Co-products and By-products of Woody Biorefinery Processing

TRANSITION TO A BIO ECONOMY
The Role of Extension in Energy

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Improving Lives. Improving Texas.

Why Biomass?

- It is the only source of renewable carbon - the essential ingredient of
  - all current transportation fuels
  - a high proportion of daily commodities
- It offers opportunities for:
  - rural development
  - land management
  - socioeconomic for agro-industrial sector

Why Woody Biomass?

- U.S. forests produce nearly 370 million dry tons annually from
  - harvest residues
  - fuel treatments
  - small diameter trees
  - urban wood waste
  - mill residues
- Millions of tons also produced from
  - insect
  - disease
  - extreme weather conditions each year

Why Woody Biomass

- All of these (except for mill residues)
  - are not currently utilized
  - do not significantly compete with other uses
  - are available on a sustainable, environmentally sound basis
- These resources are
  - currently burned
  - left in the field to decay
  - sent to landfills

Why Woody Biomass

- Utilization will alleviate environmental and economic pressures
  - help mitigate greenhouse gases
  - contribute to healthier forests
  - significantly reduce loss from catastrophic wildfires, insects and disease
  - Protect watersheds
  - help control invasive species
  - bolster rural economies.

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Quiz

How many Btu's used by US each year?

102 quadrillion

102,000,000,000,000,000 Btu

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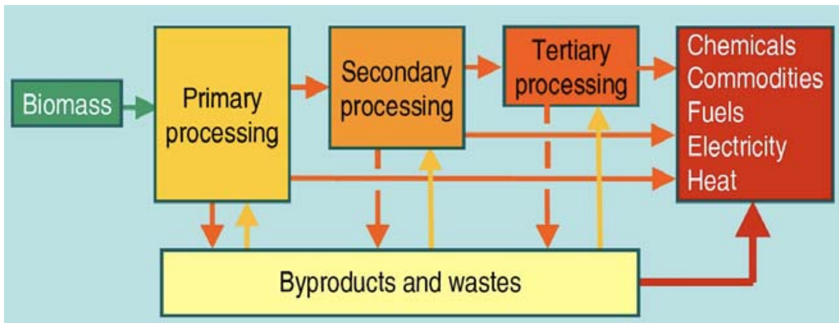
What is a Biorefinery?

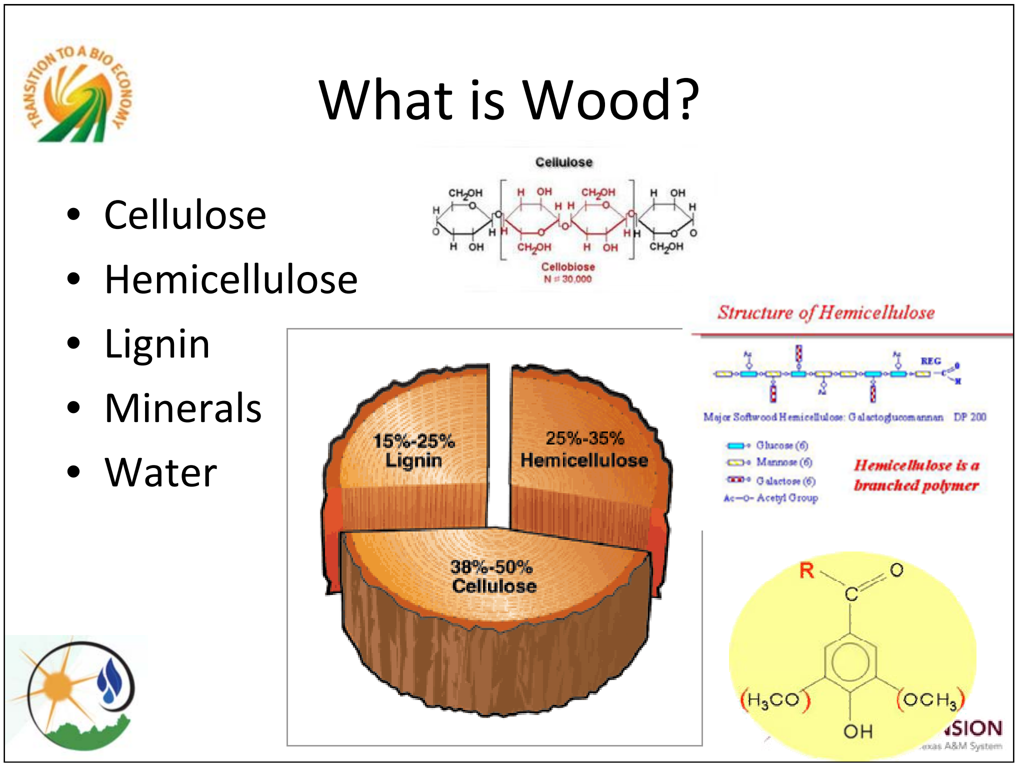
- A facility that uses biomass conversion technologies to convert biomass into fuels, power, and value-added chemicals
- Extending the Value Chain
- Making full use of co-products and by-products
  - co-products = the useful and marketable by-products, other than energy, that are produced simultaneously during biomass conversion
  - by-product = a secondary or incidental product usually waste

Biorefinery Concept

- Optimizes use of resources, maximizes profitability, maximizes benefits, minimizes waste



Aston University Bioenergy Research Group (BERG)



The four major components of woody biomass are: cellulose, hemicellulose, lignin, and minerals.
Cellulose makes up nearly 50 percent of the dry weight of woody biomass. It is the most abundant organic material on Earth. It can be isolated and later processed to yield cellophane, acetate, rayon, and nitrates.
Hemicellulose is a carbohydrate which comprises roughly 25 to 35 percent of the total dry weight of woody biomass. It is second to cellulose in abundance on Earth. Although abundant and having great potential in the production of chemicals and other materials, the use of hemicellulose is limited by manufacturing related costs.

