The best approach for the conversion job; biological thermochemical or both?

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Recommended Citation
The best approach for the Conversion job; biological thermochemical or both?
Synthetic Biology is a Technological accelerator of Metabolic Engineering
**Biological Engineering**

Technological acceleration of **Metabolic Engineering**
Strain Variant Engineering

DNA Assembly

Molecular Biology

Automation

Software

HT Strain Engineering

BUILD
Industrial Example: LS9

Synthetic biology + industrial biotechnology
= industrial microbes that efficiently convert renewable feedstocks to a portfolio of "drop in compatible" hydrocarbon-based fuels
Genetically control the structure and function of its fuels
= portfolio of products

Taken from http://www.ls9.com/technology/
Bioenergy Pathways for conversion of biomass

Feedstock:
- Vegetable Oil
- Sugar and Starch
- Ligno-cellulosics
- Wet Biomass

Conversion:
- Transesterification
- Hydrolysis – Fermentation Distillation
- Pyrolysis – Hydrogenation
- Fisher-Tropsch
- Gasification
- Pelletization
- Anaerobic Fermentation

Products:
- Bio-diesel
- Ethanol-ETBE
- Hydrocarbons
- Flue Gas
- Pellets
- Biogas

Processes:
- Hydrogenation
- Fermentation
- Distillation
- Pyrolysis
- Gasification
- Pelletization
- Anaerobic Fermentation

End Products:
- Transport Fuels
- Bio-electricity
- Bio-heating
- Combustion
The Opportunity

• From an economy based largely on petroleum to a more diversified economy in which renewable plant biomass will become a significant feedstock for both fuel and chemical production.

Source: Photo http://blogs.tnr.com/tnr/blogs/environmentandenergy/greencrude.jpg
Seizing the Opportunity

Petrochemicals as a Model

- Majority of fuels and industrial chemicals are currently derived from crude oil refining
- Large scale natural gas conversion to liquids coming

Tar Sands → Bitumen

- Crude Oil
  - Gases
  - Liquids
    - Heavy Liquids

- Natural Gas
  - Fuels
  - Industrial Chemicals
  - Specialty Chemicals
## Alberta’s Major Exports 2009 ($ Billions)

Total Exports of Goods and Services: $76.8 Billion*

<table>
<thead>
<tr>
<th>Product</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Petroleum</td>
<td>30.7</td>
</tr>
<tr>
<td>Gas &amp; Gas Liquids</td>
<td>14.2</td>
</tr>
<tr>
<td>Services*</td>
<td>7.7</td>
</tr>
<tr>
<td>Petrochemicals</td>
<td>5.4</td>
</tr>
<tr>
<td>Fabricated Metals &amp; Machinery</td>
<td>4.6</td>
</tr>
<tr>
<td>Crops &amp; Livestock</td>
<td>4.4</td>
</tr>
<tr>
<td>Processed Food &amp; Beverages</td>
<td>3.0</td>
</tr>
<tr>
<td>Forestry Products</td>
<td>1.8</td>
</tr>
<tr>
<td>Refined Petroleum Products</td>
<td>1.3</td>
</tr>
<tr>
<td>Electronic &amp; Electrical Products</td>
<td>0.8</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.7</td>
</tr>
</tbody>
</table>

* Export of services amount is an estimate.

Sources: Statistics Canada and Alberta Finance and Enterprise
Industrial Infrastructure

Alberta Scenario - Pipeline

The Alberta “hub” includes 392,608 kilometres of pipeline that deliver oil and gas to markets in Canada and the U.S (Alberta Energy)

SO: Center for Energy (2010)
Seizing the Opportunity

The New Vision “Integrated Biorefinery”

- **Biomass**
  - Grains
    - Flour
    - Starch
  - Oil Seeds
    - Vegetable oils
    - Nutraceutical Components
  - Lignocellulose
    - Lignin
    - Hexosans
    - Pentosans
    - Fuels
    - Industrial Chemicals
    - Specialty Chemicals
  - Nutraceutical Components
Alberta Bioindustry

Forestry

Bioindustrial Sector

Agriculture

Oil & Gas

Petrochemical
Key Initiatives
“ZERO WASTE” INITIATIVE

- Based on proven technology
- Cost Neutral
- Reduced environmental footprint
- Development of a Centre of New Technology and Innovation
- Incorporation of an Eco-Industrial Park
- Implementation to begin in 2012

