Biofuels and Biochemicals: Investment Opportunities?

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CanmetENERGY, Natural Resources Canada

Bioenergy II – Fuels and Chemicals from Renewable Resources
CanmetENERGY (Natural Resources Canada) assists industry to develop cleaner, energy-efficient and cost-effective biomass conversion processes.

The Biomass & Renewables Group focuses on optimizing the performance of biomass energy technologies and developing new products and technologies for sustainable development.
How do you select the technology/research in which to invest?
Difficult Financial Times

Forest Industry Commodity Prices Very Weak

Source: Don Roberts, CIBC World Markets Inc
The world economy may be weak but public support for environmentally (GHG) friendly technologies is strong.

Technological breakthroughs are emerging that will allow the “biomass” industry to take advantage of new markets for a broad array of new “biofuels” and “biochemicals”.

Systematic analysis is needed to identify the most promising “bioproducts” and their economic and environmental impacts with a view to investment opportunities.
Inquiry Tree

- Assess the status of emerging bio-fuels and bio-chemicals technologies
- Assess the potential to secure biomass feedstock at a reasonable price
- Assess economic return potential
Unit Operations

Thermochemical processes
- Combustion
- Gasification
- Pyrolysis

Biochemical processes
- Sugar fermentation
- Methane fermentation
- Syngas fermentation

Chemical processes
- Chemical reactions
- Catalytic Processes
- Esterification
- Hydrogenation
- Hydrolysis
- Methanisation
- Steam reforming
- Electrolysis
- Water gas shift

Thermal/Mechanical/Physical processes
- Drying
- Comminution
- Extraction
- Fiber separation
- Mechanical fractionation
- Pressing
- Separation
- Upgrading
- Distillation
Ethanol Pathways (Starch)

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START
Ethanol (Future) Pathways

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Assess Biomass Opportunities

Thermochemical processes
Chemical processes
Thermal/Mechanical/Physical
Biochemical processes

Energy & Fuels
Structural Materials
Fibre-based Materials
Chemicals
Food
Assess Investment Opportunities

Buy Low → Sell High

Thermochemical processes
Chemical processes
Thermal/Mechanical/Physical
Biochemical processes

Energy & Fuels
Structural Materials
Fibre-based Materials
Chemicals
Food

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“The Future is Bio-Plastics”
Benefits of “Bio-Plastics”

- Reduced CO2 emissions
- Commonly bio-degradable
- Benefit to rural economy
- Enhanced properties (composites)
Bio-Plastics

The common types of bio-plastics are based on cellulose, starch, polylactic acid (PLA), poly-3-hydroxybutyrate (PHB), and polyamide 11 (PA11).

Cellulose-based plastics are usually produced from wood pulp and used to make film-based products such as wrappers and to seal in freshness in ready-made meals.

PLA is a transparent plastic whose characteristics resemble common petro-plastics such as polyethylene and polpropylene. PLA is produced from the fermentation of starch from crops, most commonly corn starch, into lactic acid that is then polymerised.

PHB is very similar to polylpropylene, which is used in a wide variety of fields including packaging, ropes, bank notes and car parts.

PA 11 is derived from vegetable oil and is known under the tradename Rislan. It is prized for its thermal resistance that makes it valued for use in car fuel lines, pneumatic air brake tubing, electrical anti-termite cable sheathing and oil and gas flexible pipes and control fluid umbilicals.
Plant-based Chemicals

U.S. agriculture and forestry, plant-based sources cannot automatically shoulder a major share of our chemical feedstock demand. Today, U.S. industry only makes minor portions of some classes of chemical products from plant-derived materials.

Important scientific and commercial development breakthroughs are needed. Petrochemicals, agriculture, forestry, and other industries—as well as government—must make major coordinated efforts to most effectively increase the use of plant-derived chemicals.

