THE WAY FORWARD

Biopaths Phase II
The Way Forward

Source: myamazingfact.blogspot.com
Objectives of Bio-pathways Project

• Support the industry in identifying possible transformational strategies

• Create ‘sunrise’ industry vision

• Encourage federal and provincial policy makers to support transformation

• Provide analytics to investors and partners of potential opportunities
What Did We Learn In Phase I?

• Economics of different bio-product technologies vary widely depending on site conditions and mill configurations, location, scale.

• Some of the bio-product technologies have much better returns than conventional production
  – ROCE of 20%+

• The ‘best’ approach integrates conventional and new technologies (for economics and jobs)

• The most promising future involves sawmills and engineered wood products together with bio-refineries for production of pulp/bio-energy/bio-chemicals
PHASE II: OVERVIEW
Phase II: What Was Done

• Core teams of researchers assigned to:
  – Synthesize available information for biomaterials; biochemicals and bioenergy markets
  – Consider business model modifications
  – Validate Phase I results with scenarios
  – Grow the analysis to cover more technologies and carbon footprint
  – Develop bio-pathways roadmaps for chemical, mechanical pulps and lumber

• Engaged broad range of stakeholders through three workshops to road test results along the way
The Canadian forest sector is already producing a range of green and low carbon products. There are great opportunities to increase this contribution to increase the value for the sector. This will not replace the traditional forest industry, but will be an important supplement. Integrating production is crucial. There are many viable options for converting forest biomass to energy and chemicals. Phase I results were validated and expanded.

See Appendix for summary of bioenergy; biochemical and biomaterial findings.
### GLOBAL MARKET POTENTIALS FOR DIFFERENT BIO-PRODUCTS FROM FOREST BIOMASS (Billion US$)

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-energy, bio-chemicals, fiber composites</td>
<td>505</td>
<td>776</td>
<td>1309</td>
</tr>
<tr>
<td>Conventional forest industrial products</td>
<td>495</td>
<td>512</td>
<td>545</td>
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</tbody>
</table>

References:
- Building with wood and living with wood: FPInnovations 2010, and Nilsson & Goodison, 2010
## Gross Market Opportunities

<table>
<thead>
<tr>
<th>PRODUCTS</th>
<th>GLOBAL MARKET POTENTIAL, 2015 (US$ billion)</th>
<th>CAGR (%), 2009-2015 (approximate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green chemicals</td>
<td>62.3</td>
<td>5.3</td>
</tr>
<tr>
<td>Alcohols</td>
<td>62.0</td>
<td>5.3</td>
</tr>
<tr>
<td>Bio-plastic and plastic resins</td>
<td>3.6</td>
<td>23.7</td>
</tr>
<tr>
<td>Platform chemicals</td>
<td>4.0</td>
<td>12.6</td>
</tr>
<tr>
<td>Wood fibre composites</td>
<td>35.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Glass fibre market</td>
<td>8.4</td>
<td>6.3*</td>
</tr>
<tr>
<td>Carbon fibre</td>
<td>18.6</td>
<td>9.5</td>
</tr>
<tr>
<td>Revenues, Canadian forests product industry</td>
<td>50.0</td>
<td>Neg. or 0-2</td>
</tr>
</tbody>
</table>

**References:**

* CAGR for 2010-2015
MARKET CHARACTERISTICS
• Big volumes – low values
• Low volumes – high values
adapted from Estaban Chornet, November 2005
Markets: Additional Findings

**Overall:** We can not afford to wait – opportunity may pass us by through aggressive actions of others

**Bio-Fuels**
- The large-scale deployment of bio-fuels is expected to happen 2020-2030
- Political policies will play a key role in the size of the deployment

**Bio-Chemicals**
- Degree of hazard in petrochemicals is driving market toward green chemicals
There are three primary paths forward for the Canadian Pulp and Paper Industry.

- Advanced Textiles, Composites
- Power / Heat
- Refinery: Transportation Fuels, Chemicals
There are three primary paths forward for the Canadian Wood Products Industry.

- Building with Wood
- Living with Wood
- Transportation Fuels, Chemicals
BIOPATHWAYS ROADMAPS
BC INTERIOR
Top Performing Technologies

Return on Capital Employed

BC Central Interior

Cost of Capital = 11%

Note: Electricity sales at $150/MW
Pulp and Paper Roadmap – Option 1 Advanced Textiles / Composites BC Central Interior

Pulp & Paper

- Softwood Kraft
  - ROCE = 9.4%

- BCTMP Pulp¹
  - ROCE = (7%)

Pulp

- Dissolving Pulp
  - ROCE = 20.5%

- Fibre Reinforced Composites³
  - (eg. glass fibre)

- Traditional Papers²
  - ROCE = (14%) / 3.4%

- Commodity Pulps

- Reinforcement Pulps

- Transportation
  - Fuels, Chemicals, etc

- Advanced Textiles and Composites

- Commodity Papers

Notes:
1) BCTMP Pulp roadmaps options not examined
2) Newsprint / LWC
3) Not examined by Bio Pathways
Kraft Pulp (950,000 odt) 
ROCE = 9.4%

Large Scale Co-Gen 
ROCE = 5.5 / 10.7%\(^1,2\)

