How Wood Properties Influence Utilization

Wood Composition

The four major components of woody biomass are cellulose, hemicellulose, lignin, and mineral components.

Cellulose. Cellulose is a polymer composed of glucose (sugar) chains. It makes up nearly 50 percent of woody plant mass. Cellulose consists of carbon, hydrogen, and oxygen in the form of starches, proteins, and sugars

Hemicellulose. Hemicellulose consists of pentose sugar carbohydrates, mainly xylose. This carbohydrate comprises 25 to 35 percent of the dry weight of wood residues, second only to cellulose in abundance. The use of hemicellulose is currently limited due to manufacturing related costs.

Lignin. Lignin is a phenylpropane polymer that holds together the cellulose and hemicellulose components of woody biomass. Lignin constitutes about 15 to 25 percent of the weight of woody biomass. Lignin has not yet been used as a raw material for industrial purposes in large quantities. This reflects the chemical complexity of lignin.

Mineral Components. Woody biomass is composed of many mineral elements. The principal elements include carbon, oxygen, and hydrogen. While these elements do not produce energy during combustion, they do affect the energy content of woody biomass.

Other elements include nitrogen, sulfur, chlorine, and heavy metals. All potentially can have negative impacts when combustion is the technological process being employed.

MoistureContent

The moisture content of biomass material varies greatly and plays a large role in determining the most suitable energy conversion process.

Wet conversion processes such as fermentation are often more suited to biomass with a higher moisture content (e.g. corn, sugarcane, barley straw). **Dry conversion** processes such as pyrolysis, gasification, and combustion are more suited to biomass with a lower moisture content (e.g. wheat straw, pine, switchgrass, etc).

These simple formulas can calculate the moisture content of biomass:

$$\text{moisture content (wet basis)} = \frac{(\text{total weight of wet wood} - \text{oven dry weight})}{\text{total weight of wet wood} \times 100}$$

$$\text{moisture content (dry basis)} = \frac{(\text{total weight of wet wood} - \text{oven dry weight})}{\text{oven dry weight} \times 100}$$

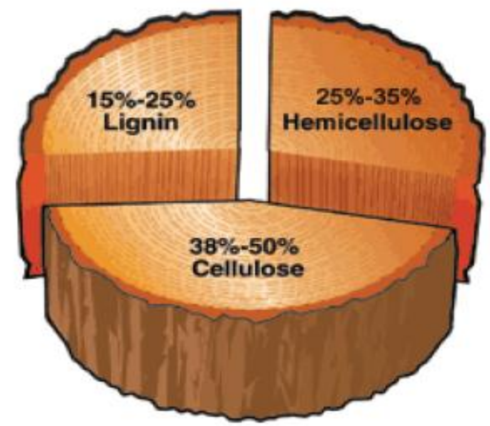


Figure 1. Percentage Breakdown of the Various Components of Woody Biomass

Wood composition and moisture content are two of the more important properties of woody biomass in terms of utilization potential and energy yield. Moisture plays a significant role in the type of conversion process used.

Moisture Content

The weight of moisture contained in a piece of wood expressed as a percentage of its oven dry weight is almost universally referred to as its moisture content.

Expressed mathematically

$$mc = \frac{(W_g - W_o)}{W_o} \cdot 100\%$$

where mc = moisture content
W_g = green weight of the wood
W_o = oven dry weight of the wood

Oven dry weight is the quasi-constant weight attained by wood samples dried at 105 C° (221 F°)

The oven dry weight is a constant value that may be determined at any time.

Technological Processes: Bio-chemical

Aerobic Digesting (Composting). Sawdust and wood chips are the most common types of woody biomass used in aerobic digestion. In this process, organic wastes are collected from mill lagoons, where naturally occurring bacteria use **oxygen** to convert the waste into **carbon dioxide, water, energy, and more bacteria.**

Additional feedstock and water mix with aerators daily to ensure constant turnover of the sludge. This process can be expensive as well as energy demanding because of the need for constant mixing.

Nutrient-rich fertilizers and composts are the major product that results from aerobic digestion of woody biomass.