“THE TECHNOLOGY ROADMAP FOR PLANT/CROP-BASED RENEWABLE RESOURCES 2020” U.S.
Global Chemical Industry

( >$1,500 billion)

R&D:
Dow Chemical
BASF
P&G
Solvay
Toyota….

“THE TECHNOLOGY ROADMAP FOR PLANT/CROP-BASED RENEWABLE RESOURCES 2020” U.S.
Investment Potential

PLA production costs estimated at $1.5 – 3 per kg

Fossil Fuel Polyethylene price is $1.70 per kg

Polypropylene price is $1.30 per kg
Ethanol
Cellulosic Ethanol Pilot Plant: 260,000 Gal/yr
Cost of Straw Feedstock

- Harvesting, storage, collection and transportation cost range between $28 to $41/tonne
- Add in the cost of procurement of the straw ($5 - $25 per tonne) and the final cost to plant could be $33 to $66/tonne
Cost of feedstock is usually negative
Large-scale chemical and biochemical conversion processes require consistent standardized homogeneous feed.

Strict fuel requirements make it difficult to “Buy Low” if you cannot take advantage of opportunity or heterogeneous waste fuels.

Thermochemical (as opposed to biochemical) conversion is more suited to take advantage of non-homogeneous feedstocks.
Thermochemical Pathways

Gasification and Pyrolysis can accommodate a range of feedstocks and produce a range of biofuels and biochemistries.
# Pyrolysis and Gasification

<table>
<thead>
<tr>
<th>Mode</th>
<th>Conditions</th>
<th>Liquid</th>
<th>Char</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast pyrolysis</td>
<td>Moderate temperature, short residence time</td>
<td>75%</td>
<td>12%</td>
<td>13%</td>
</tr>
<tr>
<td>Slow Pyrolysis</td>
<td>Low temperature, very long residence time</td>
<td>30%</td>
<td>35%</td>
<td>35%</td>
</tr>
<tr>
<td>Gasification</td>
<td>High temperature, long residence time</td>
<td>5%</td>
<td>10%</td>
<td>85%</td>
</tr>
</tbody>
</table>

A.V. Bridgwater
Product(s) Yield as f(Temperature)

X. Wang et al 2006
Biochar

- Pyrolysis produces charcoal, “which is called biochar when buried in the ground… Carbon from the waste biomass is retained in biochar and permanently sequestered in the soil, effectively removing that carbon from the atmosphere. The carbon in a ton of biochar is equivalent to 3 to 3.5 tons of CO2. Biochar is not only a carbon sink, it increases soil fertility—increasing cat-ion exchange and water retention capacity in soils, while reducing nutrient leaching and providing a "coral reef" for soil microorganisms—thereby significantly increasing productivity and crop yield.”

http://www.biocharengineering.com/
Charcoal

- Charcoal is “brittle” and not “plastic” – pyrolysis breaks down the hemicellulose matrix and depolymerizes cellulose

- Heating Value 28-32 MJ/kg

- Energy Density 9-11 GJ/m³
Charcoal: Co-firing with Coal

OPG & Responsible Fuel Sourcing

- Will not use food crops
- Wood fuel must be from sustainable harvest practices
- Keep watch on new developments
- Biomass obtained with minimal impact on consumers and existing resource users

Ontario Power Generation has just issued a Request for Proposal to supply 2 million tonnes of biomass per year for co-firing with coal within 2 years – PELLETS ONLY PLEASE!
Torrefaction

- As is the case for charcoal, Torrefied wood pulverizes easily
- Heating value is 19-24 MJ/kg (vs 18-20 for wood)
- Energy density is 15-18 GJ/m3 (vs 8-10 for wood)
- Torrefaction yield > 80%
- Dry fuel
- Does not absorb water
- Water-proof high energy pellets?
Pyrolysis Extracts/Byproducts Promise

Agritherm
Ensyn
Dynamotive
ABRI
Alterna
Organic Power
Titan

Food Flavoring

Activated Carbon

Bio-Fuel

Resins
Biomass Pyrolysis

Pyrolysis is the process to make organic liquid fuel (termed “bio-oil”) and/or charcoal by exposure of biomass to temperatures in excess of 350ºC in the absence of oxygen.