Large Scale CHP 
ROCE = 18.6 / 23.7%\(^1,3\)

Pyrolysis \(^4\) 
ROCE = 13.3%

Gasification 
ROCE = 10.1%

Notes:
1) First ROCE is based on Forest Residues / Second is based on Hog Fuel
2) At $150/MW then ROCE = 12.4%
3) At $150/MW then ROCE = 22.8%
4) Draft
Pulp and Paper Roadmap – Option 3 Refinery Pathways BC Central Interior

Kraft Pulp (950,000 odt) ROCE = 9.4%

Pyrolysis ROCE = 13.0%

Fermentation ROCE = -19.9%

Tall Oil

FT Diesel\(^3\) ROCE = 3% / 8%

Lignin ROCE = 12%

Full Fractionation ROCE = 8.6% (Viscose, Ethanol, Furfural, Lignin)

Incremental Chemicals (Methanol, Furfural, Lignin)

Gasification Ethanol / Acetate

ROCE = 11.6\(^{1}\)

ROCE = 16.3\(^{2}\)

Refinery / Chemical Plant

Transportation Fuels, Chemicals

Chemicals, Textiles, Composites

Notes:
1) Ethanol for Blending
2) Acetate to Market
3) Medium / Mega
Fermentation not included due to scale needed.
Building Materials - Wood Roadmap with ROCE Results
BC Central Interior

- SPF West Med\(^1\)  
  ROCE = 15%

- Nexterra N.G. Replacement  
  ROCE = 15.3%

- Living with Wood  
  ROCE = 18.0%

- Nexterra CHP\(^2\)  
  ROCE = 18.0%

- Pyrolysis\(^2,3\)  
  ROCE = 19.2%

- Pyrolysis  
  ROCE = 21.5%

- Gasification

- Incremental Chemicals

- Gasification

- CLT, EWP, Commodity Lumber
  CLT ROCE = 34.0%
  LVL ROCE = 18.0%

- Appearance grade products

- Power
  Power ROCE = 18.0%

- Power / Heat

- Transportation Fuels, Chemicals
  Refinery
  SynGas ROCE = 13.1%
  ROCE = 17.7%

Chemicals

Notes:
1) Based on 250 mmfbm facility, hog fuel imported to match scales.
2) Based on $150/MW
3) Draft Results
Bio Pathways Roadmaps

Results for Ontario
Top Performing Technologies

Return on Capital Employed

Ontario

Cost of Capital = 11%

Note: Contains Feed-In-Tariff estimate for pellets.
Pulp and Paper Roadmap – Option 1 Advanced Textiles / Composites Ontario

Kraft Pulp
ROCE = 12.1%

BCTMP Pulp\(^1\)
ROCE = (3%)

Dissolving Pulp
ROCE = 20.3%

Fibre Reinforced Composites\(^3\)
(eg. glass fibre)

Traditional Papers\(^2\)
ROCE = (9.5%) / 4.7%

Commodity Pulps

Reinforcement Pulps

Transportation Fuels, Chemicals, etc

Advanced Textiles and Composites

Commodity Papers

Notes:
1) BCTMP Pulp roadmaps options not examined
2) Newsprint / LWC
3) Not examined by Bio Pathways
Pulp and Paper Roadmap – Option 2 Power / Heat Pathways  Ontario

Kraft Pulp
(950,000 odt)
ROCE = 12.1%

Large Scale Co-Gen
ROCE = 6.8 / 13.2%

Large Scale CHP
ROCE = 18.0 / 24.4%

Pyrolysis
ROCE = 16.6%

Gasification
ROCE = 13.6%

Power / Heat

Notes:
1) First ROCE is based on Forest Residues / Second is based on Hog Fuel
2) Draft
Kraft Pulp (950,000 odt)  
ROCE = 12.1%

Pyrolysis  
ROCE = 16.7%

Fermentation  
ROCE = -19.9%

Tall Oil

FT Diesel  
ROCE = 1% / 5%

Lignin  
ROCE = 16.2%

Full Fractionation  
ROCE = 10.7%  
(Viscose, Ethanol, Furfural, Lignin)

Incremental Chemicals  
(Methanol, Furfural, Lignin)

Gasification  
Ethanol / Acetate

Oil

Fuel

Refinery / Chemical Plant

Transportation  
Fuels, Chemicals

Chemicals, Textiles, Composites

Notes:
1) Ethanol for Blending
2) Acetate to Market
3) Medium / Mega
Fermentation not included due to scale needed.
Building Materials - Wood Roadmap with ROCE Results

Ontario

Building with Wood
CLT ROCE = 36.6%
LVL = 20.0%

Living with Wood
ROCE = 21.0%

Nexterra CHP¹
ROCE = 18.1%

Pyrolysis¹,²
ROCE = 18.0%

Pyrolysis
ROCE = 23.7%

Gasification¹

Incremental Chemicals

CLT, EWP, Commodity Lumber

Appearance grade products

Power

Power / Heat

Oil

Refinery

Transportation Fuels, Chemicals

Gasification

SynGas

ROCE = 13.9%

ROCE = 18.9%

Notes:
1) Based on 250 mmfbm facility, hog fuel imported to match scales.
2) Draft Results
Bio Pathways Roadmaps