Lignin is the glue that holds the cellulose and hemicellulose components of woody biomass together. Lignin constitutes anywhere between 15 and 25 percent of the weight of woody biomass. Due to chemical complexity, lignin has not yet been used in large quantities for industrial purposes.

Principal Elements

- Principal elements – do not produce energy
  - Carbon
  - Hydrogen
  - Oxygen
- Mineral Elements – higher in hardwoods
  - Nitrogen
  - Sulfur
  - Chlorine
  - Heavy metals

Woody biomass is composed of many mineral elements. The principal elements include carbon, oxygen, and hydrogen. These elements do not produce energy during combustion; however, they do affect the energy content of woody biomass. On average, hardwoods have a higher concentration of mineral elements than softwoods. The presence of these mineral elements, however, is more affected by the site where the trees are grown rather than their age, size, or species type.

The Prize!

Determine or discover processing technologies that can collect and convert currently under-utilized woody biomass into products with higher value…and make it sustainable!

Bio-Product	Current	2020	2090
Liquid Fuels	1-2%	10%	50%
Chemicals	10%	25%	>90%
Materials	90 %	95%	99%

NRC Report - 2000

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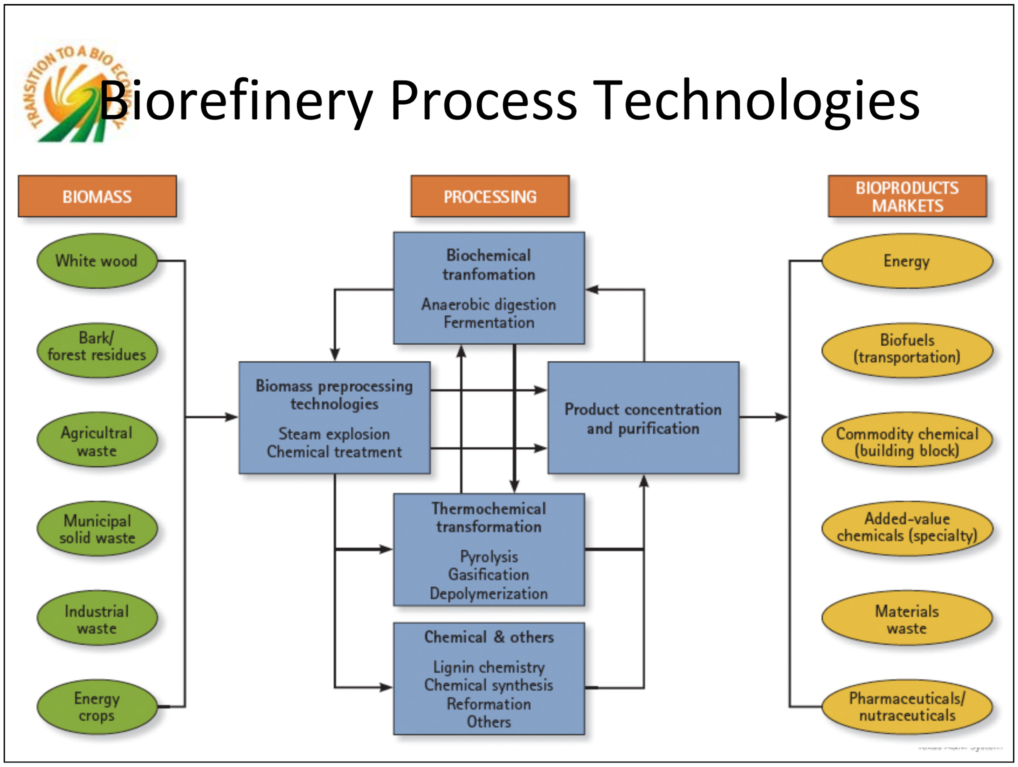
You probably all know that many different types of biomass can be used to generate electricity or converted into liquid transportation fuels. But did you also know that a wide range of "green chemicals" can be extracted from woody biomass and their bio-oil. These are a very attractive possibility to producers of bio-oil (and should encourage new investments in biorefineries) because "green chemicals" offer much higher value aded compared to fuels and electricity. Even once chemicals are extracted, the remaining bio-oil will still retain some value as a fuel.