Pyrolysis increases fuel density (>1200 kg/m3) and facilitates fuel transport and handling.

“Bio-oil” is NOT OIL but mixture of alcohols, aldehydes, ketones, esters and specialty chemicals...characterization of the “oil” is still an urgent need.

Scale-up continues to be a significant challenge and few plants greater than 100 t/d capacity.
Potential Pyrolysis Chemicals

- Levoglucosan
- Acetic Acid
- Acetaldehyde
- Furfural
- Ethanol
- Formaldehyde
- Phenol
- Propionic Acid
- Formic Acid
- Acetone
- Pharmaceuticals ($ > 10^4$ per kg)
## Composition of Bio-Oil (mass fractions)

<table>
<thead>
<tr>
<th>Class of compound</th>
<th>White Spruce</th>
<th>Poplar</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Saccharides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oligosaccharides</td>
<td>--</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>0.01</td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td>Other monosaccharides</td>
<td>0.03</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Levoglucosan</td>
<td>0.06</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>1,6 anhydroglucofuranose</td>
<td>--</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Anhydrosugars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,6 anhydroglucofuranose</td>
<td>--</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Aldehydes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glyoxal</td>
<td>0.04</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Methylglyoxal</td>
<td>--</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>--</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>--</td>
<td>0.0003</td>
<td></td>
</tr>
<tr>
<td>Hydroxyacetaldehyde</td>
<td>0.12</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Ketones</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methanol</td>
<td>0.02</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Ketalsalcohol</td>
<td>0.02</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Alcohol</td>
<td>0.02</td>
<td>0.002</td>
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</tr>
<tr>
<td>Acetic acid</td>
<td>0.06</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Carboxylic acids</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formic acid</td>
<td>0.11</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Water-Soluble – Total Above</td>
<td>0.52</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Pyrolytic Lignin</td>
<td>0.31</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Unaccounted mass</td>
<td>0.17</td>
<td>0.23</td>
<td></td>
</tr>
</tbody>
</table>

Source: R.C. Brown
Biomass

Air

GASIFICATION
850°C
About 1/3 amount of air/oxygen needed for combustion

Char & Ash

Syngas
Carbon Monoxide (CO) & Hydrogen (H2)
Gasification Potential

- Syngas Cleaning
- Gasification
- Synthesis

Products:
- Methanol
- Dimethyl Ether (DME)
- Fischer-Tropsch Fuels
- Hydrogen

General Flow:
- Syngas
- Power
Nexterra

Enerkem

13,000 tonnes /y
Gasification for Combined Heat & Power

Fixed bed gasifier (Updraft & Downdraft)

Many demonstrations - availability generally <75%
Harboore, Denmark intermittent operation since 2000
4 to 8 million euros per MWe
Electricity costs >20 eurocents per kWh

Fluidized bed

Commercial for Co-firing (e.g. Lahti)
Operating experience >60,000 hours Gussing, Austria
3 to 5 million euros per MWe
Electricity costs 10-14 eurocents per kWh
Let's invest in a gasifier at a pulp mill! We can make power and chemicals and ethanol etc...

Pulp mills = 80% of bioenergy use in Canada

Pulp mills have experience with biomass handling etc
Converted Value of Wood

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
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<tr>
<td>PELLETS, HEAT</td>
<td>$6/GJ</td>
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<tr>
<td>POWER</td>
<td>9¢/kWh</td>
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<tr>
<td>CHP</td>
<td>80%</td>
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1 DRY TONNE INPUT

$86
$124
$181

Note: All financial figures in this presentation are based on value of products only; no value is currently assigned to wood input or process modifications.
High Efficiency - BIGCC