Our Goal

An Integrated, Collaborative, Sustainable Waste-to-Resource Community
Rules of value

- Purity/Homogeneity = value
- Contents list ≠ value
- Purifications excess of 50% of value
- Compatibility is key
Biological Conversions

- Isomerically selective
- Pathways based on cycles, often require co-factors or co-enzymes, reductants, oxidants
- Vulnerable to inhibitors
- Often built in separations (cell compartmentalization)
- Usually restricted by nature
Thermal Conversions

- Many combinations of inorganic components
- Cost of metals can be prohibitive
- Catalysts subject to poisoning
- Side reactions and activities common
- Long history of industrial use
- High activities
- Ability to immobilize easier
Bio ➔ Thermochemical

- Anaerobic digestion to combined heat and power, ethanol and feed

Bio → Thermochemical

Oil Production from Sugars

• Algae
• Fungi
• Oleagenous yeast

→ Oil processing
(UOP, Neste, Forge Hydrocarbons)
Bio ➔ Thermochemical
Oilsands upgrading
—Co-feed renewables and bitumen to upgrading
Bio → Thermochemical

Oilsands upgrading

- ring opening & sulfur + nitrogen removal
- Settling tailings ponds
Thermochemical $\rightarrow$ Biological

Lignocellulosic preprocessing

$\rightarrow$ Fermentation

- ethanol
- butanol
- hydrocarbons
A Techno-economic Analysis of Polyhydroxyalkanoate and Hydrogen Production from Syngas Fermentation of Gasified Biomass

Author(s): Choi, DongWon; Chipman, David C.; Bents, Scott C.; Brown, RC.

Source: APPLIED BIOCHEMISTRY AND BIOTECHNOLOGY Volume: 160 Issue: 4 Pages: 1032-1046 DOI: 10.1007/s12010-009-8560-9 Published: FEB 2010 Times Cited: 7 (from Web of Science)
(Sugar ↦ synthetic biology ↦ olefins ↦ products)

Monster Mash, or the case of the micro-spider's web
admin | November 25, 2011 (Biofuels Digest)

“Global Bioenergies and LanzaTech attempt a mash-up of their technologies – to produce isobutene from carbon monoxide gas – can it be done?

Is this a pathway for future mash-ups? What exotic materials may result from this post-carbohydrate partnership?”
Thermochemical $\rightarrow$ Biological

Biooil $\rightarrow$ Anaerobic Digestion

Lignocellulosic Material

Pyrolysis Reactor

Bio-char

Gases

CONDENSER

Aqueous Phase

$C_1$-$C_4$ organic acids

FERMENTATION

(Yeast, Algae, Fungi)

Bio-oil $\rightarrow$

Bio-oil ($C_6$-)

Lipids
Some new Trends

- Bio-mimicry

Synthetic catalyst mimics nature's 'hydrogen economy'

“CHAMPAIGN, Ill. — By creating a model of the active site found in a naturally occurring enzyme, chemists at the University of Illinois have described a catalyst that acts like nature's most pervasive hydrogen processor.”

http://www.chemistry.illinois.edu/news/Rauchfuss_Hydrogen0518200.html
Some new Trends

- Artificial Cell systems
What are the first questions investors seek?

- Do you have feedstock availability?
- At what stage of development is the technology?
- Who is the “team”?
- What is your IP position?
- What are the “margins”?
In other words, it's about business case, and existing companies have advantages!

➢ So how do researcher best leverage these partnerships?
BCN at a glance

- Inclusive research network based out of the U of Alberta
- Funded by AI Bio Corp. (C$ 3 million over 3 years, then $4+M 2012 onward)
- Focused on biomass conversions, developed to bridge the gap between feedstock processing and product distribution to accelerate the commercialization process
Biorefining Conversions Network - Industrial Engagement in Proposed Projects 2012-15:

<table>
<thead>
<tr>
<th>Biomass Pre-Processing &amp; Logistics</th>
<th>Biocatalysis &amp; Fermentation</th>
<th>Green Chemistry for Fuels &amp; Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Program 1: Forestry</strong></td>
<td><strong>Program 2: BioFoundry</strong></td>
<td><strong>Program 3: Green Chemistry</strong></td>
</tr>
</tbody>
</table>