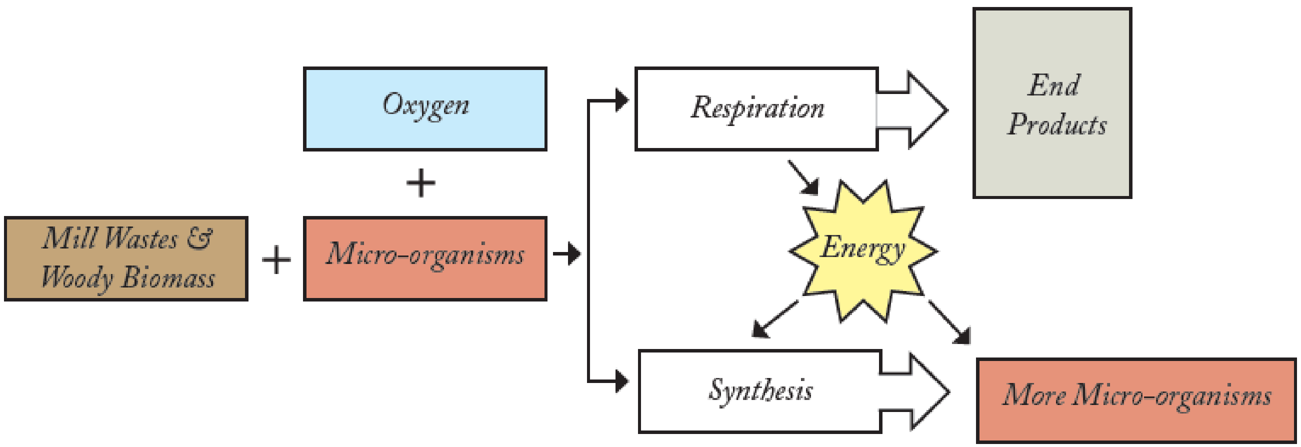


Figure 1. Aerobic Digestion Schematic

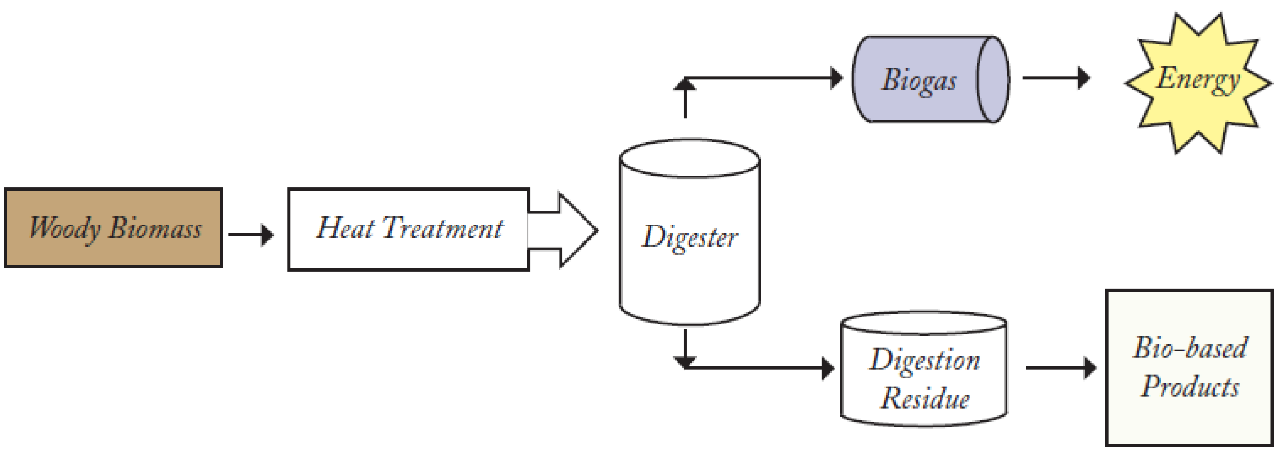


Figure 2. Anaerobic Digestion Schematic

Anaerobic Digestion. Anaerobic digestion is the decomposition of biomass by bacteria in the absence of oxygen. Biogas, or methane, is the primary product produced. Anaerobic digestion is governed by several factors, including temperature, retention time, chemical composition of the influent, and presence of toxicants. These factors, in turn, affect quantity and quality of the biogas produced.

New technologies are looking to increase yields and decrease process time by adding **ultrasound** technologies to the process. Commonly referred to as sonication, waves disintegrate the solids in the influent. This, in turn, increases surface area and allows for more complete and quicker digestion.

Fermentation. Fermentation is a biological process in which enzymes produced by microorganisms cause chemical reactions to occur.

An enormous variety of bacteria, yeasts, and fungi exist to ferment sugars. These microorganisms digest sugars to produce the energy and chemicals they need for survival while giving off byproducts such as carbon dioxide, organic acids, hydrogen, ethanol, and other products.

Producing commercial products through fermentation of lignocellulosic material is a multi-step process involving:

1) pre-treatment and hydrolysis (deconstruction of a compound by reaction with water) of the material to release fermentable simple sugars;

2) fermentation of these sugars by living organisms to produce hydrocarbons;

3) recovery from the fermentation broth of the desired products; and

4) utilization of the byproducts.

