Conversion of Lignocellulosic Biomass to:

* Commercial Grade Pulp
* High Quality Lignin
* Hemi-Cellulose
Perspective on the Value of Wood

The following slide shows the value chain for wood

- Low end value of wood is burning it as heat
- High end value of wood is turning it into commercial cellulose (pulp) for making paper

Pure Lignin’s technology:

- Turns wood into commercial pulp, lignin and hemicellulose, which doubles the value over pulp alone
- The next step to even higher value is biorefining of Pure Lignin’s products into chemicals or advanced materials
# Converted Value of Wood

<table>
<thead>
<tr>
<th>Product</th>
<th>Value ($/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pellets, Heat</td>
<td>$86</td>
</tr>
<tr>
<td>Power</td>
<td>$124</td>
</tr>
<tr>
<td>CHP 80%</td>
<td>$181</td>
</tr>
<tr>
<td>Syngas @ $10/GJ</td>
<td>$143</td>
</tr>
<tr>
<td>BIGCC (CHP)</td>
<td>$230</td>
</tr>
<tr>
<td>Pyrolysis ???</td>
<td>$??</td>
</tr>
<tr>
<td>Ethanol @ $.75/litre</td>
<td>$263</td>
</tr>
<tr>
<td>Pulp @ $700/t</td>
<td>$280</td>
</tr>
</tbody>
</table>

Note: CHP = combined heat and power

Note: only 45% of wood converts to pulp
Value of Wood from Integrated Forestry Company

- Integrated forestry companies produce both pulp and lumber, which increases the value of wood from producing pulp alone
- 50-60% of a log gets converted to lumber
- 30-35% of a log gets converted to wood chips at the sawmill which ships them to a pulp mill
  - Only 45% of these chips are converted to pulp and the byproducts are burned for energy to run the mill
- 5-20% is waste (bark, off-grade chips & sawdust)
Value of Wood from Integrated Forestry Company (continued...)

- Lumber is valued at $250 to $550 per ton depending on market prices
- Pulp is valued at $700 to $800 per ton depending on market prices
- Waste products are valued at $10 to $100 per ton depending on quality and market
- Weighted average value of a ton of logs therefore ranges from $250 to $450 or about $320 based on long term normal prices
Improving Value beyond Traditional Integrated Forestry Company

• Step 1: With Pure Lignin’s technology, get more value for waste at pulp mill or sawmill (instead of only $10 to $100 ton, convert it to products yielding a weighted average of $500/ton)
  ▫ This improves mill economics, but to create the highest value...
• Step 2: Build a stand alone large volume plant to process wood or biomass for further refining
Biorefining to Get More Value

The next two slides show the effect of refining the key components of wood processed by Pure Lignin’s technology into other products

(These slides are from other third-party presenters at various conferences on this topic)

Biorefining means converting the cellulose, lignin and hemi-cellulose into other higher value chemicals, which may include simply making ethanol or other fuels from these products
### Maximizing Value

#### Present situation

<table>
<thead>
<tr>
<th>Product</th>
<th>Price ($/ODMT)</th>
<th>Yield (%)</th>
<th>Value (US$/ODMT wood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulp</td>
<td>500</td>
<td>45</td>
<td>225</td>
</tr>
<tr>
<td>Wood as fuel</td>
<td>55</td>
<td>55</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td></td>
<td><strong>255</strong></td>
</tr>
</tbody>
</table>

**Value-Added:** 255 – 75 = 180 US$/ODMT wood

#### Future Situation

Biorefining cellulose, lignin, hemi-cellulose in chemicals

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
<th>Wood Yield (%)</th>
<th>Conversion (%)</th>
<th>Value (US$/ODMT wood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulp</td>
<td>$500/ODMT</td>
<td>45</td>
<td>100</td>
<td>225</td>
</tr>
<tr>
<td>Polymer</td>
<td>$3000/MT</td>
<td>10</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>PU foam</td>
<td>$3000/MT</td>
<td>10</td>
<td>45</td>
<td>135</td>
</tr>
<tr>
<td>Diesel</td>
<td>$630/MT</td>
<td>35</td>
<td>40</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>$2.00/gallon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>100</td>
<td></td>
<td><strong>598</strong></td>
</tr>
</tbody>
</table>

**Value-Added:** 598 – 75 = 523 US$/ODMT wood
CONVERTING A KRAFT PULP MILL INTO AN INTEGRATED FOREST PRODUCTS BIOREFINERY