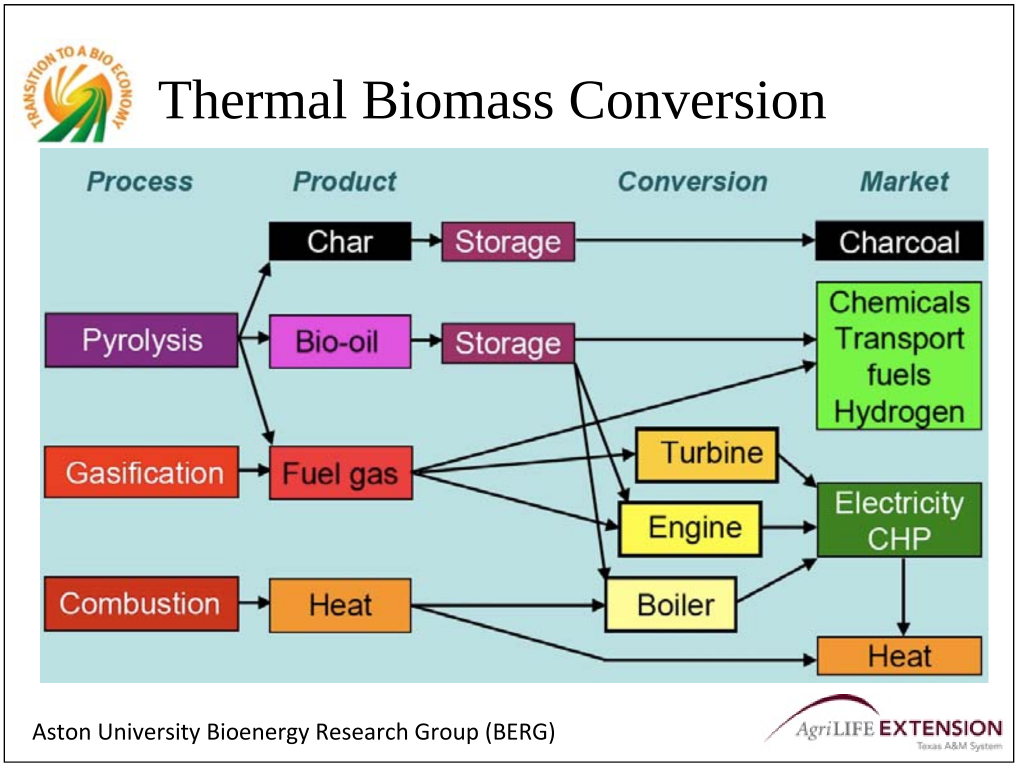


Thermochemical
- gasification
- pyrolysis

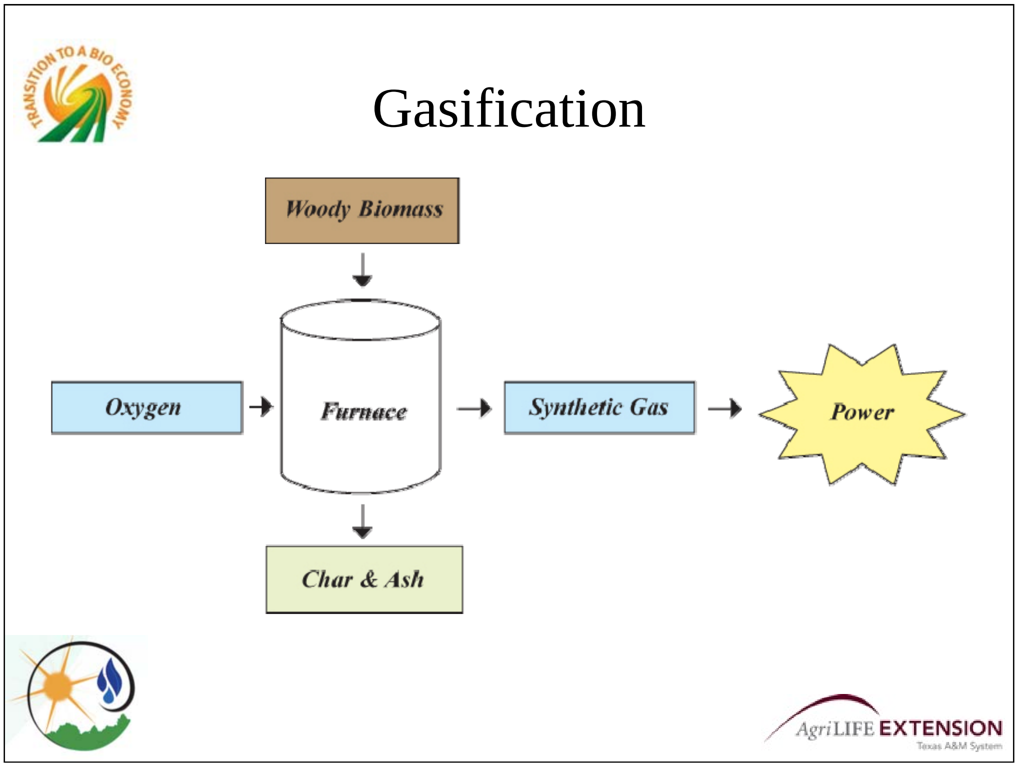
Biochemical
- anaerobic digestion
- fermentation

Chemical (chemical synthesis)

