The Value Prior to Pulping (VPP) Platform for Biomass Utilization

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Today’s Presentation

- Industry Context
- Global Issues
- Forest Products Potential
- Integrated Forest Products Biorefinery
  - Concept
  - Forest Products Industry Advantage
  - Mill Integration Model
  - Product/Offtake Options and Markets
  - Initial Economics
Industry Context

- Directly employ 1.3 million people
- Sales of forest and paper ~$230 billion/yr
- Contribute 7-9% of primary industrial energy
- Biorefinery: more efficient renewable energy
Industry in a Crisis

- Global competition
  - Latest energy efficient technology
  - Wood, energy and labor cost advantages
- Prices have declined
- Mills under intense economic pressure
- Mills have shut down
- Production moved overseas
Global Issues

- Energy Supply
- Control fossil-fuel CO2 emissions
- Climate change
Energy Use in Key Industrial Sectors

(All Figures in Trillion BTUs)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Natural Gas</th>
<th>Residual Fuels</th>
<th>Distillate Fuels</th>
<th>LPG/NGL</th>
<th>Coal and Coke</th>
<th>Derived Net Electricity</th>
<th>Other</th>
<th>Total Use, Net</th>
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Taken from “Profile of Total Energy Use for US Industry”, Energetics, Inc. for the US DOE, 12 / 04.
LPG / NGL = Liquefied Petroleum Gas / Natural Gas Liquids
Table does not include energy sources used as raw materials.
Forest Products Potential

- Cellulose – most abundant organic chemical
- 90 billion tons produced per year
- In energy terms: the amount of carbon is equivalent to ~10X the world consumption
- Renewable forest material is carbon neutral
“The Billion Ton Study” by Departments of Energy and Agriculture

- US potential: 400 million dry tons/year
- Total: 1 billion dry tons from
  - Agricultural biomass
  - Woody biomass
- Equal to 1/3 of all transportation fuels in US
Integrated Forest Products Biorefinery (IFPB)

- Sustainable renewable energy
- Forest products industry evolving into integrated forest refineries
- 1st International Biorefinery Workshop (2005)
- By 2050 all gasoline used in US could be replaced by biomass-derived fuels
Integrated Forest Products Biorefinery (IFPB)

- Unique opportunity to increase revenue
- Contribute to a sustainable stream of
  - High-value (and “green”) chemicals
  - Fuel and/or electric power
- Continue to produce traditional line of products
  - Wood
  - Pulp and paper
Agenda 2020

- Agenda 2020 Technology Alliance provides leadership for industry biorefinery strategy
  - Partnership with industry, government, and academia
  - Innovation in processes, materials, and markets
Components of the Agenda 2020
IFPB Technology Strategy

Value Prior to Pulping –
Fermentation/Biochemical Pathway

New Value Streams from residuals and spent pulping liquors –
Thermochemical Pathway

Sustainable Forest Productivity
Feedstock Pathway
Forest Products Industry Advantages

- Forest-based materials as feedstock
- Industry has infrastructure and expertise
- IFPB technologies have potential for significant national benefits
- Carbon benefits
- Initial economics are compelling
Bioconversion Pathway (Fermentation)

- Hemicellulose makes up about 20 to 30% of the wood
- Hemicellulose extracted without damaging the fiber
- Hemicellulose fermented and distilled into ethanol
Thermochemical Pathway (Gasification)

- Achieve high conversion efficiencies
- Biomass stream converted to a higher value products
- Convert all of the plant and not limited to the sugars.
- Conversion efficiencies in excess of 75%
- ~60% of energy converted into synthetic gas
  - Fuel in boilers, gas turbines, lime kilns, direct fired dryers, etc.
  - Converted to a bio-crude or (Fischer Tropsch) fuels/chemicals
- Additional 20% to 25% of the energy recovered and converted to steam
Value Prior to Pulping

Separate and extract selected components of wood prior to pulping, and process these streams to produce commercially attractive chemical and liquid fuel products

- Hot water extraction vessels
- Hemicelluloses extracted
- Acetic acid separated, and sugars fermented to ethanol
- Ethanol - low end of products
- Improves throughput potential
- Fermentation - produce high-value chemicals and ethanol
- Key Technologies
  - Hemicellulose extraction
  - Hydrolysis and Saccharification
  - Fermentation (enzymes)
Value Prior to Pulping

- Reference Mill
  - Single large Kraft pulp mill
  - Using the base case from Larson et al, 2002

- Output
  - 9.5 - 14.3 million gallons of ethanol
  - 3.0 - 4.5 million gallons of acetic acid

- Capital Cost (preliminary estimate)
  - ~ $50 million for vessels, distillers, membranes & controls

- Operating Cost
  - ~ 8.7 million or ~ 35 cents/gallon

- Net Revenue Increase
  - ~ $8.8-13.2 million per year
Value to the US Pulp & Paper Industry

- Potential economic benefit to the US Pulp & Paper Industry, given wide scale implementation of the technology:
  - 740 - $1,100 million/year of new revenue
  - 1.6 – 2.4 billion gallons of ethanol
  - 260 – 400 million gallons of acetic acid