**Partners:**

**Biomass Pre-Processing & Logistics:**
- DMI (DAISHOWA-MARUBENI INTERNATIONAL LTD.)
- West Fraser
- Alberta Newsprint Company
- Weyerhaeuser

**Biocatalysis & Fermentation:**
- TerraVerdae bioworks
- Total
- Canadian Natural
- ConocoPhillips

**Green Chemistry for Fuels & Chemicals:**
- Esso
- Imperial Oil
- P2 Science
- Autodesk
- Aveda
- Cosia
BCN: Collaboration with Alberta Forest Product Roadmap Firms

- Standardize Lignocellulosic Fractions
- Terpenes
- Lignocellulosic Separations
- Tall Oils to Fuels
- Forest-Derived Fly Ash Upgrading
Biocatalysis & Fermentation

- Biopolymers from C1 Substrates
- Accelerated Biodensification of Tailings
- Synbio Manufacturing of High-Value Phenylalanine-derived Specialty Chemicals
- High-Value Fatty Alcohols
Green Chemistry for Fuels & Chemicals

- Supercritical Fluids: Extracting Gels from Lignocellulosic Biomass
- Bioaldehyde Production from Plant Oils
- Polysaccharides for Naphthenic Acid Extraction from Tailings
- Tailings Flocculants from Agricultural Waste Proteins
### Biomass Pre-Processing & Logistics

**Program 1**
- Forest Derived Fly Ash Upgrading
- Tall Oils to Fuels
- Hemicellulose to Xylitol
- High-Value Fatty Alcohols

**Program 2**
- Aromatic Compounds from Cellulosic Waste Streams
- Bioaldehydes Production from Plant Oils
- Biopolymers from C1 Substrates
- Synbio Manufacturing of High-Value Phenylalanine-derived Specialty Chemicals

**Program 3**
- Accelerated Biodensification of Tailings
- Algae-Derived Green Flocculants
- Polysaccharides for Naphthenic Acid Extraction from Tailings
- Biopolymers from C1 Substrates

### Biocatalysis & Fermentation

- Lignocellulosic Separations
- Standardization of Lignocellulosic Fractions
- Terpenes

### Green Chemistry for Fuels & Chemicals

- Supercritical Fluids: Extracting Gels from Lignocellulosic Biomass
- Bioaldehyde Production from Plant Oils
- Algae-Derived Green Flocculants from Agricultural Waste Proteins
- Microbial Conversions to Reduce Heavy Oil Viscosity
Canadian Biofuels Research
NSERC - BioFuelNet Vision

• Central role catalyzing the rapid growth of biofuels sector in Canada
• Coordinating and aligning Canada’s biofuels research community around key commercial challenges
• 25% of Canada’s transportation fuel from renewable biomass by 2022
Structure of BioFuelNet

West BFN Platform
Prairies BFN Platform
Central BFN Platform
East BFN Platform

Feedstocks  Conversion  Utilization

Social, Economic and Environmental Sustainability (SEES)
Who’s Involved

• 82 researchers
• 22 Universities
  – McGill hosting
• 40 industry partners
• > 100 partners overall
• Wide range of national and international contacts
Networking and Partnerships

Examples for each category

Academia
- Western
- McGill
- Queens University
- University of Toronto
- UBC
- University of Manitoba

Bioconversion Network
- CRIIQ
- Mitacs
- Carbon Management Canada
- Green Aviation Research & Development Network
- Canadian Renewable Fuels Association

Government
- Natural Resources Canada
- Environment Canada
- Agriculture and Agri-Food Canada
- Government of Saskatchewan
- London
- Montreal
- Newfoundland Labrador

Industry
- Bombardier
- Greenfield Ethanol
- Lignol
- Enerkem
- Hydro Quebec
- Ford
- Delta Research
- Esso
- Imperial Oil
- Function Four
- Rio Tinto Alcan
- The Woodbridge Group
- Uniongas

Other
- Mitacs
- Inerjys
- WWF
- FPI Innovations
- Auto21

Networks
- Bioconverstion Network

http://www.biofuelnet.ca/