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
<th>Wood Yield (%)</th>
<th>Conversion Yield (%)</th>
<th>Value (USS/ODMT wood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline Pulp</td>
<td>USS$600/ODMT</td>
<td>45</td>
<td>100</td>
<td>270</td>
</tr>
<tr>
<td>Poly Itaconic Acid</td>
<td>USS$3000/MT</td>
<td>10</td>
<td>50</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>USS$1.25/Gallon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Fibers</td>
<td>USS$7000/MT</td>
<td>10</td>
<td>45</td>
<td>315</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>USS$630/ODMT</td>
<td>35</td>
<td>40</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>USS$2.00/Gallon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100</td>
<td></td>
<td>823</td>
</tr>
</tbody>
</table>

Table 7. Value of IFBR Producing Pulp, Structural and Diesel Fuel Products
The Forest Biorefinery: What is it?

Logging residues → Residues → Gasification, pyrolysis → Synthesis products

Wood → Pulp mill

Pulp mill → Conventional processes → Pulp, Paper

Pulp mill → Chemical processes → New Products

Pulp mill → Fermentation processes → Ethanol, Lactic acid

Hemicellulose → Lignin

Tom Browne, Fpinnovations Sep/2007 presentation
General concept of a biorefinery

- renewable raw materials
  - biomass fractionation
    - lipid fraction
    - carbohydrate feedstock
      - protein fraction
    - fermentation
      - chemical conversion
        - oleochemicals
      - ethanol
      - biomonomers
        - biofuels
        - bioplastics
        - fine and bulk chemicals
        - food and feed ingredients

Our Process fits here
Pure Lignin’s Technology is the Critical Front-end for a Biorefinery

• Pure Lignin’s technology is the most cost effective pretreatment process to convert wood into its basic parts: cellulose, lignin and hemi-cellulose
• The cellulose, lignin and hemi-cellulose can be sold in open market or fed to a biorefinery for further processing
• There are other common pretreatment technologies but an April 2008 scientific paper stated that none are suitable yet
Competing Pretreatment Processes

- Steam explosion
- Dilute acid
- Ammonium fibre expansion
- Aqueous ammonia recycle
- Lime
- Organosolv
- Mild alkaline
Conclusions on Pretreatment Options from Scientific Journal

“So far, there is no commercially feasible solution to efficient pretreatment of softwood materials for the production of biofuels and biobased products (Ahring et al., 1999; Chang et al., 2001; Reith et al., 2002). Breakthroughs in pretreatment are still needed for both scientific and economic reasons”

Biotechnology and Bioengineering, Vol. 99, No. 6, April 15, 2008 (Wiley Periodicals)
Forest Bio-Refinery: Why Now?

- Society is demanding renewable products
  - Chemical and fuel companies are noticing
- The forest sector needs new products to make better use of existing resources and infrastructure

Quoted from:
Tom Browne, Fpinnovations (Pulp Industry Assoc).
How to Get to Higher Value?

Quotes by pulp industry strategy experts in 2008

*Design or retrofit the facility so it can "shift the carbon" available from woody biomass, pulp and paper products, energy products and bio-refinery products to dance with the shifting markets and thus maximize those margins. The mill becomes proactive, rather than reactive. "It's a completely different way of thinking," says Stuart. "It's the way pharmaceuticals and [oil] refinery companies think."*

**Dr. Paul Stuart**, head of the NSERC Environmental Design Engineering Chair in Process Integration in the Pulp and Paper Industry and professor with the Chemical Engineering Department of École Polytechnique in Montreal
“Crude oil is chemically and thermally fractured into different products, from high-value aviation fuel to plebian road asphalt. Ditto for forest biomass,” says Browne. "Every fraction has a value and you maximize the value of as many of these fractions as you can.”

**Dr. Tom Browne**, Program Manager Mechanical Pulping and Sustainability for FPInnovations (formerly Paprican)
Pulp Industry Strengths and Weaknesses

- Why Venture Capitalists need Pulp Industry
  - Secure access to renewable biomass
  - Good plant locations and permitting
  - Tested supply chains

- Why the Pulp Industry needs outsiders
  - No product development culture ("we fired everyone")
  - Do not have the research ability or knowledge to bring on new products
Canadian Pulp Mill Advantages

• The Canadian pulp and paper industry has small, aging mills in comparison to the large modern mega-mills drawing fibre in from plantation forests.
• When it comes to converting some capacity to bio-refining, certain advantages may go to smaller mills.
• Smaller mills may be tailored to create profitable bio-products.
• Canada is close to the large U. S. markets, thus cutting transport costs.
Is it Time For Change in Pulp Industry?

