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Department of Biosystems and Agricultural Engineering

Biomass Fast Pyrolysis

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Overview

- What is pyrolysis?
- Technology
- Pyrolysis metrics
- Upgrading
- Distributed processing
- Industrial activity



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What is pyrolysis?


- Heat addition to biomass in the absence of oxygen to temperatures ranging from 400°C to 1000°C
- One step in gasification
- Products of biomass pyrolysis are a
 - Solid (char)
 - Liquid (upon condensation with cooling)
 - Gas (light hydrocarbons and carbon oxides)
- Higher temperatures and longer residence times favor gas production
- Lower temperatures and longer residence times favor char production
- Moderate temperatures and short residence times favor liquid production

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Pyrolysis

- Slow pyrolysis
 - a.k.a. carbonization
 - Used for producing charcoal
- Fast pyrolysis
 - Used for fuel production
 - High heating rates
 - Low retention times
 - Greater liquid, i.e. 'bio-oil' yield
 - Co-products
 - bio-char
 - combustible gas



<http://www.biochar-international.org/>



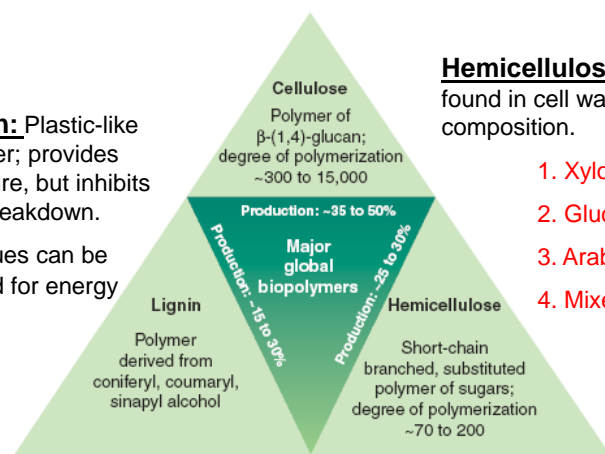
Components of Biomass (Plant Cell Wall Polymers)

Cellulose: Polymer containing glucose-same sugar as in starch

Much more resistant to degradation than starch

Lignin: Plastic-like polymer; provides structure, but inhibits wall breakdown.

