Value added opportunities for Minnesota’s primary forest products industry

Minnesota Forest Resources Council
March 19, 2014

Richard A. (Dick) Hemmingsen, Senior Fellow
Department of Bioproducts and Biosystems Engineering
Brief background

- SW MN (small) farm boy
- Vo-Ag teacher
- Farmer
- County Agent
- University lobbyist
- IREE’s Founding Director
And, A Couple of Disclaimers….

Not a lot trees in my background….
And, A Couple of Disclaimers....

Not a lot trees in my background....

I’m not a trained, licensed, (or recovering) research scientist....
And, A Couple of Disclaimers….

Not a lot trees in my background….

I’m not a trained, licensed, (or recovering) research scientist….

Information and images in this presentation from public web sites…

Descriptions of technology platforms and/or businesses does not infer endorsement….
So, where does all this “stuff” (fuels, plastics, and chemicals) come from?

Well, it doesn’t (currently) grow on trees
A Petroleum Refinery
OIL BARREL BREAKDOWN

Despite consuming a small fraction of US oil compared with fuel, petrochemical products are worth more.

- Fuels, including: motor gasoline, aviation gasoline, kerosene-type jet fuel, diesel, 70.60%
- Petrochemicals, including: naphtha, ethane, ethylene, other oils, 3.40%
- Heavy Fuel Oil, 6.10%
- Residual Fuel Oil, 3.80%
- Special Naphthas, 0.20%
- Waxes, 0.10%
- Lubricants, 1%
- Petroleum coke, 5.00%
- Asphalt and road oil, 3.00%
- Still Gas, 4.10%
- Miscellaneous products, 0.40%
- Liquified Refinery Gases, 2.30%

$385bn
Pre-tax value of transport fuels

~$375bn
Pre-tax value of petrochemical products, such as plastics, cosmetics, pesticides, detergents, paints and adhesives (excluding pharmceuticals)

The Petro-chemical “Leggo set”

Figure 2 – An Example of a Flow-Chart for Products from Petroleum-based Feedstocks
A Biorefinery mimics a petrochemical refinery.
Renewable Chemical Value-Add


Slide courtesy of BioAmber
Let's go back to the pigs
Little pigs turn into big pigs
But it didn’t all get made into SPAM
This little piggie went to market
“Use everything but the squeal”

Every ounce of Pig 05049 was used, helping create an astonishing 185 products. Here are some of the more surprising uses for the animal — and a diagram to show just which bit of the beast, from the trotter to the snout, is used where...

1. Chemical weapons testing: Because of the pig’s similarity to human tissue
2. Ice cream: Gelatine regulates the sugar crystallisation and slows down the melting process
3. Fertiliser: Made from processed pig hair
4. Low fat butter: Gelatine used for texture
5. Beer: Gelatine used as a clarifying agent. Reacts with bitter substances and tannins to absorb cloudy elements, leaving clear drinks
6. Fabric softener: Fatty acids from bone fat give colour
7. Paint brush: Made from pig hair
8. Fruit juice: Gelatine absorbs cloudy elements to give clear drinks
9. Shampoo: Fatty acids from bone fat are used to give them a pearl-like appearance
10. Candle: Fatty acids from bone fat are used to stiffen the wax and raise the candle’s melting point
11. Bread: Protein from pig hair is used to soften dough
12. Bullet: Bone gelatine used to help transport the gunpowder or cordite into the casing
13. Medicine tablets: Gelatine is used in the shell to give it hardness
14. Washing powder: Fatty acids from bone fat harden the substance
15. Paint: Fatty acids from bone fat increase gloss
16. Tambourine: Made from the pig’s bladder
17. Wine: Gelatine absorbs cloudy elements to give clear drinks
18. Paper: Bone gelatine is used to improve stiffness and reduce moisture
19. Heparin: Used to stop the formation of blood clots, it is taken from the mucus in the intestines
20. Soap: Fatty acids from bone fat act as a hardening agent and give colour
21. Corks: Bone gelatine is used as a binder
22. Insulin: Taken from the pancreas, as closest to human in chemical structure
23. Yoghurt: Pig bone calcium is used in some yoghurts
24. Cigarettes: Haemoglobin from the blood used in cigarette filters to create an artificial lung that supposedly lessens harmful chemicals reaching the smoker
25. Photographic film: Bone gelatine acts as a bonding agent on the film sheet
26. Dog food treat: Haemoglobin used as a red colouring agent
27. Photodynamic therapy: Haemoglobin used in drug to treat retina decay in the eye. Drug is activated by shining laser into eye
28. Moisturisers: Fatty acids in turn are used
29. Dog snack: Deep fried pig nose
30. Crayons: Fatty acids are used as a hardening agent
31. Shoes: Bone glue is used to improve the texture and quality of the leather
32. Train brakes: Bone ash used in production
33. Toothpaste: Glycerine from bone fat is used to give toothpaste texture
34. Hide glue: A strong glue used in the woodworking industry derived from collagen
35. Face mask: With collagen to help reduce wrinkles and lines
36. Alternative energy: Waste products used as fuel to produce electricity
37. Energy bar: Treated collagen is cheap source of protein for bodybuilders
38. Cream cheese: Gelatine used to make it stable
39. Whipped cream: Gelatine gives texture
40. Sweets: Pork gelatine used as a binding and gelling agent and to ensure the right texture is found in the following: liquorice, wine gums, chewing gum
The Carbon Slaughterhouse
Further development of the biorefinery concept