Results for Quebec
Return on Capital Employed

Quebec

Cost of Capital = 11%
Pulp and Paper Roadmap – Option 1 Advanced Textiles / Composites Quebec

Pulp & Paper

Kraft Pulp
ROCE = 12.1%

Commodity Pulps

Reinforcement Pulps

Dissolving Pulp
ROCE = 20.1%

Transportation Fuels, Chemicals, etc

Advanced Textiles and Composites

BCTMP Pulp\(^1\)
ROCE = (3%)

Fibre Reinforced Composites\(^3\)
(eg. glass fibre)

Commodity Papers

Pulp

Traditional Papers\(^2\)
ROCE = (9.5%) / 4.7%

Notes:
1) BCTMP Pulp roadmaps options not examined
2) Newsprint / LWC
3) Not examined by Bio Pathways
Pulp and Paper Roadmap – Option 2 Power / Heat Pathways  Quebec

Kraft Pulp (950,000 odt)  
ROCE = 12.1%

Large Scale Co-Gen
ROCE = 6.0 / 13.2%\(^1\)

Large Scale CHP
ROCE = 17.3 / 24.4%\(^1\)

Pyrolysis \(^2\)
ROCE = 16.6%

Gasification
ROCE = 13.6%

Notes:
1) First ROCE is based on Forest Residues / Second is based on Hog Fuel
2) Draft
Pulp and Paper Roadmap – Option 3 Refinery Pathways Quebec

Softwood Kraft Pulp (950,000 odt)  
ROCE = 12.1%

- Gasification
  Ethanol / Acetate
  ROCE = 15.1%

- Pyrolysis
  ROCE = 16.7%

- Fermentation
  ROCE = -19.9%

  Tall Oil

- FT Diesel
  ROCE = 0% / 5%

- Lignin
  ROCE = 16.2%

- Full Fractionation
  ROCE = 10.7%
  (Viscose, Ethanol, Furfural, Lignin)

- Incremental Chemicals
  (Methanol, Furfural, Lignin)

ROCE = 19.6%

Transportation Fuels, Chemicals

Notes:
1) Ethanol for Blending
2) Acetate to Market
3) Medium / Mega
Fermentation not included due to scale needed.
Notes:
1) Based on 250 mmfbm facility, hog fuel imported to match scales.
2) Draft Results
Provincial Comparisons
The overall impact on ROCE on pulp and paper pathways is generally less than on sawmill as sawmills save on residual transportation costs (as they are the source of residuals in most cases)

Larger scale pathways have the biggest impacts on the integrated facility. Regionally there are small differences between pathways with the exception of power applications where pricing policy impacts the results.

<table>
<thead>
<tr>
<th>Pathway</th>
<th>BC Central Interior</th>
<th>Ontario</th>
<th>Quebec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softwood Kraft</td>
<td>9.4</td>
<td>12.1</td>
<td>12.1</td>
</tr>
<tr>
<td>BC TMP</td>
<td>(7)</td>
<td>(3)</td>
<td>(3)</td>
</tr>
<tr>
<td>Dissolving Pulp</td>
<td>20.5</td>
<td>20.3</td>
<td>20.1</td>
</tr>
<tr>
<td>LWC</td>
<td>3.4</td>
<td>4.7</td>
<td>4.7</td>
</tr>
<tr>
<td>Newsprint</td>
<td>(14)</td>
<td>(9.5)</td>
<td>(9.5)</td>
</tr>
<tr>
<td>Large Scale Co-Gen¹</td>
<td>5.5 / 10.7</td>
<td>6.8 / 13.2</td>
<td>6.0 / 13.2</td>
</tr>
<tr>
<td>Large Scale CHP¹</td>
<td>18.6 / 23.7</td>
<td>18 / 24.4</td>
<td>17.3 / 24.4</td>
</tr>
<tr>
<td>Pyrolysis to Power</td>
<td>13.3</td>
<td>16.6</td>
<td>16.6</td>
</tr>
<tr>
<td>Gasification to Power</td>
<td>10.1</td>
<td>13.6</td>
<td>13.6</td>
</tr>
<tr>
<td>Pyrolysis Oil</td>
<td>13</td>
<td>16.7</td>
<td>16.7</td>
</tr>
<tr>
<td>Fermentation</td>
<td>(19.9)</td>
<td>(19.9)</td>
<td>(19.9)</td>
</tr>
<tr>
<td>FT Diesel²</td>
<td>3 / 8</td>
<td>1 / 5</td>
<td>0 / 5</td>
</tr>
<tr>
<td>Lignin</td>
<td>12</td>
<td>16.2</td>
<td>16.2</td>
</tr>
<tr>
<td>Full Fractionation</td>
<td>8.6</td>
<td>10.7</td>
<td>10.7</td>
</tr>
<tr>
<td>Gasification to Ethanol</td>
<td>11.6</td>
<td>15.1</td>
<td>15.1</td>
</tr>
<tr>
<td>Gasification to Acetate</td>
<td>16.3</td>
<td>19.6</td>
<td>19.6</td>
</tr>
</tbody>
</table>

Note:
1) Forest Residuals / Hog
2) FT Diesel Medium / Mega
## Building Materials Pathways