Residues can be burned for energy

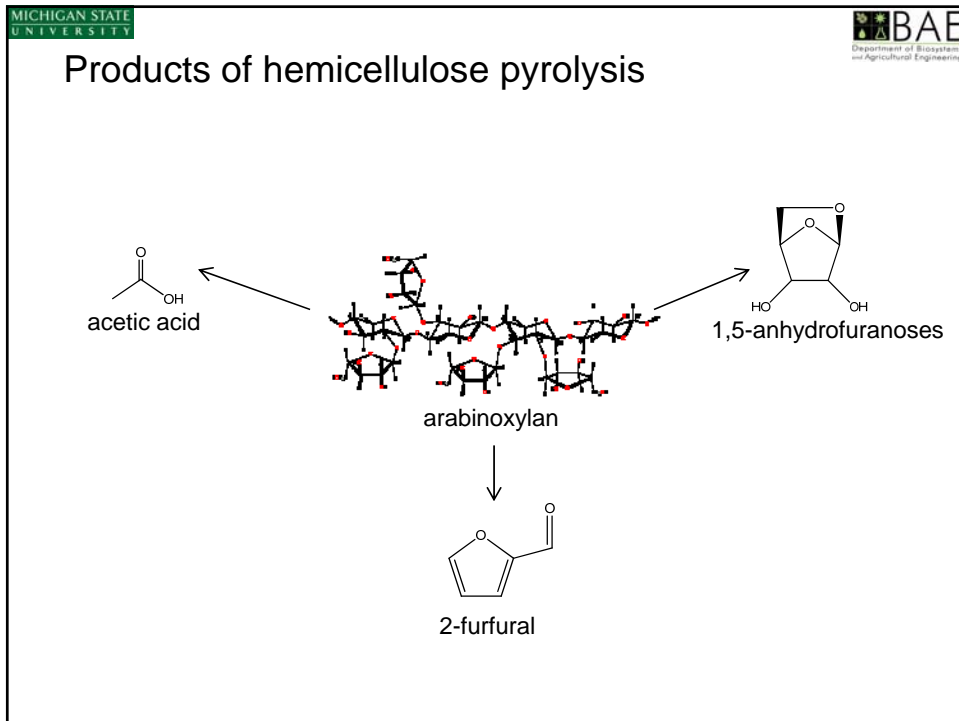
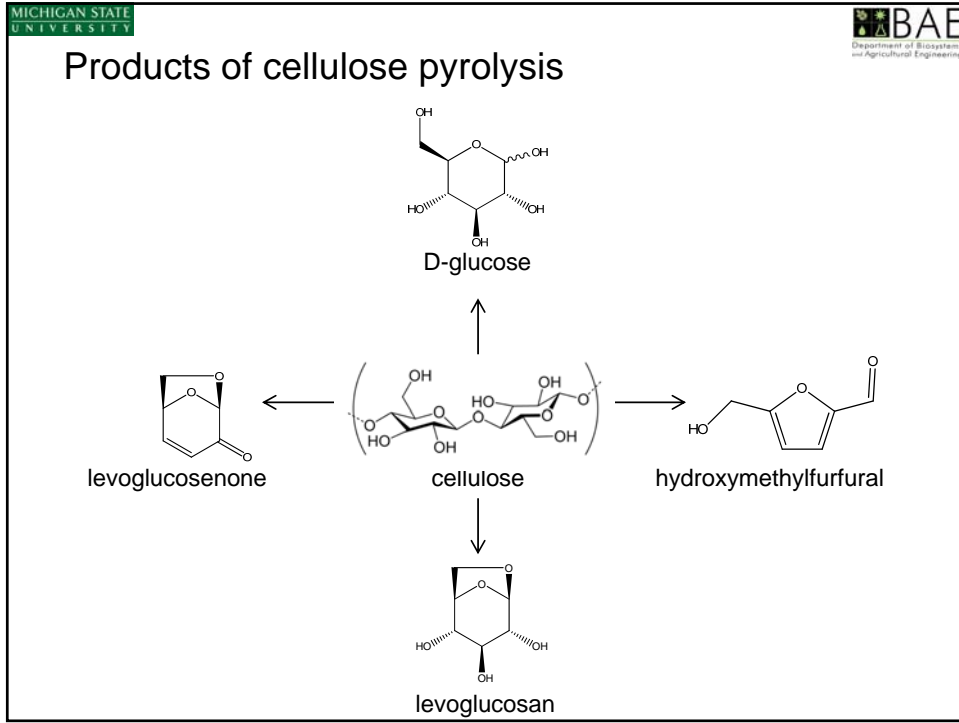