All currently being developed by many entities

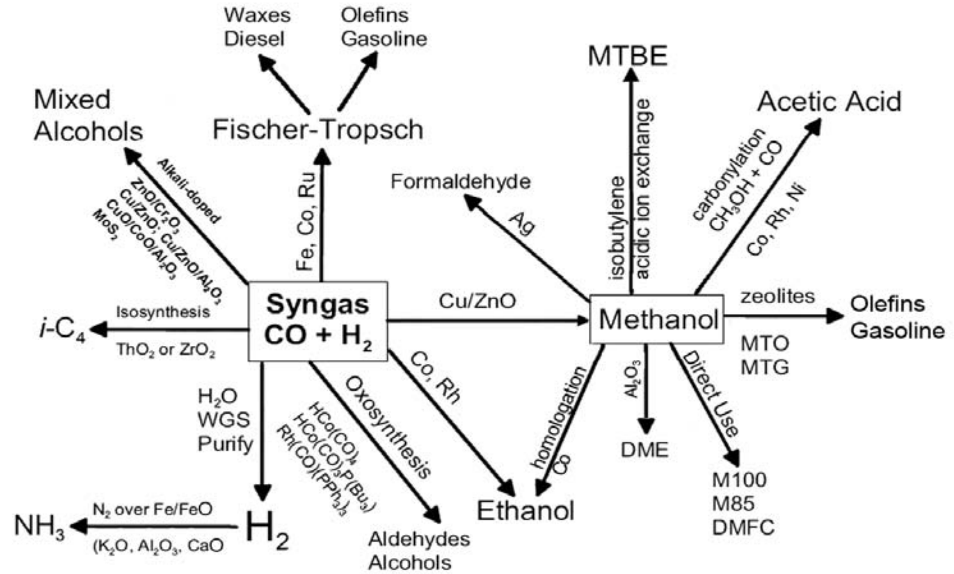


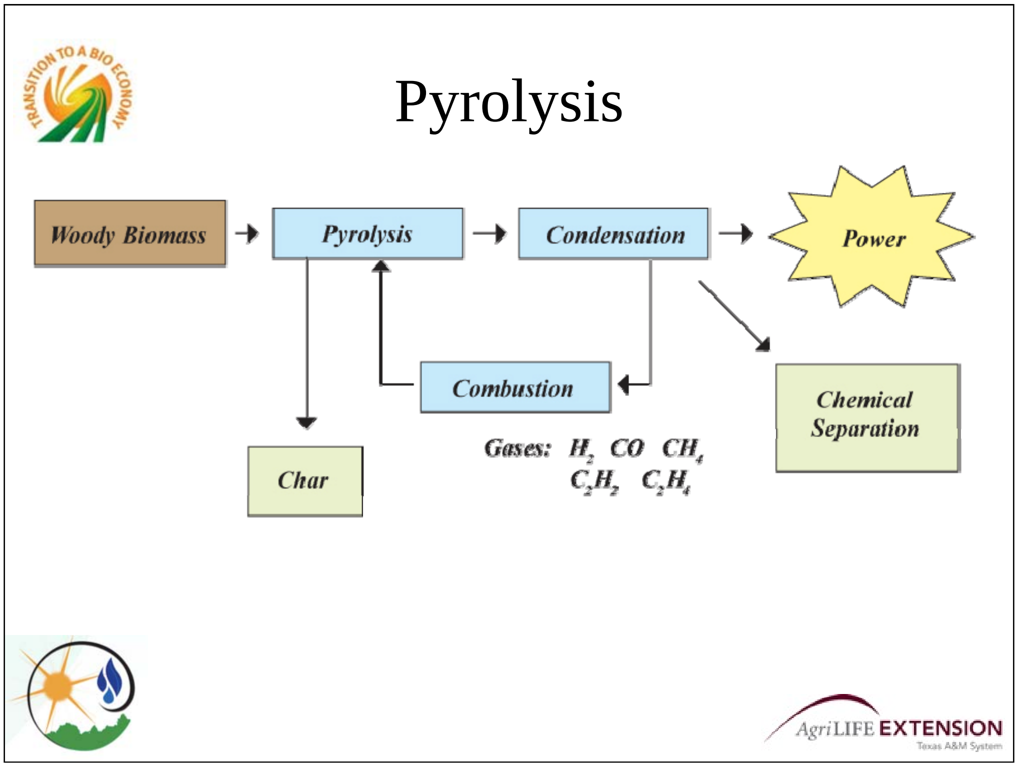
Biomass having a low-moisture content is best suited for combustion, although anything organic will burn. Combustion refers to the rapid oxidation of the feedstock as it is exposed to high heat. Most of today's biomass-powered plants are direct-fired systems, similar to fossil fuel-powered plants. The feedstock is burned in a boiler to produce high-pressure steam that is then pumped into a turbine, over a series of blades that rotate, powering an electric generator.



Gasification is a special combustion process, occurring between 1112 and 1832 degrees Fahrenheit, where biomass solids are turned directly into biogas. More specifically, complex hydrocarbons of wood are decomposed into hydrogen, carbon monoxide, and carbon dioxide. Products of gasification cannot easily be stored. Consequently, the system is often integrated with other conversion processes in an effort to utilize 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.

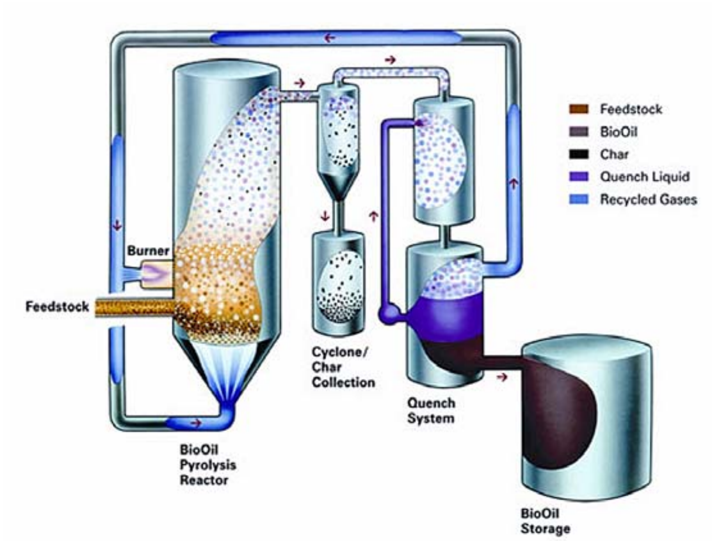
Products of Gasification





Pyrolysis is the process of rapid thermal decomposition of biomass in the absence of oxygen. This process produces energy, liquids, gases, and char. At approximately 930 degrees Fahrenheit, the material is transformed into a vapor, which in turn, is cooled, condensed, and recollected as a liquid bio-oil. Gases that are non-condensable are recycled in a reactor for co-firing, while the char is removed for fuel or use as a commercial product.