- BioMaterials:
  - Polymers
  - Composites

- BioChemicals:
  - Flavours
  - Monomers
  - Proteins
  - Fine chemicals
  - Speciality chemicals

- BioFuel:
  - Bioethanol
  - Biodiesel
  - Biogas

- BioEnergy:
  - Electricity/Heat
  - Liquid Fuels
  - Pellets

Cost/price:
- High
- Low
A Biorefinery? Oughta' be easy, right?

The Bio-based “Leggo set”

Figure 3 – Analogous Model of a Biobased Product Flow-chart for Biomass Feedstocks
Petroleum Refinery vs. Biorefinery

20th Century

Sustainability
Self-reliance
Climate

21st Century

Bio-fuels
Bio-based polymers
Bio-based materials

“It does grow on trees”
From this....

....to this

**Chemicals**
- Plastics
- Functional monomers
- Solvents
- Chemical intermediates
- Phenolics
- Adhesives
- Hydraulic Fluids
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Paper
- Fiber board
- Plastic filler
- Abrasives

**Transportation Fuels**

**End Uses**
A Biorefinery ..., Sugar Platform "Biochemical"
Biochemical Route ("Sugar platform")

- (C5) Xylans
- Xylose
- Arabinose
- Galactose
- Mannose
- Glucose (C6)

- 15%-25% Lignin
- 23%-32% Hemicellulose
- 38%-50% Cellulose

Glucose (C6)
Chemicals
- Plastics
- Functional monomers
- Solvents
- Chemical intermediates
- Phenolics
- Adhesives
- Hydraulic Fluids
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Paper
- Fiber board
- Plastic filler
- Abrasives

End Uses

From this....
Sugar
- Xylose
- Arabinose
- Galactose
- Mannose
- Glucose

Top Ten Sugar-Derived Building Blocks
- 1,4 diacids (succinic, malic, fumaric)
- 2,5 furan dicarboxylic acid
- 3 hydroxy propionic acid
- Aspartic acid
- Glutaric acid
- Glutamic acid
- Itaconic acid
- Levulinic acid
- 3-hydroxybutyrolactone
- Glycerol
- Sorbitol
- Xylitol/arabinitol

....to this

Transportation Fuels
Segetis L-Ketals – Renewable Platform Chemicals

Brian Tockman
Nov 30 2010
E3 Conference
St. Paul, MN
Segetis L-Ketal Material Systems

Engaged >100 Industrial Customers

Time to Commercialization

SOLVENTS

PLASTICIZERS

PVC
Segetis renewable
Petroleum-derived

POLYOLS

THERMOSETS
THERMOPLASTICS

MONOMERS

FUNCTIONAL OLIGOMERS

POLYMERS

OTHER
Weyland strong acid hydrolysis process converts woody biomass into fermentable sugars and high quality lignin.
Thermochemical Route

Deconstruction:
- Gasification
- Pyrolysis or Liquefaction

Upgrading:
- Syngas Cleanup & Conditioning
- Bio-oil Stabilization
- Fuel Synthesis
- Fuel Processing

Products:
- Biofuels
- Chemicals & Materials
- Specialty Products
DME (Dimethyl ether): the (green) fuel of the future?

Black liquor extracted from the pulp manufacture process can be the fuel of the future.
Photo: www.chemrec.se
Domsjö Fabriker, a specialty cellulose producer, in the outskirts of Örnsköldsvik, northern Sweden. A photomontage of the new gasification plant producing green fuels DME, dimethyl ether, and methanol, using Chemrec technology. The plant will be ready in 2013 if everything goes according to plan.
Volvo Trucks Takes DME Plunge, Biofuel Or No Biofuel
Friday, June 7, 2013 5:57
Is it the future of fuel? New Battelle mobile pyrolysis unit nets 130 gallons of bio-oil per ton

Battelle evaluating pilot-scale mobile catalytic pyrolysis unit to convert biomass to bio-oil
8 November 2013
... to Barrel

Back to field as a soil amendment

Power for conversion

Syn Gas
2,250,000 BTU

Conversion (fMAP)

Char
1,500,000 BTU

Biocrude
1.2 barrel
500 lb, 6.7 ft³,
75 lb /ft³
3,750,000 BTU
562,500 BTU/ft³

...a model for forest biomass/residues
fMAP
(fast) Microwave-Assisted Pyrolysis

Lab-scale
2004

Continuous flow reactor
2007

Aspen

Portable unit
2010

Professor Roger Ruan
A giant “homogenizer”

An example of the Advanced Uniform-Format Feedstock Supply System.
Integrated Torrefaction and Briquetting Demo Plant (12 T/day)