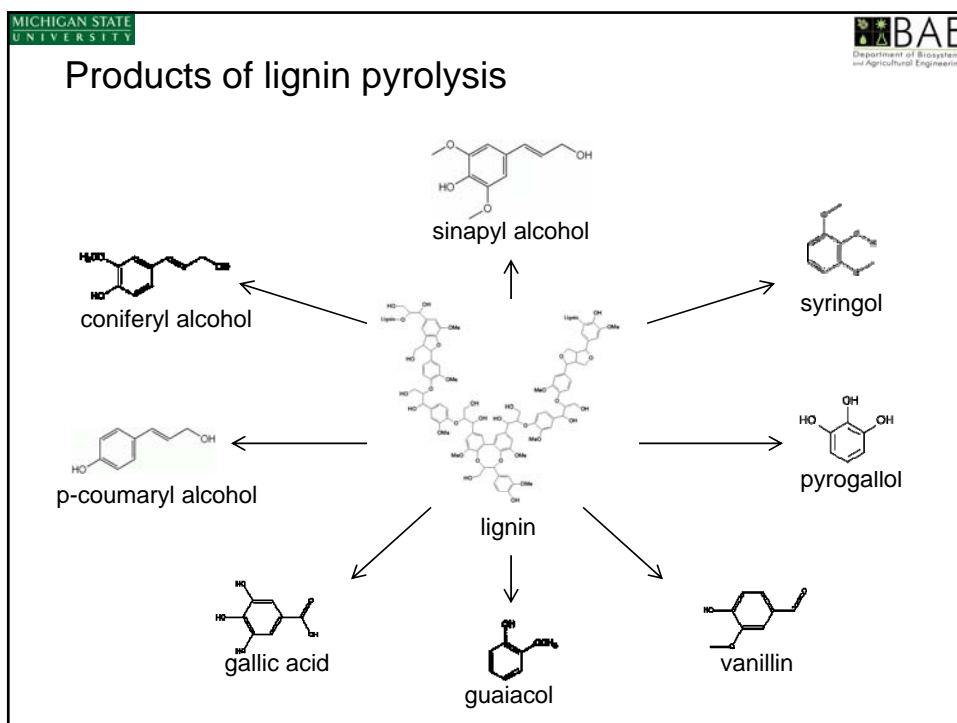
Hemicellulose: Complex polymers found in cell walls; diverse in sugar composition.

1. Xyloglucan
2. Glucomannan
3. Arabinoxylan
4. Mixed-linkage glucan

Fig. 3. Key global biomass resources from agricultural residues, wood, and herbaceous energy crops.

Ragauskas et al. (2006) Science 311:484 The path forward for biofuels and biomaterials.

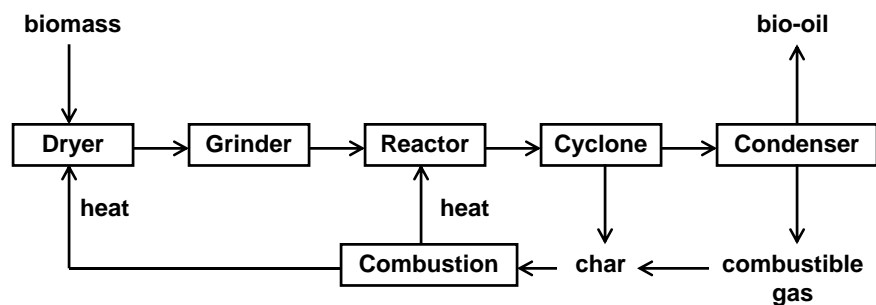




Bio-oil composition

- Hundreds to thousands of compounds
- Compounds are oxygenated
 - Not at reduced as petroleum-based fuels
- Chemical classes identified in bio-oil
 - Aldehydes
 - Alcohols
 - Carbohydrates
 - Furans
 - Ketones
 - Phenolics
 - others
- Bio-oil composition is variable
 - Interspecies variability
 - Intraspecies variability
 - Operational variability