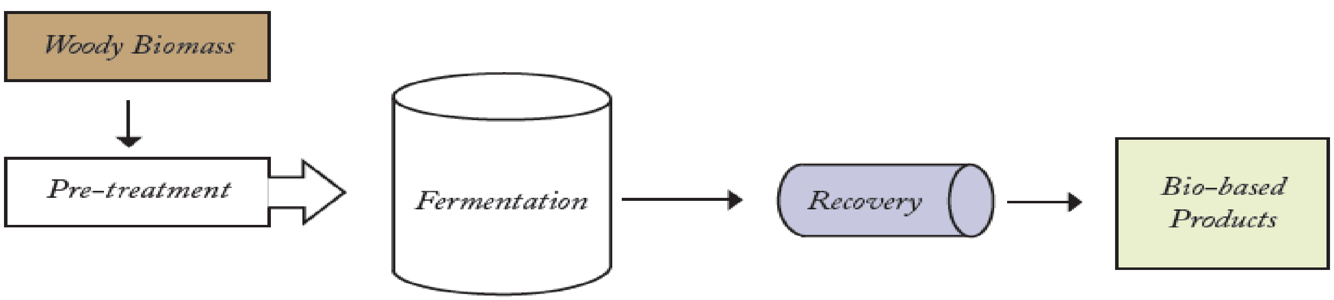


Figure 3. Fermentation Schematic

Technological Processes: Thermochemical

Woody biomass is converted into useful forms of energy (i.e. solid, liquid, or gaseous fuels) as well as useful products (e.g. polymers, bio-plastics, char, pellets, and acids) using a number of technological processes. Thermochemical processes depend on the relationship between **heat and chemical action** as a means of extracting and creating products and energy.

Gasification. Gasification is a special combustion process, occurring between 600 and 1000 degrees-celsius, in which biomass solids are turned directly into biogas. Products of gasification cannot be stored easily.

Consequently, the system is often integrated with other conversion processes in an effort to use the outputs in the form of various bio-based syngases. In addition to **biogas,** the gasification process **produces ash, char, tars, methane, and other hydrocarbons.**

Gasification systems are as much as **20 percent more efficient** than direct combustion systems.

(Figure 1)