<table>
<thead>
<tr>
<th>Pathway</th>
<th>BC Central Interior</th>
<th>Ontario</th>
<th>Quebec</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPF Medium (West / East / East)</td>
<td>15</td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td>Gasification for Dry Kilns</td>
<td>15.3</td>
<td>17.2</td>
<td>18.7</td>
</tr>
<tr>
<td>Cross Laminated Timber</td>
<td>34</td>
<td>36.6</td>
<td>37.6</td>
</tr>
<tr>
<td>Laminated Veneer Lumber</td>
<td>18</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Living with Wood</td>
<td>18</td>
<td>21</td>
<td>22.6</td>
</tr>
<tr>
<td>Gasification CHP</td>
<td>18</td>
<td>18.1</td>
<td>18.2</td>
</tr>
<tr>
<td>Pyrolysis to Power</td>
<td>19.2</td>
<td>18</td>
<td>16.4</td>
</tr>
<tr>
<td>Pyrolysis to Oil</td>
<td>21.5</td>
<td>23.7</td>
<td>24.7</td>
</tr>
<tr>
<td>Gasification to Ethanol</td>
<td>13.1</td>
<td>13.9</td>
<td>14.7</td>
</tr>
<tr>
<td>Gasification to Acetate</td>
<td>17.7</td>
<td>18.9</td>
<td>19.6</td>
</tr>
</tbody>
</table>

The major swing within the roadmaps between the regions is the relative ranking of Pyrolysis to Power in BC, vis-à-vis the ranking of Living to Wood in Ontario and Quebec. Without the energy policies in BC (Carbon Tax, Carbon Credits, and Electricity Pricing) the relative ranking in the technologies would be the same with Living to Wood moving higher in the rankings.
## Provincial Best Bets

<table>
<thead>
<tr>
<th>BC Central Interior</th>
<th>Ontario</th>
<th>Quebec</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulp and Paper</strong></td>
<td><strong>Pulp and Paper</strong></td>
<td><strong>Pulp and Paper</strong></td>
</tr>
<tr>
<td>1. Large Scale CHP</td>
<td>1. Large Scale CHP</td>
<td>1. Large Scale CHP</td>
</tr>
<tr>
<td>2. Dissolving Pulp</td>
<td>2. Dissolving Pulp</td>
<td>2. Dissolving Pulp</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Building Materials</strong></th>
<th><strong>Building Materials</strong></th>
<th><strong>Building Materials</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. CLT</td>
<td>1. CLT</td>
<td>1. CLT</td>
</tr>
<tr>
<td>2. Pyrolysis to Oil</td>
<td>2. Pyrolysis to Oil</td>
<td>2. Pyrolysis to Oil</td>
</tr>
<tr>
<td>3. Pyrolysis to Power</td>
<td>3. Living with Wood</td>
<td>3. Living with Wood</td>
</tr>
</tbody>
</table>

- For Pulp and Paper pathways as long as the residuals are available for hog fuel prices, Combined Heat and Power applications seem to lead followed by higher value chemical production like dissolving pulp and acetate.
- For Building Materials the pathway starts with CLT and Pyrolysis to Oil and then depending on the power policy is either Pyrolysis to Power or moving more production to a Living with Wood focus.
The vision presented is partial and based on knowledge we have today.

Many other avenues must be explored:
- the development of industrial bio-technology for production of green specialty chemicals
- the enzyme sector (highly profitable), a sub-sector of the chemical sector, using modern bio-technologies in production
- pro-biotic bacteria (instead of antibiotics) in hygiene fiber products
- nano-cellulose – from salad dressing to bullet-proof jackets
How To Implement

• Increase engagement by industry and governments
• Communicate results and potential
• Explore partnerships
  – Different industry sectors
  – Governments and agencies
  – Academia and research organizations
• Mobilize finances
  – partnerships with financial industry and governments
  – Investing in Forest Industry Transformation (IFIT) generated overwhelming interest in the industry
• Transfer technologies
• Review institutional responsibilities
Overall Conclusions

- Great opportunities exist for the forest industry in Bio-pathways
- Business as usual will not work; hard work required by industry, governments, and affiliated sectors
- It’s hard to draw clear borders between Bio-pathways products and value added conventional forest products
- Therefore, the next step should be a general and broad value-added concept for the complete forest sector
APPENDIX 1
Phase II Findings: Bio-Energy

- Integrated CHP production in existing mills is a good first bioenergy step
- Production of heat and power and transportation fuels is economically viable in bio-refineries where high-value byproducts are also made, or feedstock is inexpensive
- Synthetic hydro-carbons are economically viable for production of bio-energy
- The scale of bio-energy deployment depends on bio-mass availability.
- The domestic market for bio-energy use is not well-developed
- There is lack of consistent policy framework for large-scale bio-energy demand and supply
Findings: Bio-Chemicals and Bio-Products

- Opportunities exist for developing new cellulose products
- Older, smaller scale pulp-mills can convert to production for bio-chemicals niche markets
- High-value bio-chemicals will start with multiple, small-niche markets and the old mill conversion can be an interim solution until markets have developed and big efficient mills can be established
- Integrated lignin extraction and NBSK pulp-mills is already an available alternative for adding revenues to pulp-mills
- Hemi-cellulose streams in the pulp-mills can now produce new chemicals for niche markets with high prices
- There are many small market applications of bio-products, e.g., replacement of glass or other fibers in fiber-reinforced composites
- Integration of bio-refineries with pulp- and saw-mills is essential to ensure high revenues from small streams
Phase II Findings: Bio-Materials (Wood)