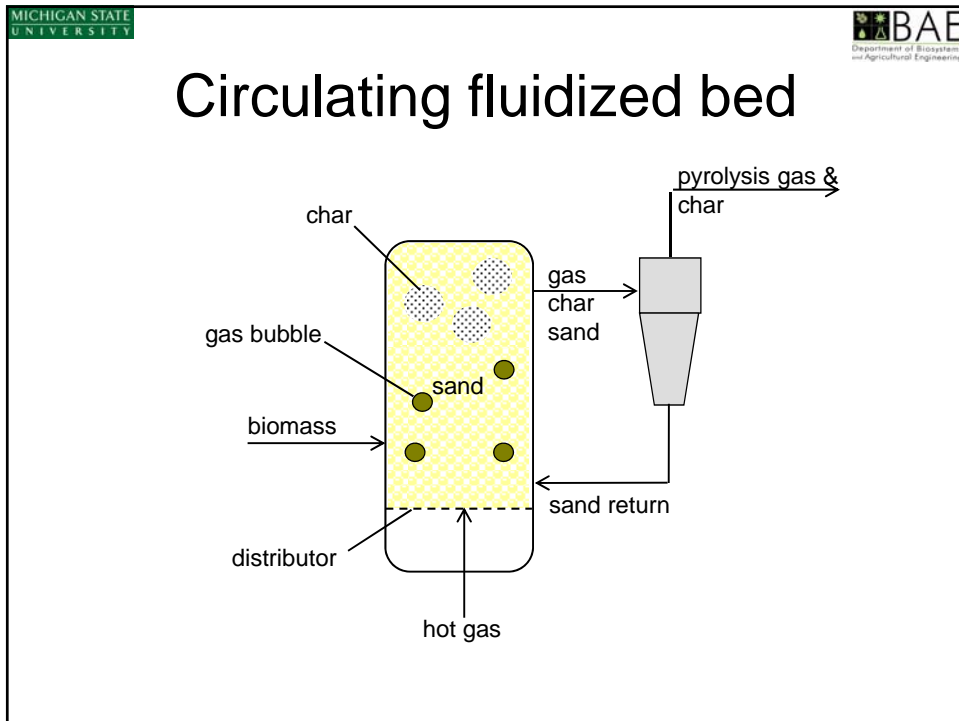
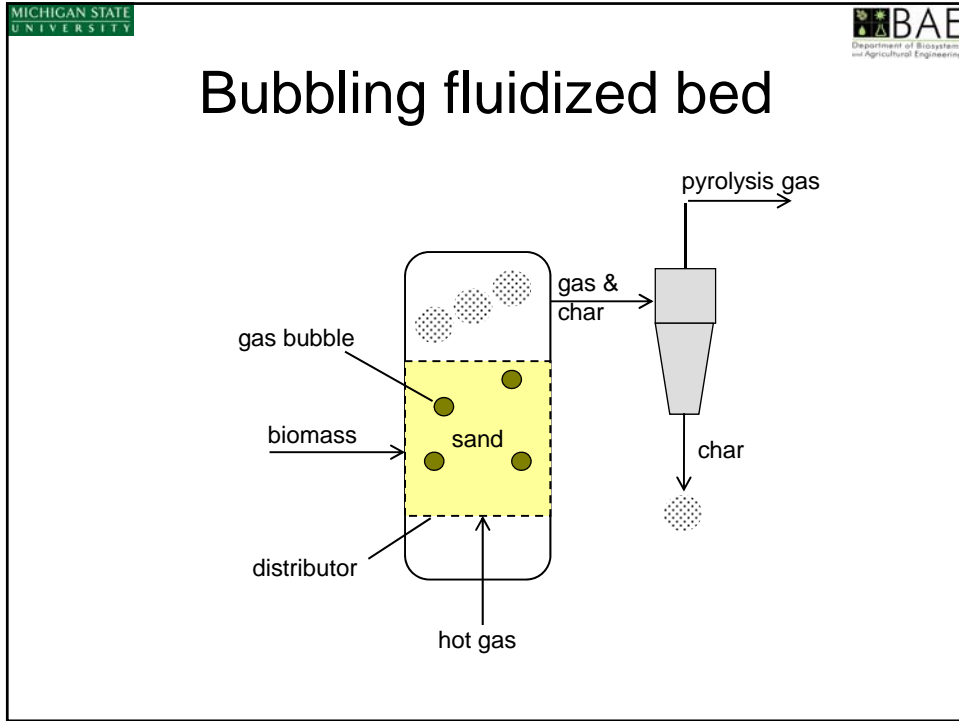
Bio-oil production

