Lignin - A Renewable Chemical Feedstock for the Future:

BIO Pacific Rim Conference
October 12, 2012
Vancouver, BC
Lignol Energy Corporation (TSXV: LEC)

- World class biorefining technology:
  - Renewable fuels and chemicals
  - High-value cellulose products
  - Unique High Purity Lignin

- Partnerships with leading companies in target industrial sectors

- Powerful IP portfolio: 90 patents in prosecution (12 granted)*

- Technology proven in integrated pilot-scale biorefinery
  - $50 million invested to date
  - Govt. funding awarded to date: $30 MM / $4MM pending
  - Ready for commercial deployment upon securing off-takes for key products
Value Streams from Lignol’s Biorefinery

**AlcellPlus™**
Organosolv Biomass Extraction

**Biomass**
- Hardwoods, Softwoods, Agri Residues

**Cellulose**

**Cellulose Derivatives**

**Sugars**

- Xylose, xylitol

**Hemicellulose Derivatives**

**Mixed Sugars (C5 +C6) & Chemicals**

**Furan chemicals**
- Furfural
- Furfuryl alcohol
- HMF

**Biofuels**
- Ethanol
- Bio-butanol
- Drop-in fuels

**Fermentation-based biochemicals**

**Lignin Derivatives**

**HP-L™ lignin**

**Petrochemical Substitution**
- Phenol
- Isocyanates
- Furans
- Plastics
- Coatings

**New Functional Products**
- Carbon fiber
- Antioxidants
- Adsorbents
- Feed additives
Established Lignin Industry

- Exclusively byproducts of fiber processing
  - Sulfite, Kraft and Soda Pulping
  - Wood and agricultural residues
- Well established applications based on the distinct chemical and physical properties of these technical lignins:
  - Chemically condensed
  - Chemically modified by pulping conditions
  - Non-lignin components:
    - Sulfur
    - Inorganics
    - Carbohydrates
- Estimates vary but this is a $2-3 billion business today
Lignin-based products in today’s market – sulfite pulping

- Lignosulfonates
  - Sulfite pulping
  - Water-soluble
  - 1 million tonnes per year
  - $1.0 – 3.0/kg ds
  - Market dominated by Borregaard and Tembec
  - $2-3 billion business worldwide

Applications
- Concrete Additives
- Animal feed pellets and molasses
- Pesticide dispersant
- Oil well drilling mud
- Dust control
Lignin-based products in today’s market – kraft pulping

- Kraft Lignins
  - Kraft (alkaline sulfide) pulping
  - Water insoluble (unless sulfonated)
  - 80-100,000 tonnes per year
  - $2.0 – 6.0/kg ds
  - MeadWestvaco is the major player

Applications
- Ag. Chemicals
- Dyestuffs
- Concrete
- Lead-acid batteries
- Resins
- Bitumen

Price
Lignin History – Unrealized Potential

- In 1838 Anselme Payen identified a substance released by the nitric acid treatment of wood.
- He referred to this substance as “encrusting material”
- This encrusting material is the largest non-petroleum source of the aromatic nucleus and the world’s second most abundant naturally occurring polymer.
- Today (after 174 years) approx. 50 Million metric tons of lignin are separated from wood annually by the world’s pulp mills
  - Mostly burnt for energy (which is essential for chemical recovery)
  - Most pulp mills have excess energy
- Only 1.1 million metric tons per year of lignin (~2%) are sold mainly as sulfonated lignin
- In spite of its massive potential, lignin is barely commercialized
- Why?
Some reasons….

- **Perception**
  - Lignin is seen as a waste product and has a high heating value!

- **Purity**
  - Most available lignin is contaminated, not sufficiently pure for many applications; highly heterogeneous

- **Petro-chemicals do it better**
  - Putting lignin into chemical systems and products that were designed for other types of chemicals like petro-chemicals is challenging (technically and commercially)

- **Difficult chemistry**
  - Lignin is a strongly self-associating, reactive, broad mixture of molecular species; highly reactive

- **Lack of knowledge**
  - Still large gaps in our knowledge of lignin and its chemistry
Unique market opportunities for HP-L lignin

- Lignol process extracts lignin fragments to produce valuable functional molecules which make up HP-L lignin
- Highly differentiated from commodity pulp mill lignin
  - High purity; low ash content, essentially sulfur-free
  - Lower molecular weight and polydispersity
  - Chemically reactive in many established chemical industry systems and products
  - Attractive to developers of new materials such as carbon fibre, films and polymers
- Market opportunities to deploy HP-L lignin in several major industrial sectors:
  - Automotive
  - Industrial equipment
  - Wood products
  - Chemicals and polymers
  - Construction
HP-L Lignin Applications Development

• Focus of Lignol’s development today is on incorporating HP-L lignin into product formulations as a substitute for incumbent petrochemicals
• Many companies are evaluating HP-L lignin in high-volume product sectors:
  – Resins
  – Coatings
  – Thermoplastics
  – Carbon fibre
  – Building materials
  – Foams
  – Wood composites
  – Adhesives
  – Filtration
• Lignol is working closely with corporate partners, Universities and Institutes to maximize breadth of application development
Key Resin Systems – Applications for HP-L

- Phenol Formaldehyde Resins
  - Foundry
  - Friction
  - Insulation
- Furan Resins
  - Molding Compounds
- Polyurethane Resins
  - Wood Products
  - Composite Materials
  - Coatings
  - Adhesives

High Purity Lignin
Displacement of Conventional Chemicals by HP-L

- Achieved displacement levels controlled by chemistry and stage of development - some examples:

<table>
<thead>
<tr>
<th>Application</th>
<th>Host Chemical</th>
<th>Achieved Displacement</th>
<th>Scale</th>
<th>Target Displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSB (&amp; MDF)</td>
<td>PF resin pMDI</td>
<td>25% 40%</td>
<td>Commercial</td>
<td>50% 50%</td>
</tr>
<tr>
<td>Rigid foam insulation</td>
<td>PF resin PIR</td>
<td>10% 5%</td>
<td>Industrial Lab</td>
<td>30% 30%</td>
</tr>
<tr>
<td>Coatings</td>
<td>Epoxy</td>
<td>10%</td>
<td>Lab&gt;Pilot</td>
<td>30%</td>
</tr>
<tr>
<td>Foundry resins</td>
<td>Furan</td>
<td>15%</td>
<td>Commercial</td>
<td>30+%</td>
</tr>
<tr>
<td>Friction binder</td>
<td>PF resin</td>
<td>40%</td>
<td>Commercial</td>
<td>50%</td>
</tr>
<tr>
<td>Thermoplastics</td>
<td>Various</td>
<td>30%</td>
<td>Pilot</td>
<td>50%</td>
</tr>
<tr>
<td>Carbon fibre</td>
<td>None</td>
<td>100%</td>
<td>Pilot</td>
<td>90-100%</td>
</tr>
</tbody>
</table>
Future directions for HP-L lignin development

• The future for HP-L Lignin – next generation uses and applications:
  
  – Bridging knowledge gaps in lignin physics and chemistry
    • Solubility, reactivity, rheology, mode of action in target systems
  – Development of products based on HP-L Lignin rather than using it as an additive or substitute ingredient
  – Development of feed, food and nutraceutical applications
  – Fractionation into narrower ranges of chemical composition
  – Chemical modification to create specific functionality
  – Breakdown into aromatic building blocks

• Priority and direction will be determined by economics and by partner priorities
Thanks