- Analysis confirmed integration of traditional lumber and panel productions with new bio-products is key for success of both traditional and new products.
- A strong future economic outlook exists for lumber through innovation, agility, and customer alignment.
- Wood products industries have great opportunities with new building and prefabricated systems.
- The non-residential construction market is a large-scale opportunity with the right products and systems.
- The repair renovation market is huge with right products and systems.
- Ultra-low density insulation and packaging are good possibilities.
Markets: A Chemical Example

- The world’s largest chemical industry is SABIC – Saudi Basic Industries Corporation
  - Expanding in specialty chemicals
  - Buying companies in the field of poly-carbonate, poly-methane, polyamid, synthetic rubber, foams, spandex-fibers, etc.
  - Targeting products for cars, aeroplanes, boats, textiles, etc.
  - Aiming at 20-25% of the world market of poly-carbonate, ethanol, propylene, and methanol

- During 2009-2011 some US $ 70 billion will be invested in chemical production in Saudi Arabia alone
- Doesn’t leave much room for investments in other places – risk of over-capacities
There are three primary paths forward for the Canadian Pulp and Paper Industry.

- Advanced Textiles, Composites
- Power / Heat
- Transportation Fuels, Chemicals
Pulp and Paper Roadmap – Option 1
Advanced Textiles / Composites

Kraft Pulp
ROCE = 9.4%

BCTMP Pulp\(^1\)
ROCE = (7%)

Commodity Pulps

Dissolving Pulp
ROCE = 19.5%

Fibre Reinforced Composites\(^3\)
(eg. glass fibre)

Traditional Papers\(^2\)
ROCE = (14%) / 3%

Reinforcement Pulps

Transportation Fuels, Chemicals, etc

Advanced Textiles and Composites

Commodity Papers

Notes:
1) BCTMP Pulp roadmaps options not examined
2) Newsprint / LWC
3) Not examined by Bio Pathways

All Data BC Normalized with Power at $150/MWh
Pulp and Paper Roadmap – Option 2
Power / Heat Pathways

Kraft Pulp (950,000 odt)
ROCE = 9.4%

Large Scale Co-Gen
ROCE = 5.5 / 10.7%¹

Large Scale CHP
ROCE = 18.6 / 22.8%¹

Pyrolysis ²
ROCE = 13.3%

Gasification
ROCE = 10.1%

Power / Heat

Notes:
1) First ROCE is based on Forest Residues / Second is based on Hog Fuel
2) Draft

All Data BC Normalized with Power at $150/MWh
Pulp and Paper Roadmap – Option 3
Reefinery Pathways

Kraft Pulp
(950,000 odt)
ROCE = 9.4%

- Gasification
  Ethanol / Acetate
  ROCE = 13%

- Pyrolysis
  ROCE = 13%

- Fermentation
  ROCE = -19.9%

- Tall Oil

- FT Diesel
  ROCE = 3% / 8%

- Lignin
  ROCE = 12%

- Full Fractionation
  ROCE = 8.6%
  (Viscose, Ethanol, Furfural, Lignin)

- Incremental Chemicals
  (Methanol, Furfural, Lignin)

- Refinery / Chemical Plant
  ROCE = 11.6%

- Transportation
  Fuels, Chemicals

- Chemicals, Textiles, Composites

Notes:
1) Ethanol for Blending
2) Acetate to Market
3) Medium / Mega

All Data BC Normalized with Power at $150/MWh
Carbon Footprint Analysis

Source: Carbon Footprint Report, 2010
### Combined Metrics of Pulp and Paper Pathways

<table>
<thead>
<tr>
<th>Pathway</th>
<th>ROCE</th>
<th>GDP ($M) / 100,000 ODT</th>
<th>Employment (FTE) / 100,000 ODT</th>
<th>Direct CO2e (kt) / 100,000 ODT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Textiles and Composites</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kraft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commodity Pulp</td>
<td>9.4%</td>
<td>20</td>
<td>163</td>
<td>13.8</td>
</tr>
<tr>
<td>Dissolving Pulp</td>
<td>19.5%</td>
<td>36</td>
<td>226</td>
<td>23.7</td>
</tr>
<tr>
<td>BCTMP</td>
<td>(7.4%)</td>
<td>34</td>
<td>284</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Paper</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newsprint</td>
<td>(14%)</td>
<td>36</td>
<td>347</td>
<td>12.3</td>
</tr>
<tr>
<td>LWC</td>
<td>3%</td>
<td>35</td>
<td>253</td>
<td>13.1</td>
</tr>
<tr>
<td><strong>Power / Heat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kraft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Co-Gen¹</td>
<td>10.7%</td>
<td>24</td>
<td>193</td>
<td>0</td>
</tr>
<tr>
<td>Large CHP¹</td>
<td>22.8%</td>
<td>30</td>
<td>193</td>
<td>7.954</td>
</tr>
<tr>
<td>Pyrolysis</td>
<td>13.3%</td>
<td>23</td>
<td>166</td>
<td>0</td>
</tr>
<tr>
<td>Gasification</td>
<td>10.1%</td>
<td>22</td>
<td>165</td>
<td>0</td>
</tr>
<tr>
<td><strong>Refinery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kraft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasification - Ethanol</td>
<td>11.6%</td>
<td>22</td>
<td>165</td>
<td>0</td>
</tr>
<tr>
<td>Gasification - Acetate</td>
<td>16.3%</td>
<td>25</td>
<td>170</td>
<td>0</td>
</tr>
<tr>
<td>Pyrolysis</td>
<td>13.0%</td>
<td>22</td>
<td>165</td>
<td>0</td>
</tr>
<tr>
<td>Fermentation</td>
<td>(19.9%)</td>
<td>12</td>
<td>180</td>
<td>4.5</td>
</tr>
<tr>
<td>FT Diesel (Medium)</td>
<td>3%</td>
<td>20</td>
<td>144</td>
<td>N/A</td>
</tr>
<tr>
<td>Lignin</td>
<td>12%</td>
<td>22</td>
<td>165</td>
<td>17.5</td>
</tr>
<tr>
<td>Full Fractionation</td>
<td>8.6%</td>
<td>23</td>
<td>130</td>
<td>6.993</td>
</tr>
</tbody>
</table>