Dynamotive Reactor



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Pyrolysis Pathway

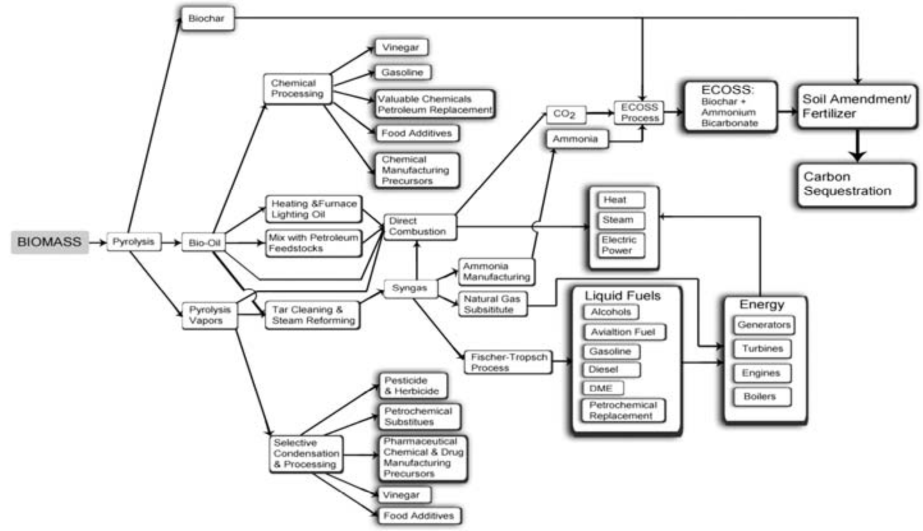

Figure 2. Co-products from Biomass Pyrolysis ©Eprida 2008

Product Yields of Pyrolysis

Process	Liquid	Char	Gas
Fast Pyrolysis	75%	12%	13%
Direct combustion	30%	35%	35%
Gasification	5%	10%	85%

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Bio-oil Compare to Other Fuels

	MJ/l	BTU/U.S. gallon
Bio-oil (wood)	21.0	75,500
Bio-oil (bark)	22.7	81,500
Fuel Oil (#6)	38.9	153,200
Fuel Oil (#2)	35.2	138,500
Methanol	17.5	62,500
Ethanol	23.5 8	4,000

Bio-oil is a dark brown mobile liquid with roughly 54% the heating value of #6 fuel oil. Its heating value compares with air-dried wood, methanol, and ethanol. Bio-oil can range in color from dark green or dark red through black, depending upon the feedstock and process used to manufacture the product. Bio-oil has a distinct smell, often described as acrid and smoky

Disadvantages of Bio-oil

- Contains 15% - 40% water (by weight)
- Immiscible with petroleum-derived fuels
- Requires further processing (biorefinery) to blend with other fuels
- Chemically unstable, and breaks down over time or when exposed to high heat

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. Bio-oil is composed of hundreds of different chemicals, ranging from volatile compounds like formaldehyde and acetic acid to more stable phenols and anhydrosugars.14 Bio-oil contains between 15% and 40% water (by weight), depending upon the process used to produce and collect the liquid. Bio-oil is immiscible with petroleum-derived fuels (though has some potential for blending with petroleum if appropriate technologies are used). The liquid is chemically unstable, and breaks down over time or when exposed to high heat. As bio-oil ages, the viscosity increases, the volatility decreases, and eventually phase separation may occur15. This chemical instability does not prevent bio-oil from being used in commercial applications, but does mean that it must be transported, stored, and used in a time frame and manner that accommodates this property16

Advantages

- Bio-oil can be transported
- Handled by equipment designed for traditional fuels
- Higher energy density and efficiency
- Transportation saving over solid fuels (whole tree, chips, slash)
- Compatible with existing infrastructure (in some cases)

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Because it is a liquid, bio-oil can be transported, stored and handled using equipment designed to handle more traditional fuels. This represents a potentially significant advantage over traditional solid fuels (whole tree chips, for example), because it is expensive and cumbersome to transport and handle moist, bulky biomass for use in energy generation. Further, bio-oil is in some cases compatible with the existing fossil fuel and electricity generation infrastructure in North America, and allows entry of a biomass-based fuel into areas traditionally dominated by fossil fuels.

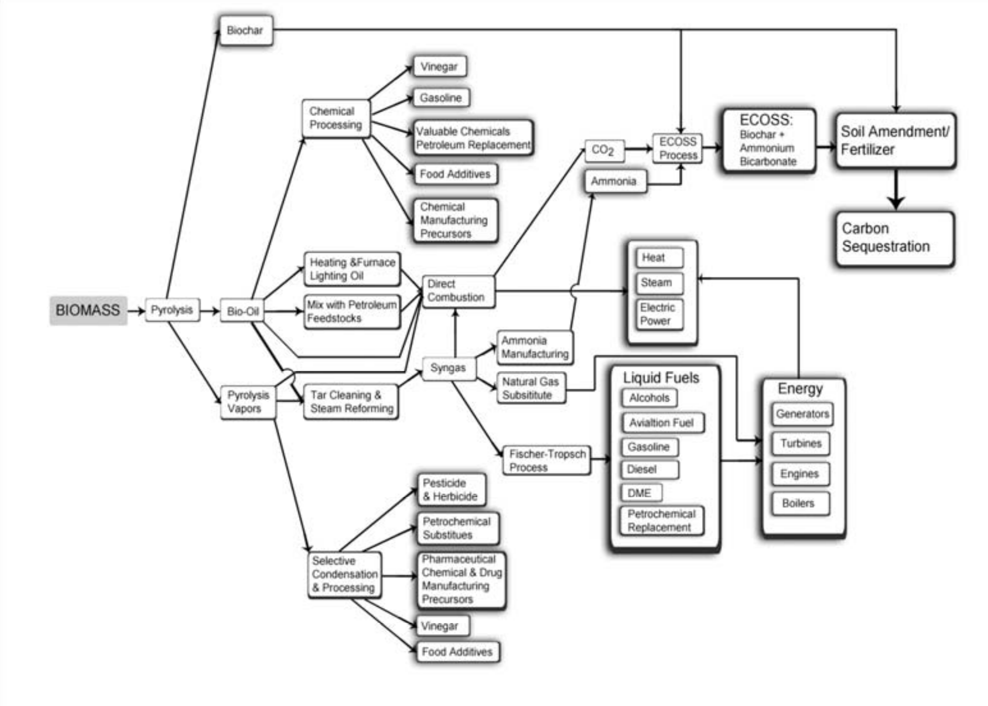
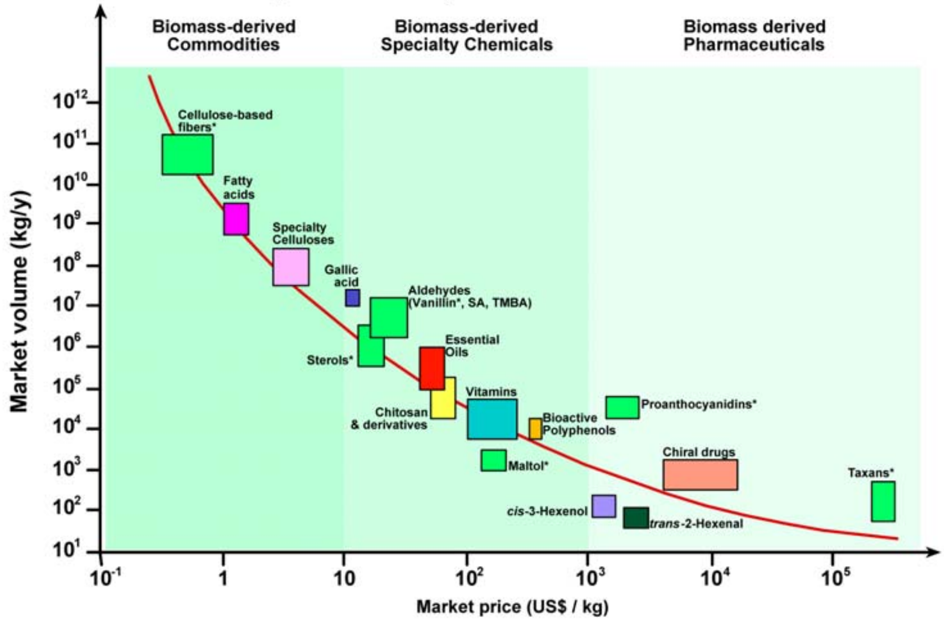