- Two years ago Dr. Brown was less optimistic about forest industry biotech industry, **but now:**
- “Some technical successes in the lab have convinced people there are some opportunities here.”
- "The industry is beginning to move and I think it is going to start moving pretty quickly in the next little while.”
- "There's something of a gold-rush mentality here; there's an awful lot of money floating around and an awful lot of people jockeying for position.”
Evidence of Action in 2008

- Weyerhaeuser and Chevron formed Catchlight Energy JV to focus on cellulosic ethanol
- Dupont Danisco to produce cellulosic ethanol
- Lignol Energy & Suncor get DOE funding to build cellulosic ethanol pilot plant in USA
- Government incentives and policy are pushing for action from industry (SDTC funding in Canada, USA has $1.07/gallon incentive plus cost sharing on projects and loan guarantees
How should Pulp Industry Proceed?

Dr. Brown of FPInnovations:

• Trade secure sources of cellulose for outside capital and smarts
• Find savvy partners or allies in oil or chemical industries
• Identify waste or under-utilized biomass streams
• Start with small scale uses of side-stream
Why Pulp Mills will Partner with Pure Lignin

- Pulp mills must lower energy consumption, lower their capital costs and find other revenue streams
- Pure Lignin has low capital and operating costs due to a simple process operating at low temperatures and low pressure that recycles all chemicals and water
- Our pretreatment process can use lower quality chips, lower cost chips or sawdust without degrading pulp
- Our process can eliminate the costly recovery boilers
- Reduces water, air pollution and landfill sludge
- Three revenue streams: pulp + lignin + hemi-cellulose = more profits
- Lower capital cost + higher profits = higher ROI
Other Potential Partners

• Sawmill Owners
• Entrepreneurs and Investors
• First Nations
• Governments & Municipalities
• Cellulosic Ethanol Producers
Sawmill Owners

Reasons to Partner with Us

• Our process will yield higher value for both pulp grade and non-pulp grade chips, fines/sawdust
• Very cost effective stand-alone plant as sawmills already have wood handling equipment and AAC
• An onsite plant allows you to choose whether to process the log through your plant or ours, depending on market prices or log quality
• If lumber prices are too low then chip the whole log and sell marketable pulp and lignin to stay profitable
• Increase value of log or wood residues from $100/ton as waste or $250/ton as lumber to $550/ton by selling multiple products from our plant
Entrepreneurs & Investors

- Fast payback on stand-alone plant using beetle-kill wood
- Ongoing return on plant from other biomass after beetle-kill timber is gone
- Plant size is economic on smaller scale (25 ton to 500 ton/day input vs. 1,000 to 3,000 ton/day)
- Multiple feed stocks and multiple end products result in lower risk than pure corn ethanol plant
- Incremental investment in advanced bio-refinery yields higher returns on total capital invested
- Generate additional revenue from GHG credits
First Nations
Reasons to Partner with Us

- Build your local economy
- Smaller scale plants economic
- Economic use of your beetle kill AAC
- Economic use of forestry waste in your area
- Local employment for range of skill sets leading to career paths in your community
Governments & Municipalities
Reasons to Partner with Us

• Diversify your economy
• Invest in initial plant in JV with your local pulp mill help it stay in business
• Re-open closed pulp mills with new lower cost processes and lower pollution processes
• Keep your tax base
• Keep your population base employed
• Build multiple mid-sized plants instead of one massive plant leading to more sustainable communities
Cellulosic Ethanol Producers
Reasons to Partner with Us

- The industry needs better pretreatment options and we have this improved process now
- Low capital costs and low operating costs due to simple closed loop design operating at lower pressures and lower temperatures
- Full recovery of chemicals and negligible pollution due to closed loop process
- Multiple revenue streams from selling high quality lignin by-product
- Works with multiple feed stocks: wood chips, sawdust, sugar cane bagasse, corn stover, etc.
- Multiple feedstock choices protect your profits if one feedstock gets too expensive
Biomass to Ethanol Process at a Glance

Our process fits at this stage

SSF = simultaneous saccharification and fermentation
Key Attributes of a Pretreatment Process for Lignocellulosic Biomass

- Conclusions from Pacific Northwest National Laboratory October 2007 Lignin research
  - Of highest importance is the need to remove lignin early and mildly in biomass fractionation processes
  - Use mild processes to preserve the structure
- Our patented technology achieves this now!!
  - Lab tests done
  - 1st generation pilot done
  - 2nd generation mobile pilot complete in Spring 2009
Key Aspects of Our Process

- Cost-effective fractionation of a wide variety of lignocellulosic biomass using a mild pretreatment process
- Pretreatment method that does not degrade key properties of cellulose, lignin and hemi-cellulose
- Marketable cellulose, lignin and hemi-cellulose allows economic stand-alone plant
- Alternatively, feed products through ethanol or advanced bio-refining processes
Pretreatment Process that Results in Marketable Pulp and Lignin or allows for further processing to Ethanol

Lignocellulosic Biomass feedstock Input (i.e. softwood chips or hardwood chips, corn stover, Sugar cane bagasse, straw, etc.)