Notes:  
1) ROCE based on hog fuel input.  
All Data BC Normalized with Power at $150/MWh
Fermentation not included due to scale needed.
Building Materials – Example Roadmap
BC Central Interior

Notes:
1) Based on 250 mmfmb facility, hog fuel imported to match scales.
2) Based on $150/MW
3) Draft Results
All Data BC Normalized with Power at $150/MWh
## Combined Metrics of Building Materials Pathways

<table>
<thead>
<tr>
<th>Pathway</th>
<th>ROCE</th>
<th>GDP ($M) / 100,000 ODT</th>
<th>Employment (FTE) / 100,000 ODT</th>
<th>Direct CO2e (kt) / 100,000 ODT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building With Wood</strong></td>
<td>SPF West Med</td>
<td>SPF West Med</td>
<td>15%</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>CLT</td>
<td>34%</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>LVL Large</td>
<td>18%</td>
<td>48.5</td>
<td>362</td>
</tr>
<tr>
<td><strong>Living with Wood</strong>¹</td>
<td>SPF West Med</td>
<td>SPF West Med</td>
<td>18%</td>
<td>26</td>
</tr>
<tr>
<td><strong>Fuels and Chemicals</strong></td>
<td>SPF West Med</td>
<td>N.G Replacement</td>
<td>15.3%</td>
<td>25.1</td>
</tr>
<tr>
<td></td>
<td>Gasification to CHP</td>
<td>18%</td>
<td>28.5</td>
<td>202</td>
</tr>
<tr>
<td></td>
<td>Pyrolysis to Power</td>
<td>19.2%</td>
<td>31.7</td>
<td>186</td>
</tr>
<tr>
<td></td>
<td>Pyrolysis to Oil</td>
<td>21.5%</td>
<td>30.4</td>
<td>203</td>
</tr>
<tr>
<td></td>
<td>Gasification to Ethanol</td>
<td>13.1%</td>
<td>31.7</td>
<td>221</td>
</tr>
<tr>
<td></td>
<td>Gasification to Acetate</td>
<td>17.7%</td>
<td>33.9</td>
<td>221</td>
</tr>
</tbody>
</table>

**Note:**

1) Living Direct CO2 emissions per 100,000 odt are assumed to be the same as SPF West Med

All Data BC Normalized with Power at $150/MWh
Metrics Summary

Pulp and Paper Pathways (clusters built on Pulp Mill sites):
• On average when a new technology is added to an existing pulp mill site we see an improvement in ROCE (average 3.7%), and improvement in contribution to GDP (10-25%) and employment (1-4%). The Heat and Power options often have stronger social metrics as the scale of the plants are larger than some of the more profitable Fuel and Chemical pathways.

Building Material Pathways (clusters built on Sawmill site):
• New technology options for sawmill improve all the social metrics with the largest impacts coming from transforming the Building with Wood section. CLT specifically has a very large impact and the Fuels and Chemicals option also have strong performance and have the added benefit of drawing down the carbon footprint for the facility.
• There are trade offs in the metrics by shifting from conventional to bio-pathways production
Trade-Offs
Building Materials - Wood Roadmap

Building with Wood / Living with Wood

Building Materials Industry

Building with Wood
- Commodity
- Customer Focused Grades
- Panels
- Engineered Wood Products

Living with Wood
- Floors / Moulding
- Doors
- Windows
- Furniture

- Distributor
- Systems / Components
- Prefab

Home Builder / Non Residential / R&R
Home Building Value Chain

Operating Margin Analysis (%)

-5% 0% 5% 10% 15% 20% 25% 30% 35%

Timber Building Materials Distributors Components Home Builders

2009 Five Year Average 2007 Five Year Average 2009 Ten Year Average
Home Building Value Chain

Operational Margin Analysis (%)
Five Year Average ending in 2007

- Timber: 35%
- Building Materials: 10%
- Distributors: 5%
- Components: 20%
- Home Builders: 7.5%
Reviewing Cluster Options