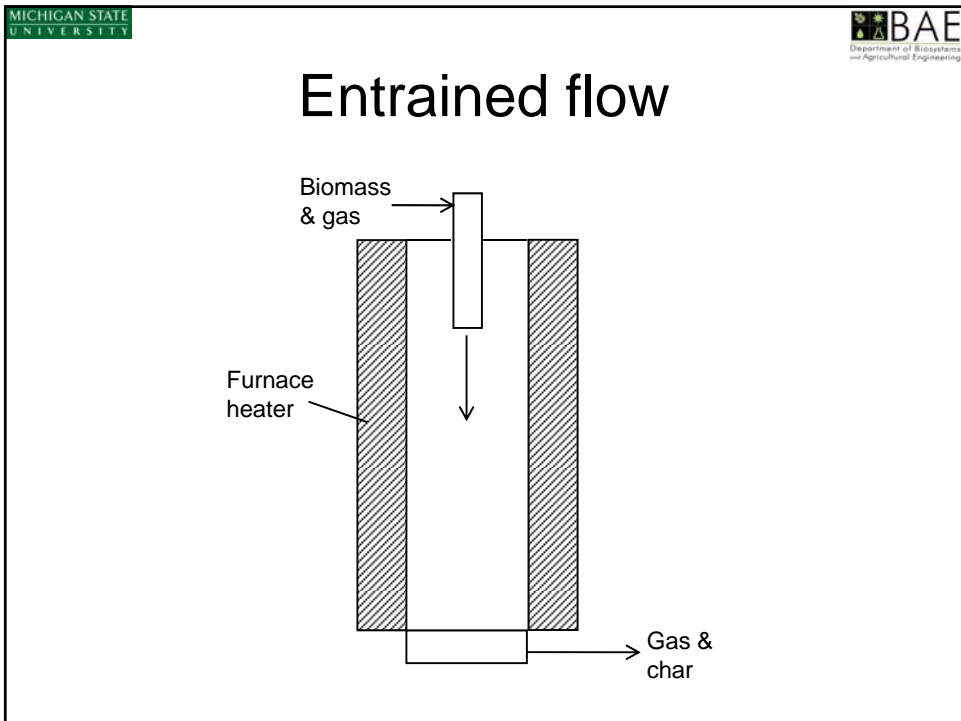
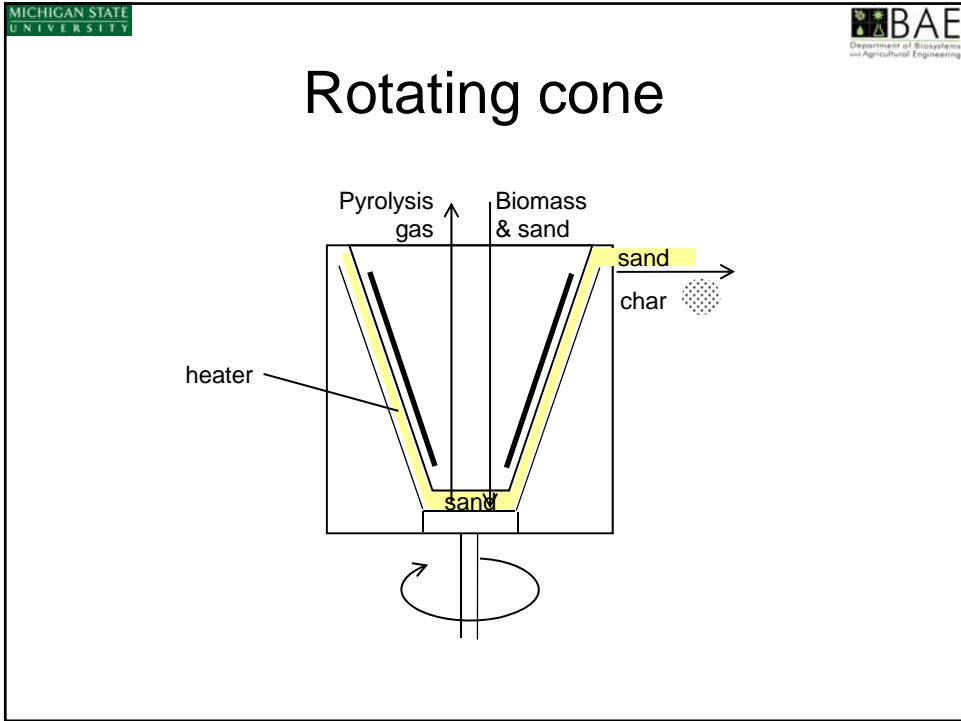