- Pretreatment process.
- Acid Catalyzed Hydrolysis process

Commercial grade Cellulose separated out.

Option

Package cellulose for sale to pulp mill

Chemicals recycled

Lignin and hemi-cellulose in black liquor. Mild Process separates them.

- High grade Lignin separated out and ready for market

Hemi-cellulose sugars ready for fermenting

Option

Cellulose sugars ready for fermenting

Standard Ethanol Production Process

Product made from hemi-cellulose in Bio-refinery
Is a Cellulosic Ethanol Plant Profitable?

• Other companies are forecasting profitability even with higher capital and operating costs than corn ethanol plants
• Profitability comes from extra revenue from lignin and hemi-cellulose by-products
• Government incentives on cellulosic ethanol production in USA $1.07/gallon, plus subsidies for biomass transport, plus loan guarantees
• Governments are also sharing the risks by subsidizing costs of commercialization (SDTC)
Sample Ethanol Plant Economics

- Levelton Consultants did a study for Alberta Research Council on cellulosic ethanol plant economics (see next page for proforma)
- Levelton used preliminary data from Lignol Energy, a local Vancouver company, that show the importance of having lignin as a second revenue stream to make the economics of a cellulosic ethanol plant work
- The proforma on the next page shows that a plant can have a 14% ROI even while paying a higher than market price for input biomass
# Balance Sheet and Ability to Pay for a Lignol Innovations Ethanol Plant

Prepared by Levelton Consultants for Alberta Energy Research Institute

<table>
<thead>
<tr>
<th>Size in litres ethanol/yr</th>
<th>93,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cdn$ per year</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Comments</strong></td>
<td></td>
</tr>
<tr>
<td>Capital cost</td>
<td>$300,000,000</td>
</tr>
<tr>
<td>Salaries</td>
<td>$5,500,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$7,093,000</td>
</tr>
<tr>
<td>Insurance</td>
<td>$900,000</td>
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<tr>
<td>Property tax</td>
<td>$1,500,000</td>
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<tr>
<td>Fuel pre-treatment</td>
<td>$3,500,000</td>
</tr>
<tr>
<td>100% of fuel is de-barked/chipped</td>
<td></td>
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<tr>
<td>Electricity</td>
<td>$4,081,000</td>
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<tr>
<td>Enzymes</td>
<td>$6,192,000</td>
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<tr>
<td>Water</td>
<td>$1,098,000</td>
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<tr>
<td>Ethanol losses</td>
<td>$4,495,000</td>
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<td>Denaturant</td>
<td>$2,552,000</td>
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<td>Natural gas</td>
<td>$1,712,000</td>
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<tr>
<td>Chemicals</td>
<td>$1,244,000</td>
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<tr>
<td>Ethanol transport (train)</td>
<td>$2,343,600</td>
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<td>700 km</td>
<td>$42,000,000</td>
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<tr>
<td><strong>Annualized Cost</strong></td>
<td>$84,210,600</td>
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<tr>
<td>Ethanol revenue</td>
<td>$68,820,000</td>
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<td>$0.74 per litre (ethanol)</td>
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<tr>
<td>Lignin revenue</td>
<td>$67,979,678</td>
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<td>$0.88/kg</td>
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<tr>
<td>Furfural revenue</td>
<td>$6,532,643</td>
</tr>
<tr>
<td>$0.29/kg</td>
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<tr>
<td><strong>Annualized Revenue</strong></td>
<td>$143,332,321</td>
</tr>
<tr>
<td>Income above ROI</td>
<td>$59,121,721</td>
</tr>
<tr>
<td>Ability to pay for fuel ($/bdt)</td>
<td>$169</td>
</tr>
<tr>
<td>350,000 bdt/yr</td>
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</tbody>
</table>
Summary

• Urgent needs from three industries
  ▫ Pulp industry needs new revenue sources
  ▫ Sawmill industry needs new revenue source
  ▫ Cellulosic Energy producers need better treatment processes now

• Pure Lignin’s patented technology aligns with:
  ▫ Timing of industry needs
  ▫ Society’s demand for non-petroleum based products, i.e. renewable cellulosic alternatives
  ▫ Government policy
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