Solid Wood Industry

Building with Wood
Living with Wood

Nexterra N.G. Replacement

Wood Markets

CHP
Nexterra

Power
Heat

Advanced Composites / Textiles Market

Pulp and Advanced Fibres
Advanced Papers, Packaging

Max Traditional Energy

Max Traditional Energy

Cdn Pulp & Paper Industry

Pyrolysis
Tall Oil
Gasification
Fermentation

Refinery

Transportation
Fuels,
Chemicals

Incremental Chemicals
(Methanol, Furfural, Lignins)

Build Economics for each Step
Refinery Capacity

Gasification
Ethanol = 42,000,000 litres or 264,172 barrels or
Refinery Capacity needed: 0.75

Pyrolysis
Fuel Oil = 83,000,000 litres or 523,941 barrels
Refinery Capacity needed: 1.5

The capacity of existing refineries would not be significantly challenged by additional production of ethanol from gasification or oil from Pyrolysis.
Refinery Capacity vis-à-vis Lumber and Paper Capacity

- Six key regions overlap the Petroleum industry including:
  - BC Vancouver (55,000 barrels / day)
  - BC Prince George (12,000 barrels / day)
  - AB Edmonton (412,000 barrels / day)
  - SK Lloydminster (111,000 barrels / day)
  - ON Thunder Bay / Sarnia (360,000 barrels / day) – barged from Thunder Bay
  - QC Montreal (491,000 barrels / day)
- Key players identified in the Petroleum industry with overlapping capacity include:

<table>
<thead>
<tr>
<th>Sawmilling</th>
<th># of Facilities</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC Vancouver</td>
<td>30</td>
<td>1,483,000 mfbm</td>
</tr>
<tr>
<td>BC Prince George</td>
<td>11</td>
<td>2,330,000 mfbm</td>
</tr>
<tr>
<td>AB Edmonton</td>
<td>14</td>
<td>1,780,000 mfbm</td>
</tr>
<tr>
<td>SK Lloydminster</td>
<td>3</td>
<td>127,000 mfbm</td>
</tr>
<tr>
<td>ON Thunder Bay</td>
<td>3 (closed 2009)</td>
<td></td>
</tr>
<tr>
<td>ON Sarnia</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pulp &amp; Paper</th>
<th># of Facilities</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC Vancouver</td>
<td>12</td>
<td>3,500,000 admt</td>
</tr>
<tr>
<td>BC Prince George</td>
<td>15</td>
<td>4,800,000 admt</td>
</tr>
<tr>
<td>AB Edmonton</td>
<td>5</td>
<td>1,900,000 admt</td>
</tr>
<tr>
<td>SK Lloydminster</td>
<td>1(1)</td>
<td>385,000 admt</td>
</tr>
<tr>
<td>ON Thunder Bay</td>
<td>3</td>
<td>1,100,000 admt</td>
</tr>
<tr>
<td>ON Sarnia</td>
<td>8</td>
<td>1,000,000 admt</td>
</tr>
</tbody>
</table>
The Pyrolysis Pathway has been a strong option for providing fuels and chemicals. There are technical challenges to overcome but there may be further synergistic options for the Forest and Paper Industry.

The primary issue with using pyrolysis oil in a further refinery pathway is the high oxygen content in the oil. This problem is being addressed by hydro-cracking / hydro-processing the pyrolysis oil. This means hydrogen is added to the oil to make it compatible with heavy oil being fed into existing refinery operations, an approach being taken by UOP/Ensyn and the BioCoup program in Europe.

As a result, Hydrogen capacity is a key to upgrading the pyrolysis oil. Hydrogen is available from several sources including production from refineries, electrolysis of water, and gasification. One of the critical uses of hydrogen is for upgrading non traditional oil such as oil from Canadian Tar Sands.

If there is excess hydrogen at an existing refinery, there is a synergistic fit between upgrading pyrolysis oil at that refinery.
In the case of no hydrogen availability then there are two options that provide synergistic fits with the forest industry.

- Gasification of Biomass
- Hydrogen capture from Sodium Chlorate production

**Gasification of Biomass:**

- Several research institutes including the US DOE are researching the production of hydrogen via gasification. One goal is to provide a distributed hydrogen production infrastructure to support future use of fuel cells. However technical challenges remain.
- As the challenges are addressed, there are opportunities for the existing industry to produce hydrogen
Hydrogen Capture from Sodium Chlorate:

- Another option that is currently technically available is capture of hydrogen from the production of sodium chlorate. This is now being done at the sodium chlorate plant in North Vancouver.
- Sodium Chlorate production is primary for the bleaching of wood fibre and is closely coupled in location to the pulp and paper industry.

