Pyrolysis of Biomass

Gareth J Mayhead
University of California Berkeley
In partnership with:
USDA Forest Service Region 5

http://ucanr.org/WoodyBiomass
Pyrolysis

- Pyrolysis is thermal decomposition occurring in the absence of oxygen
  - Heat for process may be external or internal (part of biomass load)
- It is the first step of combustion and gasification
- Family of related processes including:
  - Slow pyrolysis
  - Torrification
  - Torrefaction
  - Airless drying
  - Destructive distillation
  - Fast pyrolysis
Slow pyrolysis – batch carbonization

- Proven technology (1000+ years)
- Low temperature, long residence time (550-750°F, 30mins-days)
- Flexible feedstock specification
- Burns part of the load for the heat input
- Charcoal is main product
- Equipment available for large and small scale production
- AQ issues
- Works in the woods!

http://ucanr.org/WoodyBiomass
Slow pyrolysis – continuous auger system

External heat source (electricity)

http://ucanr.org/WoodyBiomass
Fast pyrolysis

• An emerging technology
• Moderate temperature, short residence time (930°F/~1s)
• Products are bio-oil, char (and gas)
• Tight feedstock specification (clean, $\frac{1}{16}$-$\frac{1}{8}$”, <10% moisture)
• Energy balance can be a problem (energy required for drying and process heat)
Fast pyrolysis – ROI mobile equipment demo, Oregon, Aug ‘09

http://ucanr.org/WoodyBiomass
Torrefaction or Torrification

- Mild pyrolysis
- 400-600°F
- Product is char ("bio-coal")
  - ~Loss of mass (cheaper transportation)
  - Higher energy density (10,500 BTU/lb vs 8,500 BTU/lb)
  - Hydrophobic (store outside)
  - Easier to grind than wood
  - Potential fuel for coal power plants
- Scale-up and financing is an issue

http://ucanr.org/WoodyBiomass
Pyrolysis outputs

1. Liquid (bio-oil - C, H, O and other constituents)
2. Char
3. Gas

Vary depending upon process conditions (residence time and temperature)…

<table>
<thead>
<tr>
<th>Mode</th>
<th>Conditions</th>
<th>Liquid</th>
<th>Char</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast pyrolysis</td>
<td>moderate temperature, short residence time</td>
<td>75%</td>
<td>12%</td>
<td>13%</td>
</tr>
<tr>
<td></td>
<td>particularly vapour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbonisation</td>
<td>low temperature, very long residence time</td>
<td>30%</td>
<td>35%</td>
<td>35%</td>
</tr>
<tr>
<td>(slow pyrolysis)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasification</td>
<td>high temperature, long residence times</td>
<td>5%</td>
<td>10%</td>
<td>85%</td>
</tr>
</tbody>
</table>

Source: PyNe

http://ucanr.org/WoodyBiomass
Bio-oil

- Potential to substitute for conventional fuels in boilers, engines, turbines (*note*: may damage equipment, invalidate warranty)
- Heating value 40% of fuel oil/diesel (~17 MJ/kg at 25% wt. water)
- Does not mix with hydrocarbon fuels
- Acidic (pH 2.5)
- Not as stable as fossil fuels (storage issues)
- Needs further refining steps for most applications

http://ucanr.org/WoodyBiomass
Char, Biochar, Charcoal, Torrefied wood

- Charcoal – barbeques, restaurants
- Filtration (water and air) using activated carbon
- Soil improvement
- Growth media (substitute for vermiculite)
- Artists charcoal
- Fuel for coal (or other power plants)
- Prices vary with quality and end-use

http://ucanr.org/WoodyBiomass
Current status – fast pyrolysis

• Many demo projects (inc OR and CA)
• Few commercial installations (~2 in USA producing liquid smoke)
• 10+ vendor US/Canada companies (eg, Dynamotive, Ensyn, ABRI, ROI, RFT)
• Potential mobile in-woods units – unproven
• Pricing unclear
  – $250,000+ for 1ton/day unit
• Tampere, Finland integrated pilot facility (Metso/UPM/VTT) linked to BFB boiler

http://ucanr.org/WoodyBiomass
Key points

• Slow pyrolysis
  – Proven technology
  – Markets exist for product (charcoal)

• Mild pyrolysis (torrefaction)
  – Almost proven technology
  – Proven markets
  – Scale-up issues (finance, feedstock and market for product)

• Fast pyrolysis
  – Emerging technology
  – Limited markets
  – May use more energy in process than it produces
  – Cost basis unclear – need high value products or zero cost feedstock
  – Use of bio-oil as a chemical feedstock or for liquid smoke makes sense
  – Larger scale integrated systems (eg with power plant) may work

• Carry out due diligence

http://ucanr.org/WoodyBiomass
Questions?

http://ucanr.org/WoodyBiomass
Key Questions to Ask

• Is the technology commercially deployed (proven)?
• What is the feedstock specification?
• What are the markets for the output products?
• Do the economics work?
• Is the process a net energy user?
• Permitting requirements?
• Do not rely on technology vendors for balanced information

http://ucanr.org/WoodyBiomass