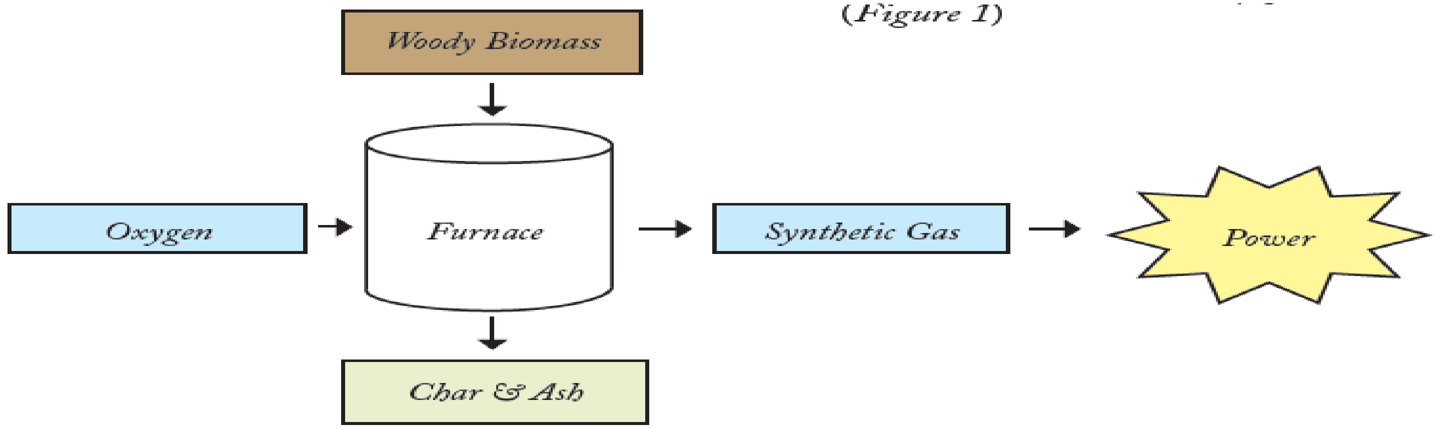


Figure 1. Gasification Schematic

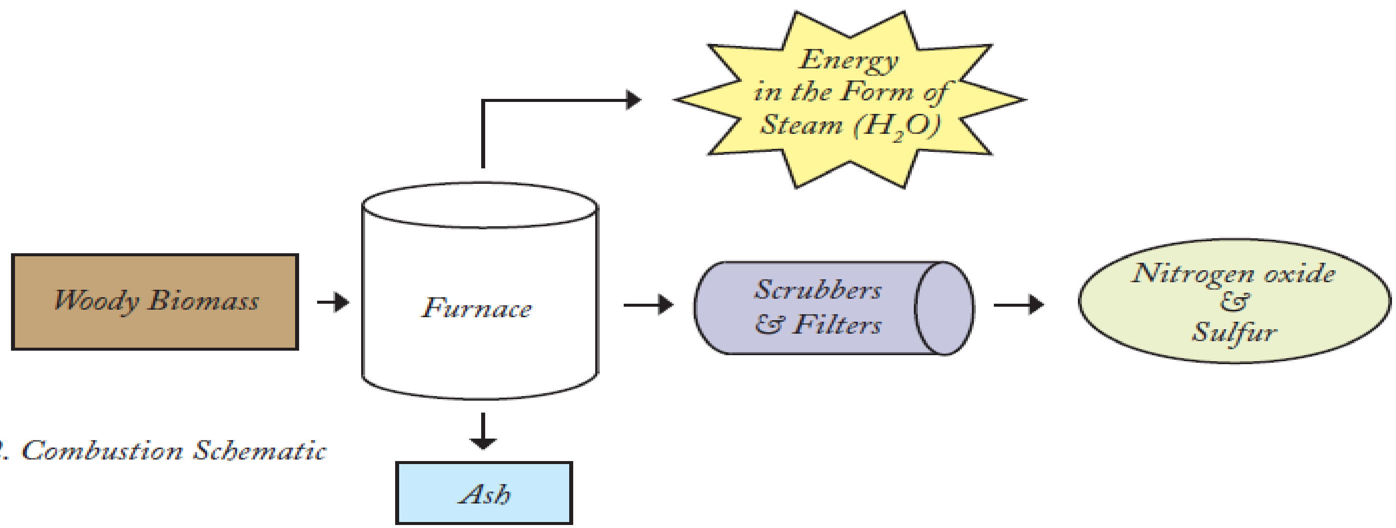


Figure 2. Combustion Schematic

Consequently, some types of woody biomass may prove more costly to gasify than others. For example, wood residues **high in sodium or potassium will require pre-cleaning prior to utilization.**

Combustion. Almost anything organic will burn. However, biomass having a low-moisture content is best suited for combustion. Combustion refers to the rapid oxidation of the feedstock as it is exposed to high heat.

Typically, biomass-powered boilers are in the production range of 20 to 50 MWh, compared with coal-fired boilers in the production range of 100 to 1,500 MWh. Small-capacity plants generally have lower efficiencies because the equipment needed to increase energy-efficiency is not economically viable. The most economic near-term solution is co-firing boilers with both fossil and biomass feedstocks.

Pyrolysis. Pyrolysis is the process of rapid thermal decomposition of biomass in the absence of oxygen. This process produces energy, liquids, gases, and char.

