCA) is an accounting tool that is used to track inputs and outputs of processes and keep a running tally on specific traits.

Here, LCA is used to track two items:

- How much energy (Net Energy Value or NEV) is used to produce and deliver biomass, perform pyrolysis, upgrade the bio-oil and create gasoline and diesel fuel compared to the energy content of the fuel;
- Carbon dioxide (a greenhouse gas) uptake by biomass and outputs from processing.

In both cases, a desirable outcome from pyrolysis of biomass would be to increase energy output and reduce CO₂ emissions compared to fossil based alternatives.

The NEV (Figure 1) is 1.09 MJ km⁻¹ for pyrolysis-derived gasoline and 0.92 MJ km⁻¹ for pyrolysis-derived diesel, both higher than the NEV for conventional fossil-based gasoline of -1.2 MJ km⁻¹. A positive number indicates that there is more energy in the fuel than is used to create it – or a positive gain in total energy. Note the negative number for fossil-based gasoline indicating a net loss of energy. The gain in energy for biomass-based fuels is a major reason why this technology is being considered.

Figure 2. Life Cycle Analysis of GHG emissions of pyrolysis based fuels compared to fossil-based gasoline

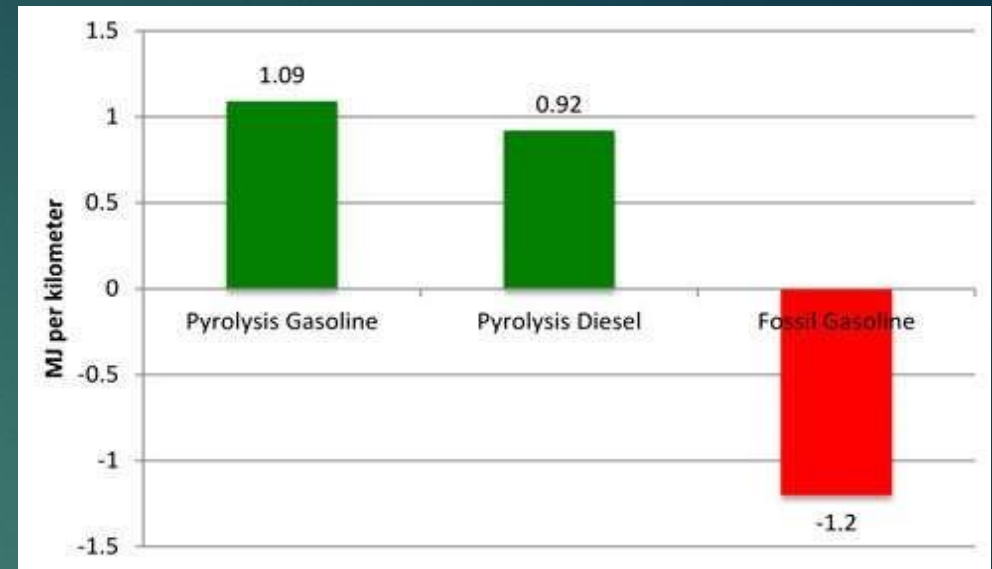
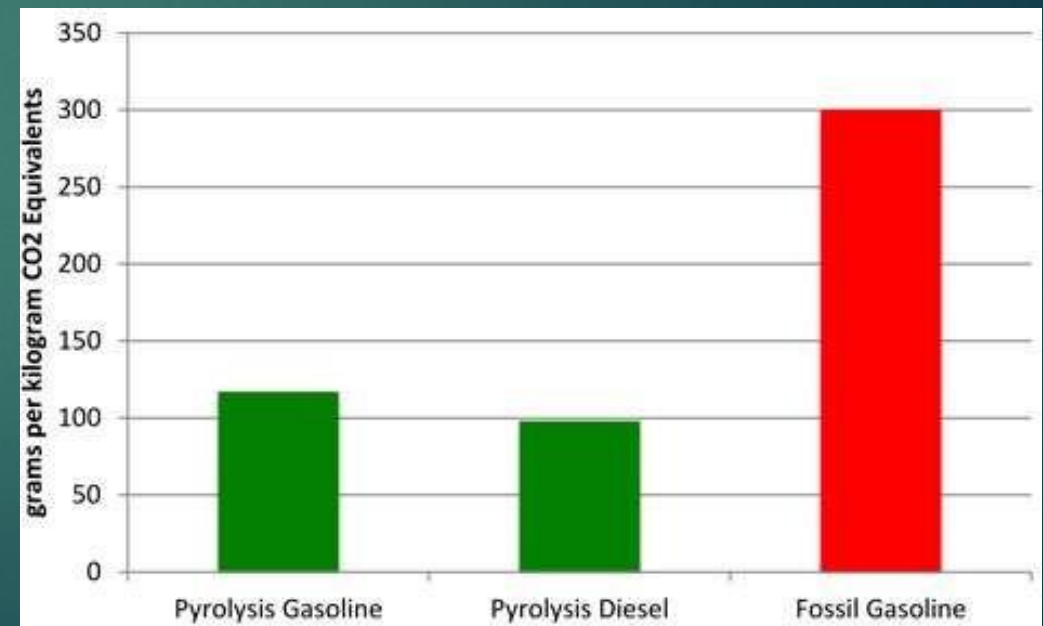


Figure 1. NEV of biomass based pyrolysis fuels compared to fossil-based gasoline. (MJ=Megajoules is a measure of energy content.)



Biomass Energy in context of India

- India produces about 450-500 million tonnes of biomass per year. Biomass provides 32% of all the primary energy use in the country at present.
- MNRE estimates that the potential for power from biomass in India is about 18,000 MW.
- The current share of biofuels in total fuel consumption is extremely low and is confined mainly to 5% blending of ethanol in gasoline, which the government has made mandatory in 10 states.
- Currently, biodiesel is not sold on the Indian fuel market, but the government plans to meet 20% of the country's diesel requirements by 2020 using biodiesel.
- MNRE has been implementing biomass power/co-generation programme since mid 90's.
 - A total of **288** biomass power and cogeneration projects aggregating to **2665 MW** capacity have been installed in the country for feeding power to the grid consisting **158** bagasse cogeneration projects in sugar mills with surplus capacity aggregating to **1666.0 MW**.
 - States which have taken leadership position in implementation of bagasse cogeneration projects are Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and Uttar Pradesh.
 - The leading States for biomass power projects are Andhra Pradesh, Chattisgarh, Maharashtra, Madhya Pradesh, Gujarat and Tamil Nadu.

Bottlenecks faced by the Indian Biomass Industry:

One of the most critical bottlenecks for biomass plants (based on any technology) is the supply chain bottlenecks that could result in non-availability of feedstock. A related problem is the volatility, or more precisely increase, in the feedstock price. Both these could render the project unviable. There are other concerns and bottlenecks as well such as:

- Lack of adequate policy framework and effective financing mechanisms
- Lack of effective regulatory framework
- Lack of technical capacity
- Absence of effective information dissemination
- Limited successful commercial demonstration model experience

Conclusion

- ▶ *Biomass pyrolysis* has been attracting much attention due to its high efficiency and good environmental performance characteristics.
- ▶ It also provides an opportunity for the processing of agricultural residues, wood wastes and municipal solid waste into clean energy.
- ▶ In addition, 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.