### PRODUCERS AND CAPACITIES - SODIUM CHLORATE - THOUSANDS OF SHORT TONS - 2006

#### UNITED STATES:

<table>
<thead>
<tr>
<th>PRODUCER</th>
<th>LOCATION</th>
<th>CAPACITY</th>
<th>PRODUCER</th>
<th>LOCATION</th>
<th>CAPACITY</th>
</tr>
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<tbody>
<tr>
<td>Eka Chemicals</td>
<td>Columbus, MS</td>
<td>219</td>
<td>Kemira</td>
<td>Eastover, SC</td>
<td>60</td>
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<tr>
<td>Eka Chemicals</td>
<td>Moses Lake, WA</td>
<td>63</td>
<td>Kerr-McGee</td>
<td>Hamilton, MS</td>
<td>138</td>
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<tr>
<td>Erco Worldwide</td>
<td>Valdosta, GA</td>
<td>110</td>
<td>Other Integrated</td>
<td>Captive Producers</td>
<td>97</td>
</tr>
<tr>
<td>Kemira</td>
<td>Augusta, GA</td>
<td>145</td>
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</table>

**TOTAL UNITED STATES**: 862

#### CANADA:

<table>
<thead>
<tr>
<th>PRODUCER</th>
<th>LOCATION</th>
<th>CAPACITY</th>
<th>PRODUCER</th>
<th>LOCATION</th>
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<tr>
<td>BC Chemical</td>
<td>Prince George, BC</td>
<td>70</td>
<td>Erco Worldwide</td>
<td>Bruderheim, Alba</td>
<td>82</td>
</tr>
<tr>
<td>Canexus</td>
<td>Beauharnois, Que.</td>
<td>48</td>
<td>Erco Worldwide</td>
<td>Hargrave, Man.</td>
<td>44</td>
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<tr>
<td>Canexus</td>
<td>Brandon, Man.</td>
<td>260</td>
<td>Erco Worldwide</td>
<td>Saskatoon, Sask</td>
<td>55</td>
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<td>Canexus</td>
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<td>77</td>
<td>Erco Worldwide</td>
<td>Buckingham, Que.</td>
<td>140</td>
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<td>Canexus</td>
<td>Nanaimo, BC</td>
<td>18</td>
<td>Erco Worldwide</td>
<td>N. Vancouver, BC</td>
<td>100</td>
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<tr>
<td>Domtar</td>
<td>Lebel-Sur-Quevi, ON</td>
<td>25</td>
<td>Erco Worldwide</td>
<td>Grand Prairie, Alba</td>
<td>55</td>
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<tr>
<td>Eka Chemicals</td>
<td>Magog, Que.</td>
<td>185</td>
<td>PCI Canada</td>
<td>Dalhousie, Que.</td>
<td>21</td>
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<tr>
<td>Eka Chemicals</td>
<td>Valleyfield, Que.</td>
<td>125</td>
<td>St. Anne Chem.</td>
<td>Nackawic, NB</td>
<td>11</td>
</tr>
</tbody>
</table>

**TOTAL CANADA**: 1299
Revised Refinery Cluster based on Sodium Chlorate - Upgrader at Pulp Mill Site

Unmodified Pyrolysis Oil

Pyrolysis Plant
  Sawmill

Pyrolysis Plant
  Sawmill

Pyrolysis Plant
  Pulp Mill
  Sodium Chlorate
  Pyrolysis Oil Upgrader
  Hydrogen

Modified Pyrolysis Oil

Refinery
  (Hydrogen Deficient)

Pyrolysis Oil Upgrader

Refinery
  (Hydrogen Surplus)
Revised Refinery Cluster based on Gassi-fied Biomass - Upgrader at Sawmill Site

- Pyrolysis Plant
  - Sawmill
- Pyrolysis Plant
  - Sawmill
- Pyrolysis Plant
  - Sawmill
  - Biomass Gasifier
  - Pyrolysis Oil Upgrader
- Hydrogen

Unmodified Pyrolysis Oil

Modified Pyrolysis Oil

Refinery (Hydrogen Deficient)

Pyrolysis Oil Upgrader

Refinery (Hydrogen Surplus)
Refinery Integration – Furthering The Pyrolysis Pathway (3)

- Even with technical hurdles for moving down the Fuels and Chemicals roadmap there are synergistic options with the existing industry;
  - in a pulp and paper facility through a hydrogen source such as sodium chlorate or biomass gasification,
  - or in a sawmill through a hydrogen source such as biomass gasification.
- The technical hurdles don’t however rule out the pyrolysis pathway as heat and power options can still be exercised.
- Key to the long term success of this roadmap will be partnerships with the petroleum industry.
Calculations for Integrated Bio-pathways

- Pulp and Paper
  - Heat and Power (9.4% - 22.8%)
  - Refinery Paths (11.6% - 16.3%)

- Building Materials
  - Heat and Power (15.3% - 19.2%)
  - Refinery Paths (13.1%-21.5%)
  - Building Systems (18% - 34%)

- Most of the value is from upgrading the value of non chip residuals
Ideas for Innovation System
Support Program for Bio-pathways Production (1)

**Market and strategic analyses of Bio-pathways products**

**Pulp & Paper**

- Transform old mills into bio-refineries
- Develop pathways for chemicals, fuels and polymers from sugar and lignin
- Develop efficient separation technologies of wood into valuable components
- Develop new composites of cellulose materials and inorganic materials
- Develop nano-technologies for wood fibers
- Improve performance/weight ratio
Support Program for Bio-pathways Production (2)

Market and strategic analyses of Bio-pathways products

Wood Products

- Investigate technologies from other sectors
- Develop building systems
- Investigate wood properties
- Develop composites
- Increase durability
- Improve performance/weight ratio
The Complete Industry Value Chain

Source: Agenda 2020 Technology Alliance, 2010