- Replacing 1.6 to 2.4 billion gallons of gasoline with ethanol eliminates
  - 15 to 21 million tons of CO₂,
  - 13 to 20 thousand tons of nitrous oxide
  - 8.5 to 13 thousand tons of VOCs.
Value Prior to Thermo Mechanical Pulping

- Reference Mill
  - 350 BD bleached TPD Spruce TMP pulp mill
- Ethanol Output
  - ~ 1.5 million gallons ethanol
- Energy Savings
  - 20% reduction in refiner energy
  - 62 megawatt-hours saved annually
  - $3,400,000/year energy savings ($55/Mwh)
- Softwood Kraft Savings due to stronger TMP
  - 5-6 parts of SWK reduced
  - $5,500,000 saved fiber costs
- Operating Costs = $1-2 million/year
  - Extra wood costs and pretreatment costs
  - Enzymes, fermentation, and distillation costs
- Potential = $10,000,000/year in net revenue and cost reductions

- Given wide scale implementation in the US
  - 40 million gallons/year ethanol
  - $250,000,000 in new revenue and variable cost reductions
Value to Our Industry

- Potential of changing the nature of the pulping process - pulping without sulfur
  - A sulfur-free pulping process - simplify the downstream processes
  - Improve the economic and environmental outlook
- Maintain the competitive position of paper industry
- New facilities built — significantly expanding production potential
- Pulp mills - attractive sites/partners for ethanol producers
  - The incremental capital much less than for a “green field” plant
  - The integration of ethanol production facility - significant savings in operating costs
## Potential Markets for Fuels and Chemicals

<table>
<thead>
<tr>
<th>FUELS</th>
<th>U.S. Market Size, 2005</th>
<th>Average refinery gate price (excl. taxes), 2005</th>
<th>Approximate market U.S. wholesale, 2005</th>
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<tbody>
<tr>
<td></td>
<td>Physical Units</td>
<td>Quads per yr</td>
<td>$/gal</td>
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<tr>
<td>Motor gasoline</td>
<td>9.13 million bbl/day</td>
<td>17.2</td>
<td>$1.67</td>
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<tr>
<td>Motor diesel</td>
<td>4.11 million bbl/day</td>
<td>8.74</td>
<td>$1.75</td>
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<td>LPG</td>
<td>2.02 million bbl/day</td>
<td>3.05</td>
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<td>Ethanol</td>
<td>0.26 million bbl/day</td>
<td>0.34</td>
<td>$1.89</td>
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<tr>
<td>Natural Gas</td>
<td>21.98 trillion SCF</td>
<td>22.6</td>
<td>$7.51</td>
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### CHEMICALS

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<tr>
<td>Methanol</td>
<td>0.185 million bbl/d (2001)</td>
<td>3-4 B$/yr</td>
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<td>Hydrogen</td>
<td>10 million t (15% of which is merchant)</td>
<td>15-75 M$/yr (merchant)</td>
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<td>Ammonia</td>
<td>21 million tons (2001)</td>
<td>2-7 B$/yr</td>
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<tr>
<td>Mixed Alcohols</td>
<td>3.7 billion pounds</td>
<td>3-4 B$/yr</td>
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Source: Princeton/Navigant
Pulp & Paper Mills and Petroleum Refineries

Location of U.S. Refineries and Pulp and Paper Mills

Industry Goals of Project

- Objective of VPP - Demonstrate commercial feasibility
- Goal - develop scientific and economic information to make informed decisions:
  - Credible and convincing business case?
  - Sufficient positive societal impact?
  - Move to commercialize and deploy technology?
VPP Status – Where are we?

<table>
<thead>
<tr>
<th>Concept Generation</th>
<th>Risk Assessment</th>
<th>Proof of Concept</th>
<th>Proof of Process</th>
<th>Demonstration Approach</th>
<th>Transfer</th>
<th>Deployment Decisions</th>
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VPP Status – 2008

- Project Kickoff meeting held in 2007
- DOE grant for $1,523,000 project finalized
- Total current committed resources - $2,656,000
- Additional resources being pursued - $580,000
- Additional VPP membership being pursued
VPP Status – Project Teams

- Pre-Extraction & Pulping
- Extract Processing
- Fermentation & Ethanol Production
- Modeling & Business Case Development
Proof of Concept Deliverables

- Pre-extraction of hemicellulose sugars
- maintaining value and quality of pulp
- High yield production of ethanol from pentose and hexose sugars
- Recover acetic acid
- Integration of production processes into pulp mills
Compelling Business Case Deliverables

- Process modeling, capital costs, equipment, energy & environmental analysis and economics
- Business Cases developed for both kraft and TMP
- Economic implications of non-sulfur pulping options
Participating Pulp & Paper Companies

- New Page
- International Paper Company
- MeadWestvaco
- Potlatch
- Longview Fibre
- SAPPI
- Weyerhaeuser

- DOE contract Managed by Clean Tech Partners
Questions?

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