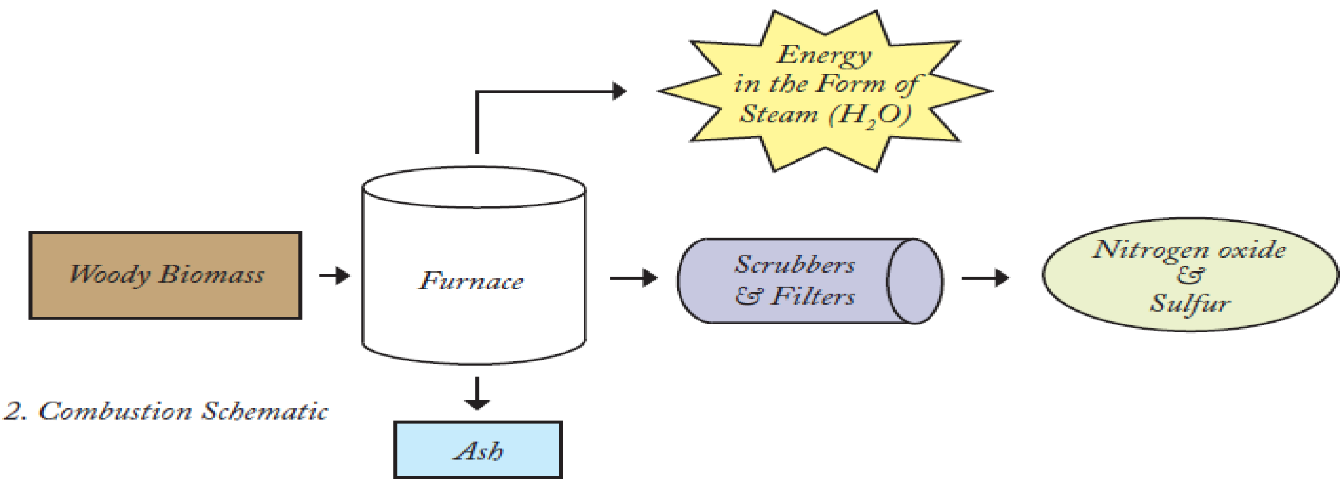


Figure 2. Combustion Schematic

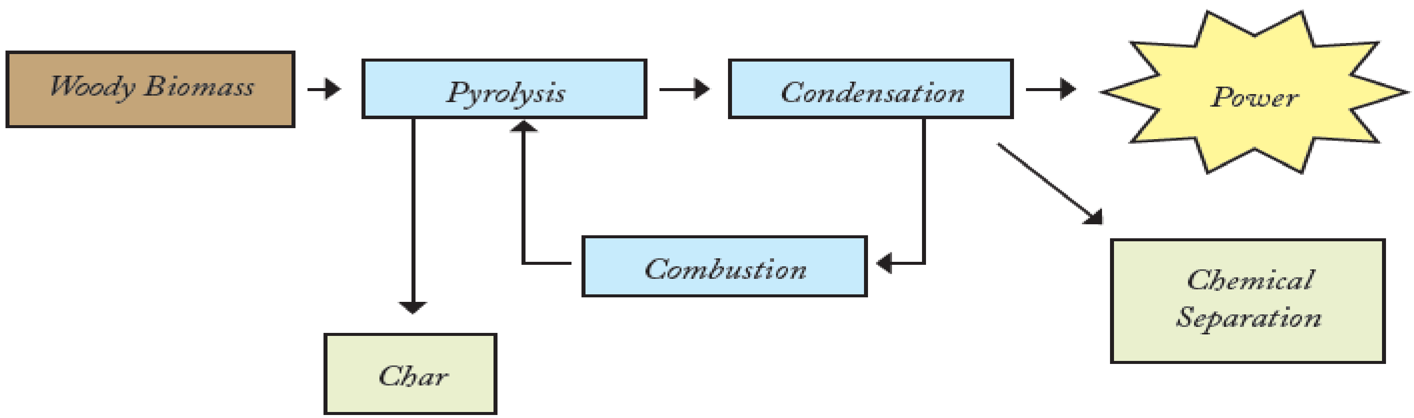


Figure 3. Pyrolysis Schematic

PYROLYSIS

DEFINITION

thermal decomposition of organic material at elevated temperatures in the absence of oxygen

