Update on Lignol’s Biorefinery Technology

October 15, 2009

www.lignol.ca
Introduction to Lignol

- A leader in emerging cellulosic ethanol technology
- Burnaby, BC and Berwyn, PA based, public company (LEC:TSX-V)
- Lignol’s Biorefining technology offers:
  - Attractive economics for production of cellulosic ethanol and high purity lignin derivatives;
  - Major GHG emission reductions
  - Lowest carbon footprint of any biofuel
  - A demonstration-ready process
- 50 employees
Lignol’s mission and strategy

- Lignol was formed to commercialize its world class biorefining technology
- Step-wise roll-out of biorefining technology culminating in optimized commercial design

<table>
<thead>
<tr>
<th>Stage</th>
<th>Capacity</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab</td>
<td>Grams/hour</td>
<td>✓ Complete</td>
</tr>
<tr>
<td>Small Pilot Plant</td>
<td>Kilos/hour</td>
<td>✓ Complete</td>
</tr>
<tr>
<td>Industrial Pilot</td>
<td>1 tonne/day (100,000 l/y)</td>
<td>✓ Progressing</td>
</tr>
<tr>
<td>Demonstration</td>
<td>100-300 tonnes/day (10-30 million l/y)</td>
<td>✓ Developing</td>
</tr>
<tr>
<td>Commercial</td>
<td>400-2000 tonnes/day (40-200 million l/y)</td>
<td>✓ Planning</td>
</tr>
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</table>
Lignol’s integrated biorefinery process technology maximizes added value from biomass feedstock

- Cellulosic ethanol
- HP-L lignin
- Biochemicals

**Wood Composition**

- Cellulose: 40%-45%
- Hemicellulose: 25%-35%
- Lignin: 20%-30%
- Extractives: 5%
Integrated biorefinery process technology maximizes added value from biomass feedstock
- Cellulosic ethanol
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Lignol Biorefinery - Process Overview

- Wood chips
- Agricultural residues
- Energy crops

**Biomass**

**Solvent-based Pretreatment/Fractionation**

**Black Liquor** (Dissolved Lignin + Hemicellulose Sugars)

**Lignin Recovery**

**Solid (Cellulose)**

**Lignin Dewatering and Drying**

**Liquor (Mixed Sugars & Biochemicals)**

**Hydrolysis & Fermentation**

**Future**

**Additional Ethanol Product**

**Biochemicals**

**Distillation**

**Fuel Ethanol Product**

**HP-L™ Lignin Product**

**Furfural**
Lignol’s Integrated Biorefinery Pilot Plant

- Capacity: 1 tonne per day (dry basis)
  - Fully integrated mini-biorefinery
  - Fully instrumented
  - Industrial equipment
  - Rated at 100,000 l/yr ethanol
- Feedstocks: Hardwood & softwood, agricultural residues, energy crops
- Products: Ethanol, HP-L™ lignin, furfural, other chemicals
- Operation: 24/7 in campaigns
Business Models - Lignol and Partners

Wood
Ag. Residues
Energy crops

LIGNOL
Biorefinery

HP-L lignin

Customer Applications

Wood Ag. Residues Energy crops

Cellulose substrate

Pulp and cellulose derivatives

Sugar platform chemicals

Biochemical

Ethanol

Sugars

Customer Applications

Pulp and cellulose derivatives

Sugar platform chemicals

Customer Applications

Ethanol

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Biochemical

LIGNOL Biorefinery

Cellulose substrate

Sugars

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Wood Ag. Residues Energy crops
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Feedstock

LIGNOL Biorefinery

HP-L lignin

Customer Applications

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LIGNOL Biorefinery

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Customer Applications

Cellulose substrate

Sugars

Sugar platform chemicals

Enzyme partners

Sugars

Biochemicals

Ethanol
Chemical Values in Woody Biomass

- Cellulose and hemicellulose are sources of sugars and other chemicals, including acetic acid, furfural and other sugar derivatives

