Renewable Chemicals from the Forest Biorefinery

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The Forest Biomass in Canada

• Canada has 347.7 Mha of forest, 41.8 Mha of other wooded land and 7.8 Mha of other land with tree cover, a total of 397.3 Mha

• This represents 10% of the world’s forest cover, 30% of the world’s boreal forest and 39% of Canada's land area

• The Canadian forest industry accounts for $23.7 billion, about 1.9% of the gross domestic product and gives direct employment of 234 000 Canadians
The Forest Industry in Transition

• The demand for commodity products (newsprint) is decreasing: 9.2 Mt in 2000 vs 4.6 Mt in 2010 (Canadian production)

• New production facilities in emerging industrial regions have a large production cost advantage

• High energy and chemicals cost

• Stringent environmental regulations

The Canadian forestry sector is developing new products to generate additional revenues
The Forest Biorefinery & The Chemical Industry

A promising partnership

- Bio-based products generated by the forest biorefinery can be used as:
  - platform chemicals to produce alternatives of fossil-derived products
  - substitutes for commodity chemicals
  - intermediate products in the petrochemical conversion chain

- The selection of the optimal transfer point from the biorefinery to the downstream processing chain is a function of technological, economic and environmental criteria
The Forest Biorefinery: Contributions

• Can benefit from the added value of the specialty products, taking the example of the chemical industry

<table>
<thead>
<tr>
<th>Final use - petroleum products (%)</th>
<th>Revenues (%)</th>
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<tbody>
<tr>
<td>Fuels</td>
<td>70</td>
</tr>
<tr>
<td>Specialty chemicals</td>
<td>4</td>
</tr>
<tr>
<td>Other products</td>
<td>26</td>
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</tbody>
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• Can contribute to meet the growing demand for biobased products

<table>
<thead>
<tr>
<th></th>
<th>Market (G$)</th>
<th>Annual growth rate 2005-2025 (%)</th>
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<tbody>
<tr>
<td>Global chemical industry</td>
<td>3 000 (2012)</td>
<td>3</td>
</tr>
<tr>
<td>Biobased products</td>
<td>21.2 (2005)</td>
<td>18</td>
</tr>
</tbody>
</table>
Product Platforms Based on P&P Processes

- Wood pulp → Cellulose → Glucose → Sugar Platform
- Wood chips → Hemicelluloses → C₅/C₆ sugars
- Black liquor → Lignin → Phenolic Platform
- Process streams → Extractives → Specialty Products
Examples of Biorefining Processes for P&P Mills

- Kraft pulp mills - appropriate receptors of biorefining technologies:
  - Hemicelluloses extraction and conversion into furfural, butanol, ethanol
  - Lignin extraction from black liquor by acid precipitation
  - Electrodialysis treatment of Kraft black liquor
  - Wood biomass gasification and syngas valorization

- Energy and material integration between the biorefinery and the receptor mill should be considered
New Developments for Biorefineries

- Butanol: Efficient detoxification of hemicellulosic hydrolysates using nanomembranes prior to fermentation
- Furfural: Pre-hydrolylate concentration with membranes - reduction of chemical and energy consumption in the conversion and purification steps
- Ethanol: Simultaneous hydrolysate concentration and detoxification - positive impact on fermentation and distillation
- Synergies between forest and agricultural biorefineries:
  - Use of culture media derived from agro-biomass to enhance biofuels production
The Sugar Platform

Based on Kraft process for dissolving pulp production

Wood Chips → Hemicelluloses Hydrolysis → Pulping → Washing → Bleaching → Drying → Dissolving Pulp

- Causticizing
- Concentration
- Recovery Boiler
- Lime Kiln
- Biorefinery Unit

Sugar-based products

Hydrolysate

White liquor → Black liquor

Smelt

MP & LP Steam → Turbines → Power

HP Steam

Steam

Fossil fuel

Bark/
The Sugar Platform: Furfural

- World production: 365 000 t/a
- 75 % produced in China
- Market price: 1 500 - 1 800 $/t

Feedstock in the production of adhesives, resins and solvents ...
For a successful biorefinery development, the use of resources *(energy, water and chemicals)* has to be optimized.

**Means:**

- Novel energy enhancement and integration methodology - the potential reductions of steam and water consumption identified by this methodology are far superior to the current engineering practice.
- Equipment performance analysis based on exergy as a key performance indicator - identifies opportunity for improvement in equipment and process performance.
Energy Enhancement Methodology

1. Process evaluation
   • Process Simulation
   • Benchmarking
   • Targeting
   • Efficiency & Diagnostics

2. Steam & Water Savings Projects
   • Equipment Performance Analysis
   • Simultaneous Steam & Water Analysis
   • Heat Exchanger Network Design

3. Post-Analysis and Implementation
   • Energy Upgrading & Conversion
   • Post-Benchmarking
   • Implementation Strategy
Energy Integration: Furfural Process

Total heating requirement ($\Sigma Q_H$) = $14.6 \text{ MW} \rightarrow 8.0 \text{ MW}$

Total cooling requirement ($\Sigma Q_C$) = $25.6 \text{ MW} \rightarrow 19.0 \text{ MW}$

Heat Exchanger Network (HEN) optimization and Absorption Heat Pump implementation contribute to reduce $\Sigma Q_H$ and $\Sigma Q_C$. 
Energy Integration: Receptor Mill

Fossil fuel savings & Electricity generation / Utilities available to support a biorefinery
Opportunities for Biorefinery Clusters

Integrated Forest Biorefinery

- Forest biomass
- Water
- Chemicals

Dissolving pulp to market
- Furfural
- Heat & Power

Chemical Making Plant

Effluents

External resources

Resources shared within the boundary of the cluster

Products from the cluster
## Benefits of Collaboration

### P&P Mill
- Additional revenue streams:
  - furfural
  - heat & power
- Access to new markets
- New knowledge

### Chemical Plant
- Bio-based feedstock
- Shared infrastructure with the P&P mill
- Reduced transportation cost
- Reduced environmental impact

- Competitive advantage – increased market share and revenues
- Shared business risk
Conclusions

• The Canadian forest is an abundant source of renewable feedstock

• As a transition of the P&P industry from the traditional market to new markets, it is proposed to extract streams from the P&P processes and to send them to biomass conversion plants

• The integration of the biorefinery plants may increase the demand for thermal energy and water, a strategy for steam and water enhancement of the biorefinery and the receptor pulp mill should be developed

• P&P mills should consider opportunities for collaboration with the chemical industry when making decision on biorefinery processes and products

• The forest biorefinery cluster could be an opportunity to build links between the forest and the chemical industry
Thank you!

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