***Figure 2**. Co-products from Biomass Pyrolysis ©Eprida 2008*

Resins & polymers
Activated carbon
Preservatives
Food flavorings
Slow release fertilizer
NOx/SOx reduction
SynGas/Hydrogen

Market size / price for co-products derived from biomass



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Quiz

Using woody biomass to produce electricity will help alleviate our dependency upon foreign oil.

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False

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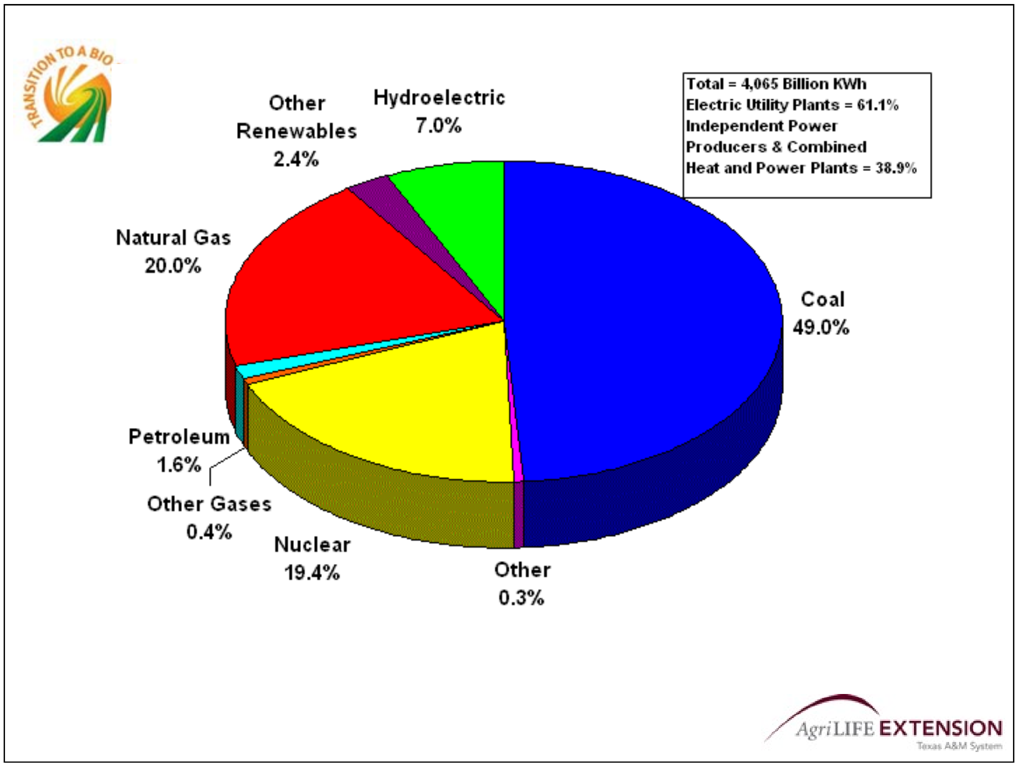

The US has more than 250 years of coal supply remain at current consumption?

489 billion short tons. The U.S. uses just over a billion short tons of coal each year

delivered price is $35 per ton = $1.73 per million Btu
1 short ton of coal = 20,169,000 Btu

How many barrels of petroleum are consumed each day in US?