- Native Lignin:
  - The natural binding material in all plant matter
  - A matrix aromatic polymer composed of phenolic structures
  - The only major source of aromatic structures in nature
  - The second most abundant bio-polymer after cellulose
  - A huge potential resource for the chemical and energy industries
Challenges for Conventional P&P Lignin

- Difficult to extract lignin from the recalcitrant woody structure while maintaining desirable properties
- Conventional chemical pulping processes (Kraft and sulfite) do extract lignin but resulting lignin is degraded in the process:
  - Chemical adulteration (Na, S, Mg, etc)
  - Chemical modification
  - Requiring extensive and expensive post-treatment to return desired properties
- By definition, sulfite and Kraft lignins are byproducts of processes whose primary goal is producing pulps with particular fiber properties and qualities
- Other cellulosic pretreatment process can only produce adulterated low-value lignin - most will burn it
How is Lignol’s HP-L™ Lignin different?

- HP-L™ lignin is a family of unique native lignin derivatives produced from Lignol’s Biorefining process
  - High purity with minimal chemical adulteration
  - Natural phenolic bio-polymer
- HP-L lignin is a core product of Lignol’s biorefining process
  - Lignin production is a key consideration when setting the biorefinery operating parameters
- Properties of HP-L lignin can be manipulated by adjusting:
  - Feedstock
  - Biorefinery process conditions
  - Post-treatment techniques
- Value enhanced from 10 cents/kg as fuel to >$1.00 /kg as a primary product
### HP-L™ Lignin compared to other lignin-based products

<table>
<thead>
<tr>
<th>Properties (typical values)</th>
<th>HP-L™</th>
<th>Kraft lignin</th>
<th>Sulfite lignin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>&lt;0.5%</td>
<td>2 - 4%</td>
<td>5 - 10%</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>&lt;1%</td>
<td>1 - 3%</td>
<td>5 - 7%</td>
</tr>
<tr>
<td>Sulfur</td>
<td>&lt;0.5 ppm</td>
<td>1.5 - 2%</td>
<td>5 - 15%</td>
</tr>
<tr>
<td>Hildebrand Solubility - $\delta$</td>
<td>-20</td>
<td>11 - 12</td>
<td>45 - 47</td>
</tr>
<tr>
<td>Polar Solvent (e.g. acetone)</td>
<td>100%</td>
<td>65-70%</td>
<td>&lt;5%</td>
</tr>
</tbody>
</table>
HP-L can be customized

- Lignol works with partners to develop HP-L lignin derivatives tailored to specific applications
  - Major chemical companies
  - Industrial research and development centers
- Examples of areas of applications development:
  - Resins and resin ingredients
  - Adhesives and coatings
  - Carbon fiber
  - Animal feeds
Variation of properties for various grades of HP-L lignin

Normalized Bond Strength (MPa/g/cm²)
Lignol’s Demonstration Project in USA

- US DOE grant awarded in 2007 - $30 million towards Colorado-based demonstration plant with partner - Suncor
- Presently restructuring project after departure of Suncor as host/partner
- Project development will seek additional leverage from DOE award:
  - New site - likely co-location
  - New location - improved feedstock supply, State funding
  - New partners - including product off-takers
  - Possible capacity increase - higher returns, more HP-L lignin available
  - More money - DOE grant expanded by stimulus funding, possible loan guarantees available
Biorefining and the Pulp and Paper Industry

- Biorefining represents a clear opportunity for the Pulp and Paper Industry
  - New business
  - Increased revenue from existing core assets
  - Synergistic operations
  - Use of excess feedstock and fiber waste
Lignol’s Technology and the Pulp and Paper Industry

- Co-location
  - Pulp mill could be ideal site to locate Lignol’s demo plant
    - Feedstock
    - Land
    - Utilities
    - Water and waste
    - Operating synergies
  - Mill could benefit from co-location of Lignol’s demo plant
    - Additional revenue - lignin, utilities, biofuels, chemicals
    - Additional fiber
    - Substantial capital assistance
Business Models - Lignol and P & P

LIGNOL Biorefinery

Feedstock

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Ethanol
Thanks!

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