Wood Based Lignin Co Products
An overview

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Chemical & Biomass/Products & Processes
A NARA Member Company
An Overview

• Historical
• Lignin Markets
• Commercial and Scientific Lignins
• Observations & Future
Wood based co-products... It Depends

<table>
<thead>
<tr>
<th>Entity</th>
<th>Product</th>
<th>Co-Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landowner</td>
<td>Timber</td>
<td>Recreation, Watershed</td>
</tr>
<tr>
<td>Lumber Mill</td>
<td>Lumber</td>
<td>Chips, Hog Fuel, Steam, Electricity</td>
</tr>
<tr>
<td>Furniture Mill</td>
<td>Furniture</td>
<td>Sawdust, Steam, Electricity</td>
</tr>
<tr>
<td>Plywood Mill</td>
<td>Plywood</td>
<td>Chips, Poles, Hog Fuel, Steam, Electricity</td>
</tr>
<tr>
<td>Pellet Mill</td>
<td>Fuel Pellets</td>
<td>Bedding, Soil Amendments</td>
</tr>
<tr>
<td>Pulp Mill – Sulfite</td>
<td>Pulp, Paper</td>
<td>Alcohol, Lignin, Steam, Electricity</td>
</tr>
<tr>
<td>Pulp Mill – Kraft</td>
<td>Pulp, Paper</td>
<td>Turpines, Tall Oil, Lignin, Steam, Electricity</td>
</tr>
<tr>
<td>Wood and Wood Residuals</td>
<td>Benefits Society</td>
<td>Renewable, Low Carbon</td>
</tr>
</tbody>
</table>
Georgia Pacific - Bellingham, WA
GP Bellingham History

- Originally operated by Puget Sound Pulp & Timber (PSP&T)
  - Bellingham mill built in 1917 on apple box and other lumber debris
- $\text{Ca(HSO}_3\text{)}_2$ pulping process
- World War II & synthetic rubber
- Ethanol from waste wood sugars (1946)
- Butadiene route / ethanol not required
- PSP&T purchased ethanol plant & started lignin business
  - 1946-2001 6,000,000 gallon/year, 190 and 200 proof
  - 1948-2001 240,000 tons/year, lignin co-products
- PSP&T acquired & operated by Georgia Pacific 1965-2001
- Bellingham Pulp & Chemical closed in 2001
NW Lignin Co-Product Producers

- Rayonier – Hoquiam, WA
  - Vanillin
  - Lignin
- Marathon Corp – Lebanon, OR
  - Lignin
- Boise Cascade - Salem, OR
  - Yeast
- Georgia Pacific Corp – Bellingham, WA
  - Alcohol 190° & 200°, 6MM g/yr
  - Lignin, 240,000 t/yr

GP Bellingham Lignin Products

- Oil well mud additives
- Concrete and gypsum dispersants and conditioners
- Emulsifiers/dispersants, carbon black, textile dye & Pigments, wax & oils
- Plant nutrition, micro nutrients
- Road stabilization, compaction & dust
- Pelletizing – Animal Feed, wood mineral pelleting
- Dust collection
- Mining – Floatation aids
- Refraction Clays Binder
- Phenolic Resins – plywood industry
## World Consumption (Lignosulfonate)

<table>
<thead>
<tr>
<th>Region</th>
<th>Million Tons (Metric)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia, India, Australia</td>
<td>250-320</td>
</tr>
<tr>
<td>Africa Middle East</td>
<td>70-90</td>
</tr>
<tr>
<td>Europe</td>
<td>350-400</td>
</tr>
<tr>
<td>North America</td>
<td>400-450</td>
</tr>
<tr>
<td>South America</td>
<td>50-70</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>1120-1330</strong></td>
</tr>
</tbody>
</table>

TSI Market Analysis 2001-2004

<table>
<thead>
<tr>
<th>Region</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia, India, Australia</td>
<td>23%</td>
</tr>
<tr>
<td>Africa Middle East</td>
<td>7%</td>
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<tr>
<td>Europe</td>
<td>31%</td>
</tr>
<tr>
<td>North America</td>
<td>35%</td>
</tr>
<tr>
<td>South America</td>
<td>4%</td>
</tr>
</tbody>
</table>

Region Million Tons (Metric)

- **Asia, India, Australia**: 250-320
- **Africa Middle East**: 70-90
- **Europe**: 350-400
- **North America**: 400-450
- **South America**: 50-70

**Totals**: 1120-1330

509-279-2124
World Production (Lignosulfonate)

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<th>Region</th>
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<tr>
<td>Asia, India, Australia</td>
<td>50-100</td>
</tr>
<tr>
<td>Africa Middle East</td>
<td>165-200</td>
</tr>
<tr>
<td>Europe</td>
<td>400-500</td>
</tr>
<tr>
<td>North America</td>
<td>200-270</td>
</tr>
<tr>
<td>South America</td>
<td>20-40</td>
</tr>
<tr>
<td>Totals</td>
<td>835-1110</td>
</tr>
</tbody>
</table>

TSI Market Analysis 2001-2004

4/28/2014

NW Wood-Based Biofuels + Co product Conference
Seattle, WA
Lignin Market History

- World Production of Paper (MM Tonnes)
  - Lignin to Fuel
  - Lignin to Waste
  - Lignin to Chemicals
  - Recycled Paper

- 1930 Recovery Boiler
- 1867 Bisulfite Patent
- 1877 First Bisulfite Mill
- 1890 First Kraft Mill

4/28/2014 NW Wood-Based Biofuels + Co product Conference Seattle, WA
The Lignin Market

• Unusual Lignin Market
  – Potentially 200-300 million ton/yr commercial lignin available
  – Lignin Market 1.3 million ton/yr – Sulfite Lignin
  – Sulfite Mills are old technology and are closing

• Conclusion:
  – Potentially very large supply of lignin available
  – Customers are worried about supply
Commercial and Scientific

Commercial Lignin
• By product of paper industry – many components
• Softwood Sulfite Example
  – Lignosulfonate 50-60%
  – Hexose & Pentose 15-25%
  – Sugar Acids & Residuals 10-14%
  – Resin & Extractives 2-4%
  – Ash 8-12%

Scientific Lignin
• Laboratory produced pure lignin

What’s the issue
• Separation of lignin from commercial lignin is difficult
• Source species
• Residuals
• Science needs to deal with purification issues
Observations

• Wood to sugar, bio-chemicals, or bio-fuels
  – Protection of cellulose fiber not required
  – 150 years of paper tradition not required

• Lignin is the issue
  – Paper industry fuel
  – Bio-fuel industry is not economically viable without valuable co-product
  – Scientific GMO to reduce lignin... society may reject

• Current Commercial Lignin
  – Potential large supply
  – Sulfite closures → shortage of sulfite lignin → customer change use
  – Fuel will predominate

• Paper & Bio-products combination & synergy
  – Paper better economics than sugar
  – Part to paper, part to sugar & other
Future

• Utilize new sciences (bio) to extract chemicals from existing paper wastes
• Utilize new sciences (bio) to extract chemicals from wood
• Co-mingle paper production with bio-refinery science to benefit both

Wood Residuals → Pulp → Paper
↓  ↓
Bio-Refinery → Sugar → Bio-Fuels
↑  ↑
Bio Chemicals