20.7 million barrels

1 barrel (42 gallons) of crude oil = 44 gallons of liquid products

> 73% of all liquid fuels goes towards transportation

Pause for Minute

- Continued and increase use of wood for building material
- Includes using low-value woody biomass to produce high-quality building materials
- Don’t fall into the trap – using wood to generate electricity – forced to use concrete and steel for building
- Public attitude
- Other issues

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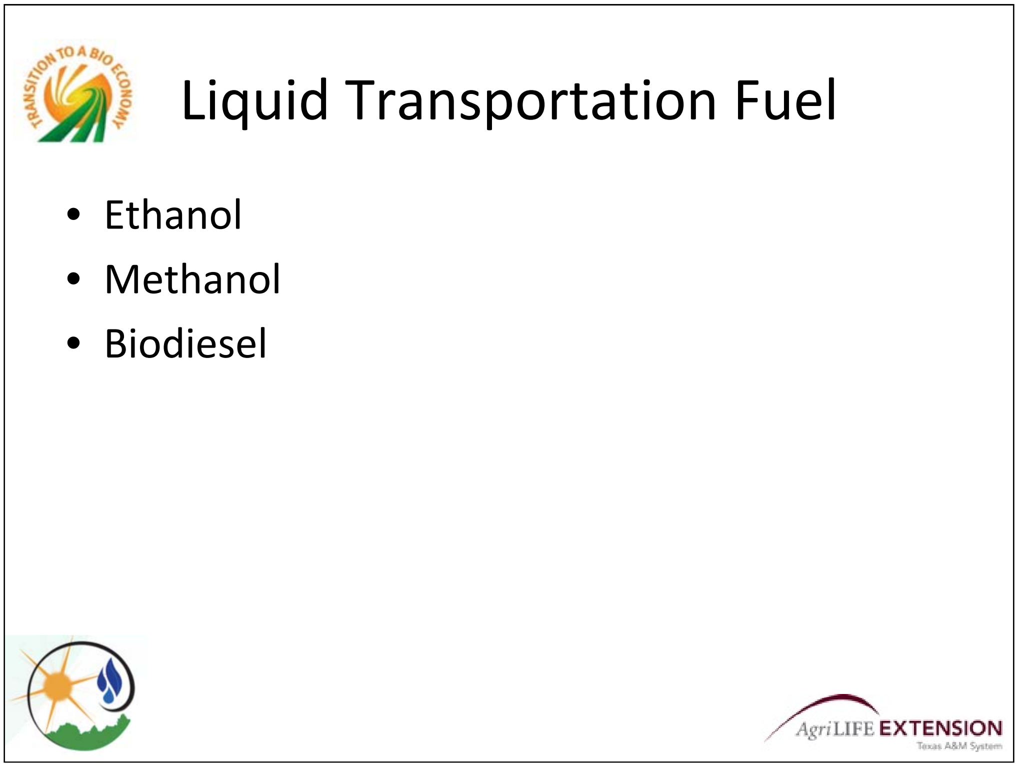
Cellulose fibers have inherent properties such as tensile strength and density that can add considerable value to durable materials. These include products ranging from fiberboard, where solids are almost entirely wood-based, to siding composed of wood-cement mixtures. Such wood composites have been manufactured for decades, but have primarily used virgin fiber supplies. A number of technologies are being developed that can produce high-quality materials with low-value lignocellulosic feedstocks that have previously not been exploited by industry.

Products

- Energy
  - heat
  - electricity
  - Transportation fuels
- Building Blocks
  - industrial products
  - specialty chemicals

Three major product types can result from the efficient use of woody biomass. These product types are energy (heat and electricity), transportation fuels, and industrial products.



Interest in and use of biobased liquid transportation fuels such as ethanol, methanol, and biodiesel, are increasing rapidly as oil prices increase. Currently, most of the ethanol and biodiesel generated in the United States comes from food-based feedstocks (i.e. corn, soybean, etc.), however neither ethanol nor biodiesel could replace petroleum without impacting food supplies. Woody biomass can be put through a process called liquefaction to create bio-oil and through biological fermentation processes to create liquid fuels such as ethanol, methanol, and bio-diesel.

Industrial Products

- Chemicals
- Bio-based products

At the turn of the century, most non-fuel industrial products such as dyes, paints, medicines, chemicals, fibers, and plastics were made from biomass feedstocks. By the 1970s, petroleum had largely replaced those feedstocks capturing more than 95 percent of the market. Today, numerous opportunities are emerging to expand industrial needs through the production and processing of woody biomass. Annual sales of biochemicals exceeded $13 billion in the US. A wide range of bio-based industrial products will be introduced to diverse industrial markets in the near future.

Chemicals

- Bio-based Acids
- Bio-based Oils
- Specialty Chemicals

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Biological feedstocks can be used as a substitute for petroleum-based feedstocks to make a variety of bulk, intermediate, and specialty chemicals. Biomass-related chemical products typically fall into three general categories: **bio-based acids, bio-based oils,** and **specialty chemicals**. The following slides highlight some of the more important bio-based chemicals derived from biological feedstocks.

Specialty Chemicals

- Enzymes
- 3-HP
- Syngas
- Butanol
- Glycerin
- Used in the production of paints, solvents, fibers, and plastics

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Specialty chemicals, which are chemicals produced in small volumes for specific end uses, often mixtures or formulations of different chemicals, play an important role in the economy of the United States. Currently, organic chemicals are primarily synthesized from a petroleum base and used in the production of paints, solvents, fibers, and plastics. Specialty chemical markets represent a wide range of high-value products. These chemicals generally sell for more than $2.00 a pound and their market is steadily growing.

Biobased Products

- Pellets
- Char
- Glass Aggregates
- Polymers
- Anaerobic Digestion Effluent
- Bioplastics

Petroleum-based feedstocks have dominated as industrial inputs over the past century. The rising petroleum prices, a decline in petroleum reserves, and consumer demand for environmentally benign products are resulting in numerous opportunities for bio-based materials in the marketplace. The following slides present a partial list of bio-based materials that are currently on the market.

Pellets

- Uniform
- Easy to handle
- Easy to transport
- Burn efficiently
- Large market

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Pellets are small biomass particles such as straw, sawdust, and chip that have been processed and converted into small, dense, uniformly shaped aggregates. Increasing density allows for easier handling and storage. In addition, the uniformly low moisture content of pellets leads to high combustion efficiency.