Endothermic

Involves chemical change of chemical composition and physical phase

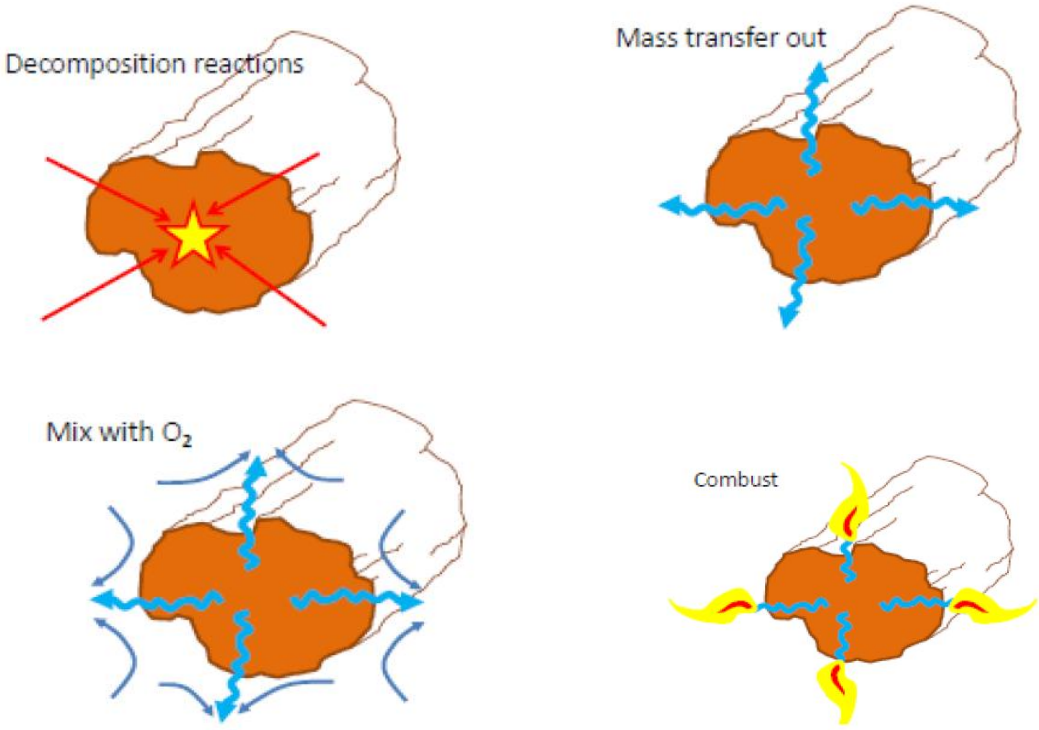
Irreversible

WHAT IS PYROLYSIS?

- Pyrolysis does not involve reactions with oxygen, water, or any other reagents.
- In practice, it is not possible to achieve a completely oxygen-free atmosphere.
- Because some oxygen is present in any pyrolysis system, a small amount of oxidation occurs.

WHAT IS PYROLYSIS?

Pyrolysis is :



PRODUCT of PYROLYSIS

Bio Oil

Char

SynGas

PROCESS

- operating temperatures above 430 °C (806 °F).
- For agricultural waste, for example, typical temperatures are 450 to 550 °C (840 to 1,000 °F).

PRO'S N CON'S

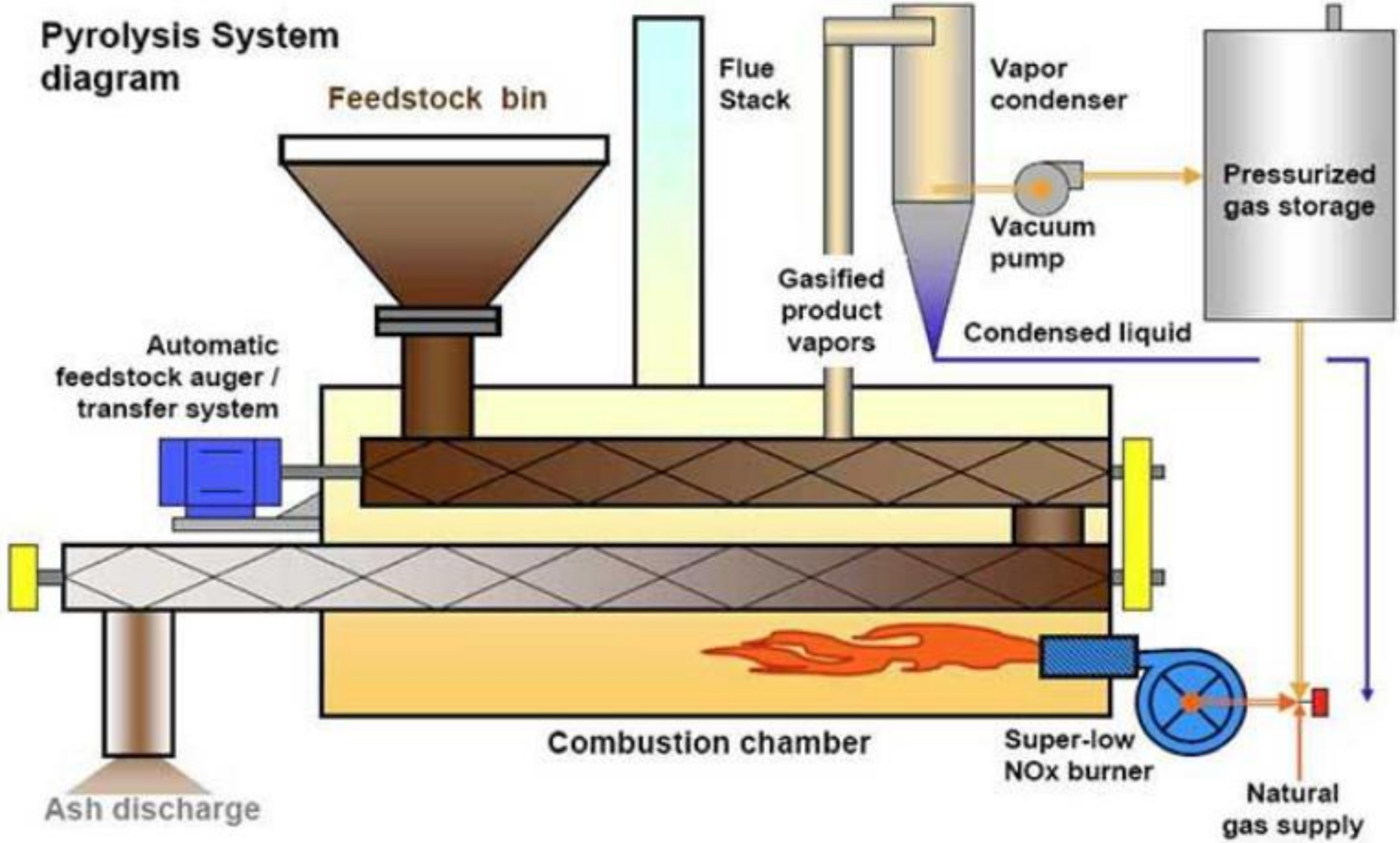
- Cheap and economical system
- Environment-friendly,
- Energy-efficient