Biomass Integrated Gasifier Combined Cycle
### Converted Value of Wood

<table>
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<th>Service</th>
<th>Price $/GJ</th>
<th>Value $</th>
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<td>Pellets, Heat</td>
<td>$6</td>
<td>$86</td>
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<tr>
<td>Power @ 9¢/kWh</td>
<td></td>
<td>$124</td>
</tr>
<tr>
<td>CHP @ 80%</td>
<td></td>
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</tr>
<tr>
<td>Syngas @ $10/GJ</td>
<td></td>
<td>$143</td>
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<tr>
<td>BIGCC (CHP)</td>
<td></td>
<td>$230</td>
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Westbury demonstration plant will treat 12,000 tonnes of biomass-rich residues per year and produce 4 million litres of alcohols per year.
Converted Value of Wood

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<td>Ethanol @ $.45/litre</td>
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Converted Value of Wood

- **PELLETS, HEAT @ $6/GJ**: $86
- **POWER @ 9 ¢/kWh**: $124
- **CHP @ 80%**: $181
- **SYNGAS @ $10/GJ**: $143
- **BIGCC (CHP)**: $230
- **Ethanol @ $.45/litre**: $158
- **Pulp @ $800/t**: $320
Bioenergy Scenario 1 (Current Mill)

Generic Pulp Mill

1 DRY TONNE INPUT

Kiln NG: 1 GJ

Power: 120 kWh

0.4 tonnes Pulp $320

Value of Products: $296 / tonne of wood input

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Bioenergy Scenario 2 (BIGCC)

Pulp Mill with BIGCC (Just Enough Power to be Self-Sufficient)

1.16 DRY TONNE INPUT

Power: 165 kWh

Kiln NG: 0 GJ

Power: 0 kWh

0.4 tonnes Pulp $320

Value of Products: $289 / tonne of wood input
Bioenergy Scenario 3 (Large BIGCC)

Pulp Mill with Large BIGCC (Become Power Producer)

1.28 DRY TONNE INPUT

Power: 800 kWh

Kiln NG: 0 GJ

Power: 0 kWh

0.4 tonnes Pulp $320

Value of Products: $306 / tonne of wood input

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Bioenergy Scenario 4 (BIGCC + Ethanol)

Pulp Mill with Large BIGCC and Ethanol instead of Power

1.28 DRY TONNE INPUT

Ethanol: 105 litres

0.4 tonnes Pulp $280

Value of Products: $265/ tonne of wood input

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# Assumptions: Expected Conversion Efficiencies/Costs

<table>
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<tr>
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<th>Unit Price</th>
<th>Conversion Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulp Production</strong></td>
<td>$/tonne 800</td>
<td>Pulp % per tonne of wood 45</td>
</tr>
<tr>
<td><strong>SYNGAS GJ</strong></td>
<td>$/GJ 10</td>
<td>Efficiency of gasification 75</td>
</tr>
<tr>
<td><strong>Ethanol</strong></td>
<td>0.45</td>
<td>Litres per tonne of wood (gasification) 350</td>
</tr>
<tr>
<td><strong>Power from Syngas (CC)</strong></td>
<td>9</td>
<td>Electrical Efficiency 40</td>
</tr>
<tr>
<td><strong>Combined Heat and Power From Syngas</strong></td>
<td></td>
<td>Overall Efficiency 40</td>
</tr>
<tr>
<td>Power</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Heat</td>
<td>6</td>
<td></td>
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Bioenergy Opportunities: Summary

- **Biomass Pathways**
  There are a multitude of pathways and selecting one for investment requires careful evaluation including long term supply (at specific cost), sustainability and life cycle analysis

- **Pulp Mills Scenarios**

  Value of products per tonne of wood input
  - Current generic $296
  - BIGCC (Self-sufficient) $289
  - Large BIGCC (export power) $306
  - Large BIGCC (ethanol) $265

  Note: All financial figures in this presentation are based on value of products only; no value is currently assigned to wood input or process modifications
Thank You!

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http://canmetenergy.nrcan.gc.ca/