(ADDITIONAL INFO)
Pellet stoves, stoves designed to burn pellets, are a heating alternative for residential or small-scale use and are increasing in popularity. Clean burning, the stoves offer convenience along with energy efficiency. Bags of fuel pellets stack compactly, store easily and they are uniform and small shape allow them to flow easier, making the automation of fuel handling easy. Currently, the Southeast has approximately 15 manufacturers of wood pellets for use in pellet stoves. The Pellet Fuels Institute, which can be accessed at www.pelletheat.org, provides detailed information about the wood pellet market. In addition, the group provides a comprehensive list of pellet manufacturers in the Southeast along with the entire United States.

Char

- Solid
- Usable byproduct
  - Energy
  - Filtration
  - Fertilizer

Char is the solid portion of biomass that does not fully react during pyrolysis, combustion or thermochemical liquefaction. It is used for producing steam for heat and energy after being recycled. It can also be used as a filtration agent when converted to activated carbon. Additionally, char is used as fertilizer as well as charcoal briquettes.

Ash Content

- Origin
  - Minerals in the woody biomass
  - Soil contamination
- Depends upon species and process
- Improves physical and chemical properties
- Improves growing conditions for vegetation
- Raises pH in acidic soils
- Corrects some nutrient deficiencies

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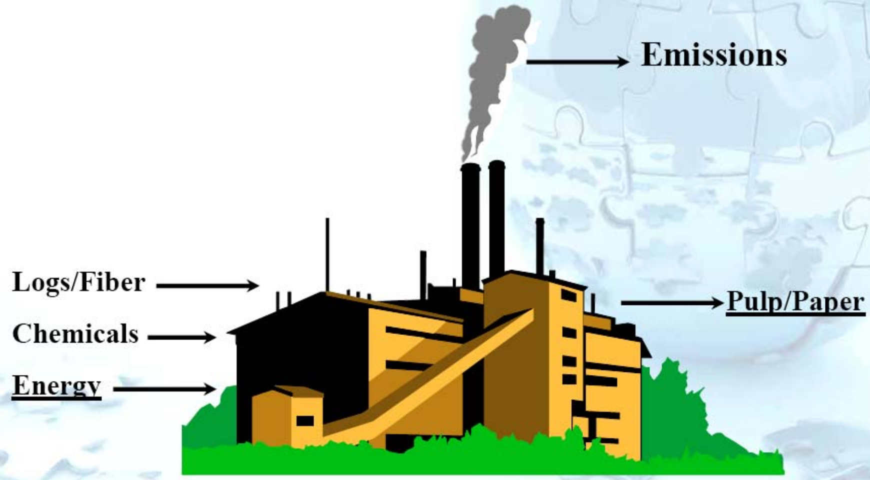
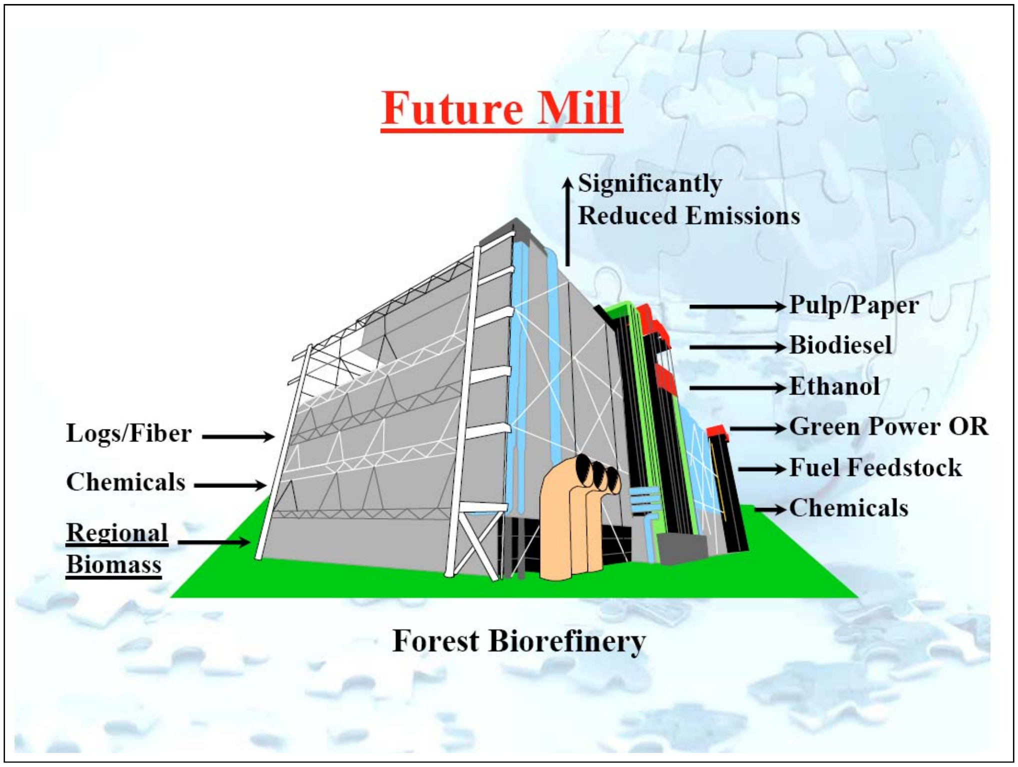
Ash comes from minerals present in the structure of the woody biomass in addition to any soil contamination. Properties of wood ash depend on a variety of factors including : species, part of tree (bark, bole, foliage), type of waste (wood, pulp, paper residue), combination with other fuels, soil and climate, and conditions of combustion.

The presence of ash presents both a problem and opportunity.

Current Mill



Kraft Mill


Future Mill
Significantly
Reduced Emissions
Pulp/Paper
Biodiesel
Ethanol
Green Power OR
Fuel Feedstock
Chemicals
Logs/Fiber
Chemicals
Regional
Biomass
Forest Biorefinery

So, what IS the role of Extension in a Bioeconomy?