- Requires drying of soil
- Ineffective in destroying or physically separating inorganics from the contaminated medium.
- Requiring proper treatment, storage, and disposal for hazardous wastes.

Dry Pyrolysis

- Process of thermal decomposition without access of oxygen (O_2)
- Product of dry pyrolysis are gas with high heat of combustion, liquid and solid carbon residue.
- Type of dry pyrolysis depend on the temperature of the process.

Pyrolysis Process



Oxidizing Pyrolysis

- It's impossible to achieve a completely oxygen-free atmosphere.

- Thus, a small amount of oxidation occurs. If volatile or semi-volatile materials are present in the waste, thermal desorption will also occur.

Oxidizing Pyrolysis

- Thermal decomposition of industrial waste by its partial burning or direct contact with end product of fuel combustion

- This method is used for neutralization of most wastes including "inconvenient" ones for burning


Dynamotive's
Fast Pyrolysis Process
Burner
Feedstock
Cyclone /
Char Collection
Quench System
BioOil Pyrolysis Reactor
BioOil Storage
Dynamotive

The Alternative

- Biodiesel is a cleaner burning replacement fuel made from renewable sources like new and used vegetable oils and animal fats
- Low-level blends (≤20% biodiesel) can be used in almost any existing diesel engine
- High-level blends (>20% can be used in most new diesel engines

Biodiesel Background

- Four main production methods
  - Direct use and blending
  - Micro emulsions
  - Thermal cracking
  - Transesterification
- Transesterification
  - Most common production method
  - Uses vegetable oils and animal fats as feed stocks
  - The reaction of a fat or oil with an alcohol to form esters (biodiesel) and glycerol

Technological Challenges

- Expensive feed stocks and inefficient production methods
- Strict standards for product quality
- NO_x emissions
- Transportation and storage concerns

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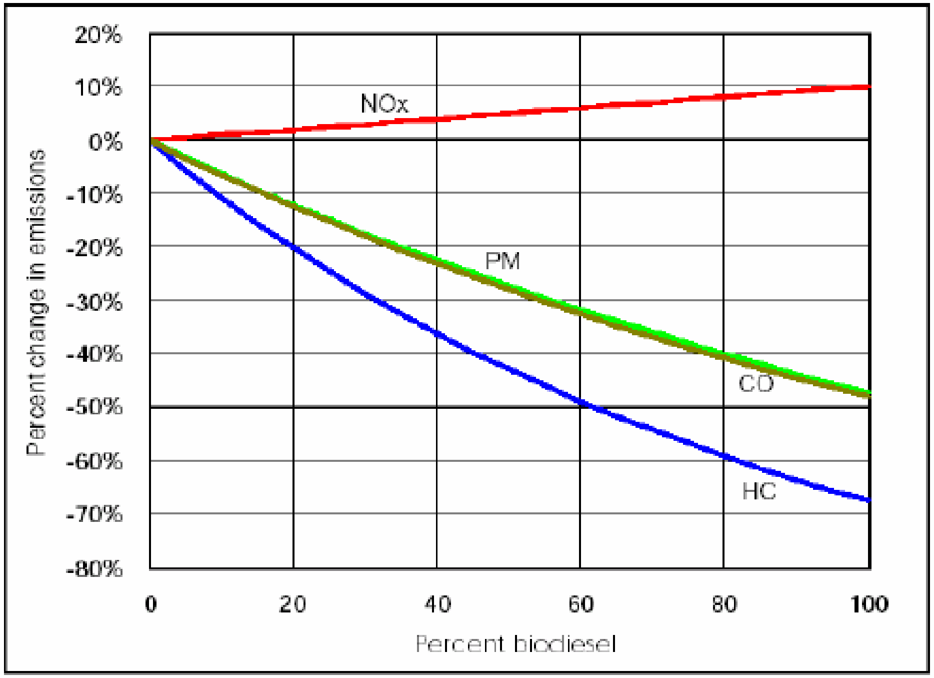


Storage

- Biodiesel should be stored 5-10 degrees F above cloud point.
- Above ground fuel systems should be protected with insulation, agitation, heating systems, or other measure.

