The Lignin Biorefinery
(Kraft pulp mill biorefinery)

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(presented by Göran Gellerstedt, KTH)
Mini-symposium Wageningen UR Lignin Platform
December 6, 2011
Biorefinery – Simultaneous production of Fibres, Energy and Chemicals

- **More value from wood needed**
  - Increasing costs for wood and energy
  - Decreasing trend prices on pulp

- **Biorefinery may be the solution**
  - Handling of large volumes of biomass
  - New pulp mill products
  - New efficient separation processes
  - Add “side” processes

- **Innventia approach**
  - Kraft/soda pulp mill platform
  - Focus on the major components
  - Efficient separation process and mill integration
The Modern Kraft Pulp Mill –
An Existing Biorefinery Platform

Source: Aker Kvaerner
Karft Pulp Mill Products of Today

Wood chips → Pre-treatment → Pulping → Fibres

Forestry residues → Separation/upgrading → Energy and Recovery → Energy

Products
- Paper pulp
- Special cellulose
- Power, heat
- Motor fuels, pellets
- Tall oil, turpentine
Why Lignin Removal from Black Liquor?

• Increased pulp production by elimination recovery boiler bottlenecks

• Elimination of fossil fuel in lime kiln

• External fuel and higher value added applications
Near Future Kraft Pulp Mill Biorefinery Products

Wood chips → Pre-treatment → Pulping → Fibres
  |                        | LignoBoost             | Lignin → Polymeric carbohydrates
  |                        |                         |                         → Energy and Recovery → Energy
Forestry residues → Separation/upgrading → Lignin

Products:
- Paper pulp
- Special cellulose
- Fuel
- Carbon fibres
- Activated carbon
- Binder
- Fibre additive
- Barriers
- Co-polymers
- Lactic acid
- Power, heat
- Motor fuels, pellets
- Tall oil, turpentine
### Organic Substance in a Kraft Pulp Mill, kg

<table>
<thead>
<tr>
<th></th>
<th>Spruce/ pine</th>
<th>Birch</th>
<th>Eucalypt</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulp fibres</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>All can be used</td>
</tr>
<tr>
<td>Lignin</td>
<td>600</td>
<td>470</td>
<td>440</td>
<td>2/3 can be removed</td>
</tr>
<tr>
<td>Xylan</td>
<td>70</td>
<td>260</td>
<td>210</td>
<td>1/3 can be removed</td>
</tr>
</tbody>
</table>

- **Cellulose fibres - main product**
- **Added value from other components**
Wood/plants – a Mine for Valuable Polymers
- lignin

<table>
<thead>
<tr>
<th></th>
<th>Softwoods</th>
<th>Hardwoods</th>
<th>Agro/annual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spruce</td>
<td>Pine</td>
<td>Euca. glob.</td>
</tr>
<tr>
<td>Lignin, %</td>
<td>27</td>
<td>28</td>
<td>24</td>
</tr>
</tbody>
</table>

Physical/chemical properties vary with species and process
Principal Scheme of the LignoBoost process

Precipitation

Black liquor

Dewatering

Reslurry stage

Spent acid + H$_2$SO$_4$

Washing

H$_2$O + H$_2$SO$_4$

Lignin

CO$_2$

To evaporation plant

To evaporation plant
LignoBoost Process a la Metso

Axegård, Lignin Refinery, Mini-symposium Wageningen UR Lignin Platform, 6 Dec 2011
The First LignoBoost Plant Has Just Been Sold

- Announced by Metso November 2011
- To a customer in North America
- Name of customer to be announced shortly

2011-12-21
Axegård, Lignin Refinery, Mini-symposium Wageningen UR Lignin Platform, 6 Dec 2011
Inventias LignoBoost Demo plant

Nordic Paper, Bäckhammar mill

Demo plant
LignoBoost Lignin – a New Material
LignoBoost Demo Plant
First truck load for external use 2006
Lignin from Innventias LignoBoost Demo Plant

Carbon 64 - 66 %
Ash 0.3 - 1 %
Carbohydrates 0.5 - 1.5 %
Energy Density Key-issue for Biofuels

KWh/m3

- Forestry residues: 0.4 kWh/m3
- Chips: 0.8 kWh/m3
- Wood pellets: 3 kWh/m3
- Lignin: 5 kWh/m3
- Ethanol: 6 kWh/m3

Our focus
Successful Lignin Fuel Applications

- Lignin in oils
- Lignin fuel in lime kilns
- Lignin in pellets

Co-firing with bark

Co-firing with coal
Kraft Lignin Applications

Carbon fibre

Activated carbon

Binder in fibreboard

Hydrophobizing agent

Asphalt emulsions
Lignin Based Carbon Fibres

- Low ash content
- Low sugar content
- Thermal properties
# Targeted LignoBoost Lignin Properties

**Softwood kraft lignin**

<table>
<thead>
<tr>
<th></th>
<th>Standard LignoBoost</th>
<th>Modified process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ash</strong></td>
<td>%</td>
<td>0.4 - 1.0</td>
</tr>
<tr>
<td><strong>Na</strong></td>
<td>%</td>
<td>0.2 - 0.4</td>
</tr>
<tr>
<td><strong>Carbohydrates</strong></td>
<td>%</td>
<td>1 - 2</td>
</tr>
<tr>
<td><strong>Sulfur</strong></td>
<td>%</td>
<td>1 - 3</td>
</tr>
<tr>
<td><strong>Mw</strong></td>
<td>Dalton</td>
<td>3000</td>
</tr>
<tr>
<td><strong>Tg</strong></td>
<td>°C</td>
<td>140 - 150</td>
</tr>
</tbody>
</table>

|                 | ≤ 0.02              |
| **Ash**         | 0.4 - 1.0           |
| **Na**          | ≤ 0.01              |
| **Carbohydrates** | ≤ 0.4             |
| **Sulfur**      | 0.3 – 0.7           |
| **Mw**          | 1600 - 7000         |
| **Tg**          | 110 - 170           |

*(soda ≈ 0.1)*
## Potential Global Kraft Lignin Supply

<table>
<thead>
<tr>
<th>Fibre type</th>
<th>Demand Mtons/year</th>
<th>Lignin potential kg/ADt</th>
<th>Lignin potential Mton/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market HW</td>
<td>28</td>
<td>225</td>
<td>6.3</td>
</tr>
<tr>
<td>Market SW</td>
<td>24</td>
<td>325</td>
<td>7.8</td>
</tr>
<tr>
<td>Integrated pulp</td>
<td>115</td>
<td>225</td>
<td>25.9</td>
</tr>
<tr>
<td>Total</td>
<td>167</td>
<td></td>
<td>40</td>
</tr>
</tbody>
</table>

Source: Metso/RISI Outlook Briefings November 2010

Maximum lignin yield assumed, energy shortage covered by purchased fuel
Conclusions Lignin Refinery

- Lignin cost be efficiently produced with the LignoBoost process
- New commercial process owned and offered by Metso
- First commercial LignoBoost plant purchased

- LignoBoost lignin is very pure with low ash and sugar

- Demo plant available for large scale trials with lignin

- High quality bio-fuel

- Targeted lignin properties for value added applications i.e. carbon fibres, activated carbon etc