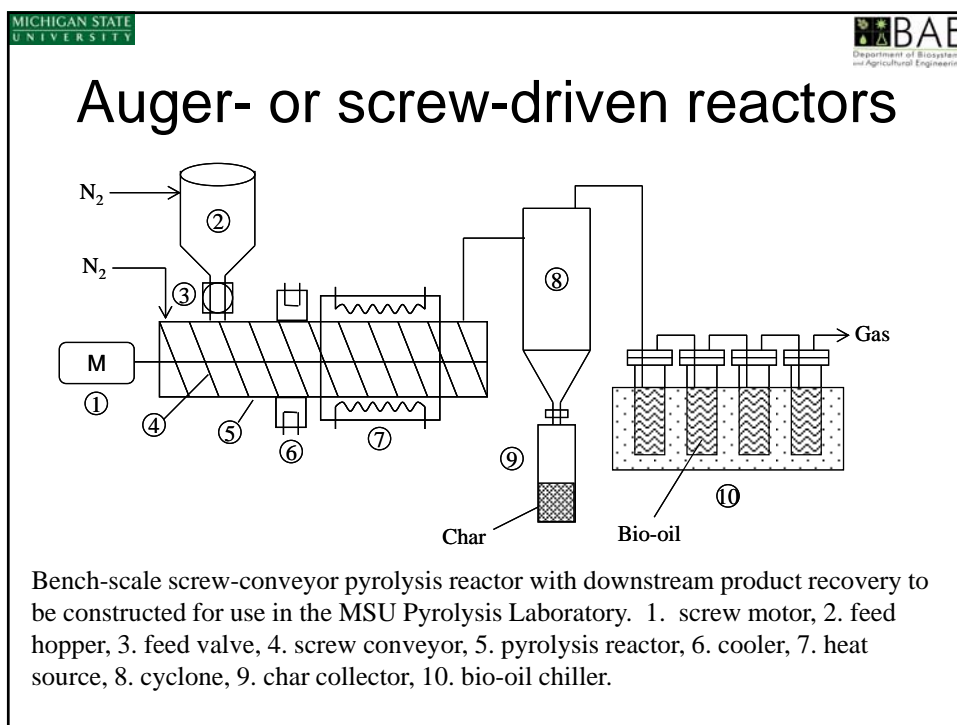
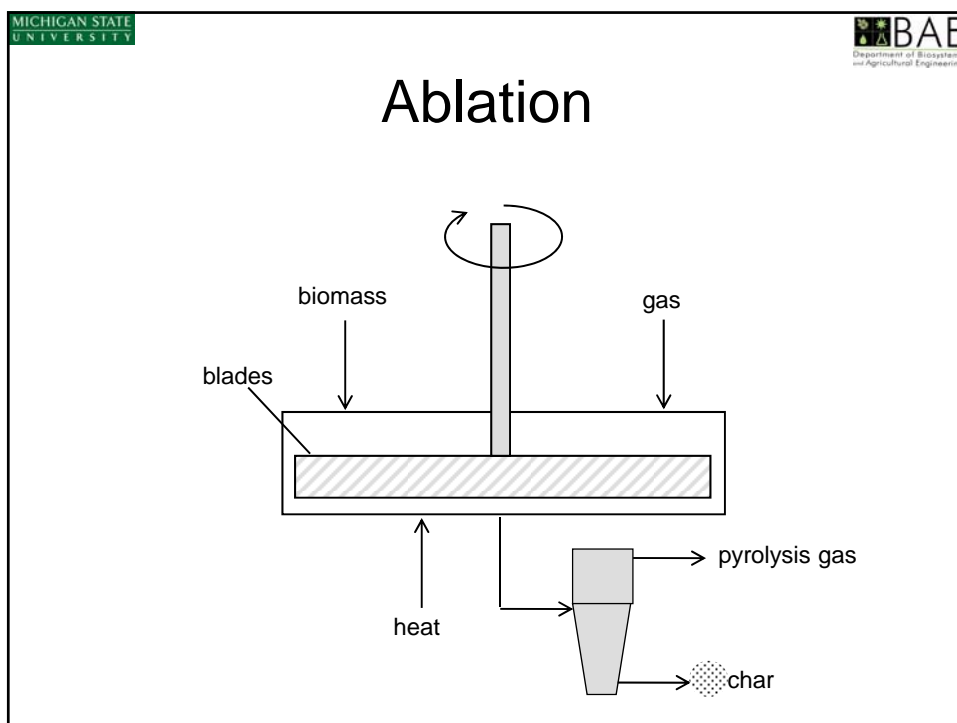
Adapted from Bridgwater, A. V.; Peacocke, G. V. C. *Renewable Sustainable Energy Rev.* **2000**, *4*, 1.