Test Method	**Cloud Point ASTM D2500**		**Pour Point ASTM D97**		**Cold Filter Plug Point IP 309**	
B100 Fuel	**ºF**	**ºC**	**ºF**	**ºC**	**ºF**	**ºC**
Soy Methyl Ester	38	3	25	-4	28	-2
Canola Methyl Ester	26	-3	25	-4	24	-4
Lard Methyl Ester	56	13	55	13	52	11
Edible Tallow Methyl Ester	66	19	60	16	58	14
Inedible Tallow Methyl Ester	61	16	59	15	50	10
Yellow Grease 1 Methyl Ester	--	--	48	9	52	11
Yellow Grease 2 Methyl Ester	46	8	43	6	34	1

Transportation

- Should not be contaminated

- Trucks or railcars should be washed from previous load to prevent mixing with leftover residuals or water.

- In cold weather can be shipped in several ways
  - Hot for immediate delivery (80-130 F)
  - Hot (120-130 F) in railcars for delivery within 7-8 days
  - Frozen in railcars equipped with steam coils
  - Blended with winter diesel, kerosene or other low cloud point fuel

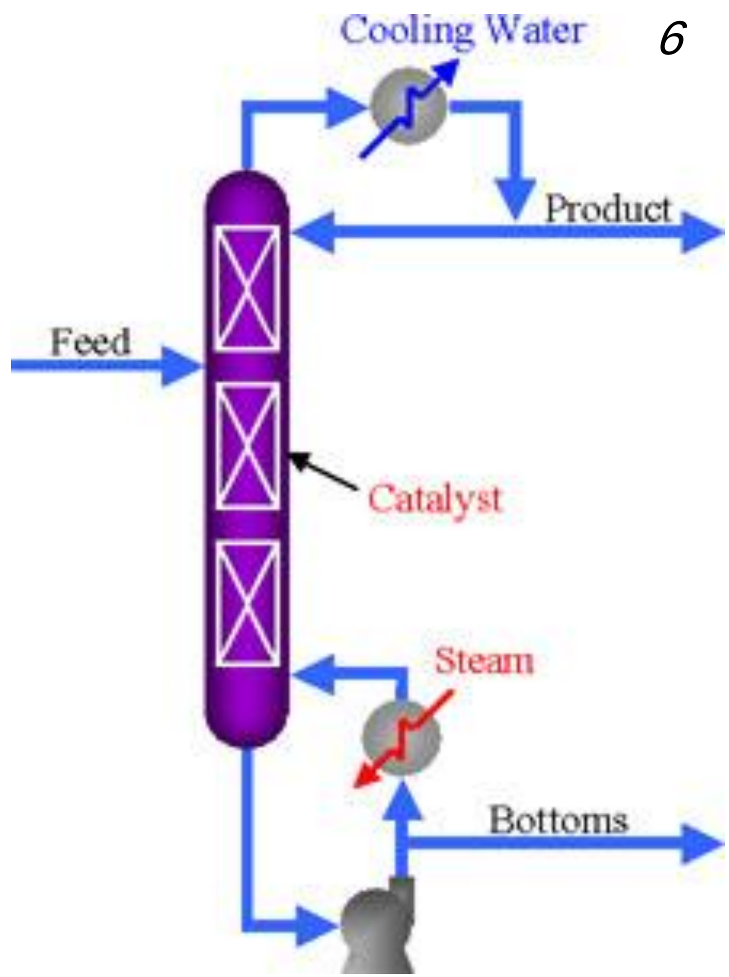
Biodiesel Economics

- 60-70% of the cost to process biodiesel is from feed stock costs
- Yellow Grease has a limited supply
- Soybean and other plant oils have long term price issues

Marketing Year	Soybean Oil	Yellow Grease	Petroleum
2004/05	2.54	1.41	0.67
2005/06	2.49	1.39	0.78
2006/07	2.47	1.38	0.77
2007/08	2.44	1.37	0.78
2008/09	2.52	1.40	0.78
2009/10	2.57	1.42	0.75
2010/11	2.67	1.47	0.76
2011/12	2.73	1.51	0.76
2012/13	2.80	1.55	0.75

Biodiesel Economics

- **There is ample room for improvement in the efficiency of processing biodiesel**
  - Development of a continuous transesterification process
  - Recovery of high quality glycerol



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