Torrefaction

A thermochemical treatment process, similar to roasting or mild pyrolysis

Energy density increases as ~70% biomass remains with 90% of original energy content

Demonstration Scale Kiln -12,000 kg/day

Komarek Briquetter
A Biorefinery
Specialized Cellulose Value Chain

1. Chemical Cellulose
   - Pulp with high purity cellulose content (>90%)
   - Product specifications are different than kraft pulp and need to be managed with tighter tolerances

2. Intermediate Fiber
   - Viscose staple fiber
   - Lyocell
   - Acetate
   - Others

3. End Product
   - Textiles (like rayon)
   - Food
   - Disposable wipes
   - Pharmaceuticals
   - Cosmetics
   - Cigarette filters
   - etc.
Nanocellulose --- The next “wonder material”?

stronger than steel
stiffer than Kevlar®
very lightweight,
conductive
non-toxic
highly absorbent

USDA Under Secretary Sherman Unveils Nanocellulose Production Facility

Posted by Rebecca Wallace, USDA Forest Products Laboratory, on August 3, 2012 at 11:57 AM

The U.S. Forest Service Forest Products Laboratory recently opened a $1.7 million production facility for renewable, forest-based nanomaterials.
7 incredible uses for nanocellulose

**Ultimate Body Armor**
- Strength: weight = 8X stainless steel

**Bendable Batteries**
- Nannocellulose wrapped in graphene

**Super-Flexible Screens**
- Insanely thin - and flexible screens

**Incredibly Fuel-Efficient Cars**
- Shave 750 # off the weight of your car

**Ultra-Absorbent Aerogels**
- Float 10,000 times it’s weight, super absorbent

**Future Filters**
- Make saltwater drinkable, filter blood cells

**Bounteous Biofuel**
- Tweak the DNA of algae to chomp through wood pulp to make nanocellulose and create biofuel as a by product
You can make anything you want out of lignin…….

….. Except
Lignin -- A folded protein

One thing we do know about lignin is that it forms clumps and lumps. Persnickety scientists call them aggregates.

Lignin is known for its near-chaotic variety – virtually no two lumps are the same, with a wide variety of complex aromatic rings and structures.

If you know your Star Wars, lignin is sort of like the Force. “It surrounds us, penetrates us, and binds the galaxy together,” as Obi-Wan Kenobi observed.

Lignin is the single biggest technical bio-processing barrier to cellulosic biofuels. It’s exceedingly difficult to separate lignin from cellulose, and costly. After separation, lignin remains a low-value, unloved byproduct that is typically burned to generate power.

As Catullus wrote in *Odi et Amo*, so it is with lignin, “I hate and I love, how can I explain this contradiction? I can only feel it, and I am in agony.”
You know, we’d plant a lot more of you if you’d just ease back on the LIGNIN!
What would you have if you had the lignin?

If you had trees without lignin?
Recombinant Lignin Depolymerase with Enhanced Stability and Catalytic Activity

“….developing new thermoplastics with the highest attainable contents of simple lignin derivatives.

“….lignin biodegradation as a vehicle for producing the first true lignin degrading enzyme that biobleaches chemical pulp.”

“….how lignins may be biosynthesized in nature”
Lignin

- Potential feedstock for wide range of chemicals (aromatics!) and performance products.
- Valorisation lignin improves carbon footprint & economics lignocellulose biorefinery.

- No large-scale commercial market for lignin at the moment (in contrast to sugar derivatives).
Biorefinery Lignins

- Approximately 20 weight percent of biomass, on average (2nd most abundant polymer)
- Value-added markets, like carbon fiber, can generate additional revenue
- 1.2 million tons @ $5/lb = $12 Billion market (automotive & light truck)
- In producing 1 lb of carbon fiber
  - 2 lbs of biomass could replace 3 lbs of PAN derived from 6 lbs of petroleum (Polyacrylonitrile)
Future of Forest Products Industry

*Forests can be made to produce fifty times their present volume of end products and still remain a permanently self-renewing source for raw materials … Only forests – no other raw material resource – can yield such returns. The forest can, and so must, end the chronic scarcities of material goods that have harassed man’s experience since the beginning of history.*

Egon Glesinger, 1949
Today

Minnesota Wood Consumption

- Engineered Wood Products: 23%
- Pulp and Paper: 52%
- Lumber and Specialty Products: 17%
- Heat and Electricity: 8%

21st Century

Bio-fuels
Bio-based polymers
Bio-based materials

Figure 5.5
HF2465/SF2101: A bill for an act…creating

1. A Renewable Chemical and Advanced Biofuel Capital Equipment Loan Fund;

2. (Cash) Producer Payments to eligible producers of advanced biofuel at a qualifying facility*;

2. (Cash) Producer Payments to eligible producers of renewable chemicals at a qualifying facility;

3. (Cash) Producer Payments to eligible producers of biomass thermal at a qualifying facility;

* 80% of feedstock from MN agricultural or forestry sources or organic content of municipal solid waste.
Why Minnesota? Why Not?

Zu früh alt, zu spät schlau.
Vee grow too soon oldt, und too late shmart.