Technology

- Reactor configuration
 - Fluidized bed
 - Circulating fluidized bed
 - Rotating cone
 - Entrained flow
 - Ablative
 - Auger







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Performance metrics

- Bio-oil yield
 - Liquid yield 60 - 80% (w/w)
- Bio-oil properties
 - Heating value = 16 – 20 MJ /kg
 - Viscosity = 40 - 100 cP
 - Specific gravity = 1.20
 - pH = 2.5
 - Moisture content 15 – 30% (w/w)
- Energy requirement
 - About 15% of the energy is biomass required to heat the pyrolysis reactor
 - This energy can be supplied by combusting the non-condensed gas and char

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Upgrading

- Due to oxygen content in bio-oil:
 - Lower heating value
 - Reactive carbonyl and carboxylate functionality lead to polymerization
 - Organic acids reduce pH and increase corrosiveness
- Bio-oil requires upgrading before use as a liquid transportation fuel

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Upgrading technologies


- Catalytic cracking
 - Most widely used process for converting the heavy fraction of petroleum into hydrocarbons (e.g. gasoline)
- Hydrotreating
 - More expensive than cracking
 - Addition of H₂ for reduction of bio-oil components
 - Increase bio-oil heating value
 - Uses Co-Mo or Ni-Mo as catalysts
- Addition of methanol
- Emulsification with diesel fuel

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Distributed processing

- Regional Biomass Processing Centers (RBPCs)
- Advanced combines
- Mobile technology



<http://www.agri-therm.com/solution.html>

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Industrial activity

- **Dynamotive***
 - Biomass pyrolysis
 - Bio-oil used for power generation at West Lorne, Ontario
 - 2.5 MW cogeneration plant
 - 66,000 dtpy of biomass when fully operational at Guelph, Ontario
- **Ensyn†**
 - Biomass pyrolysis
 - Bio-oil used for heat, replacing #2 to #6 heating oil
 - Stationary power
 - Use bio-oil as feedstock to existing refineries
 - Food flavors with Red Arrow Products
 - Pyrolytic lignin to make phenol-formaldehyde resins for OSB
 - Extraction of pyrolytic lignin for conversion to BTX chemicals

*<http://www.dynamotive.com/>
 † <http://www.ensyn.com/>

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Industrial activity

- **Riverside Technologies, Inc.***
 - Pyrolysis of scrap tires
 - Carbon black for reinforcing rubber
 - Oil for further refinement
 - Gas for combustion
 - Scrap steel from belts in tires
- **Ecovolve†**
 - Electricity production
 - Project management, equipment procurement
 - Carbon negative technology
- **Agri-Therm^**
 - Canadian Company converting agricultural residues into bio-oil
 - Fluidized-bed reactor on a mobile pyrolysis plant

*<http://www.rtiworldwide.com/products.html>
 † <http://www.ecovolve.com/>
 ^<http://www.agri-therm.com/>

Questions

