



# 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



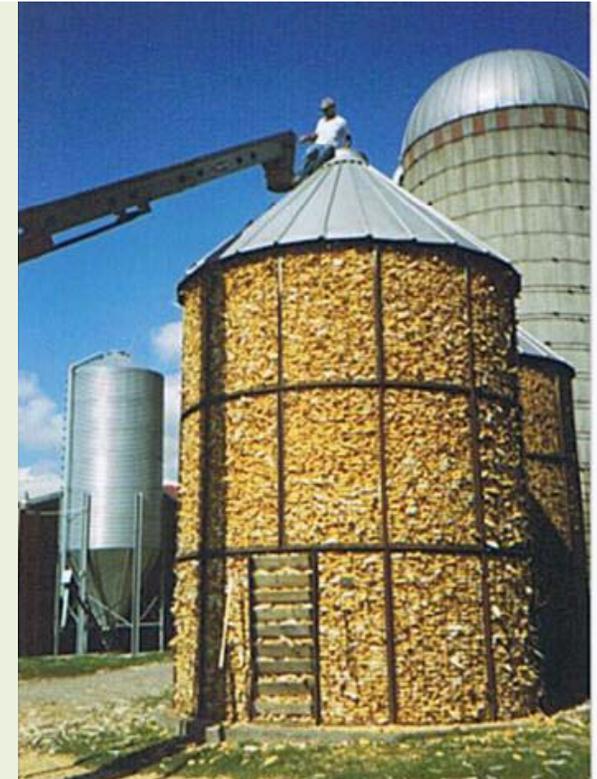
UNIVERSITY OF MINNESOTA  
Driven to Discover™



## Brief background

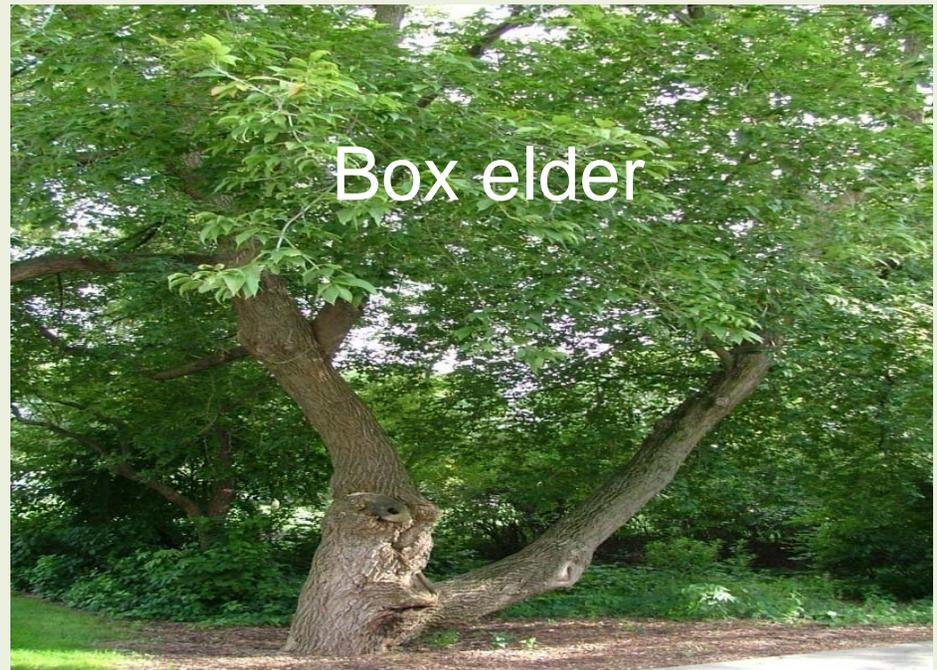


- SW MN (small) farm boy
- Vo-Ag teacher
- Farmer
- County Agent
- University lobbyist
- IREE's Founding Director

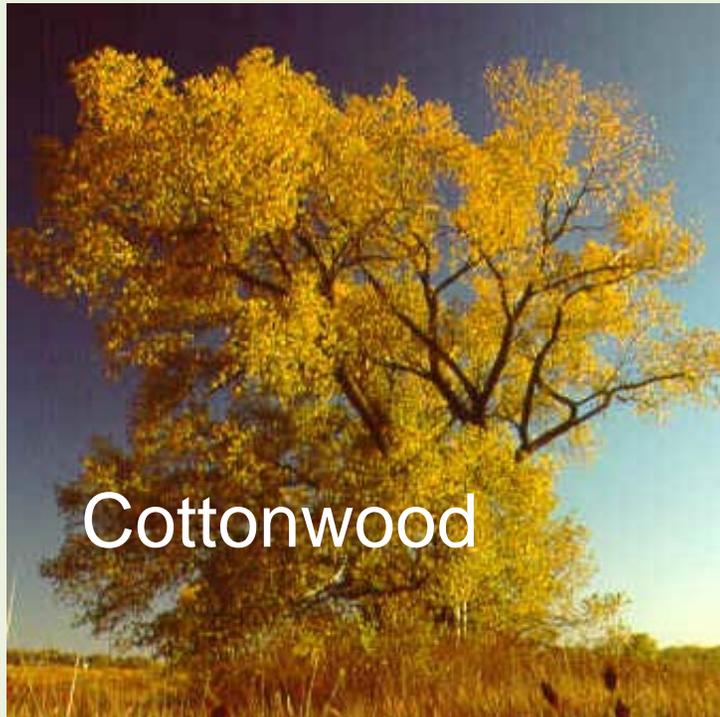


And, A Couple of Disclaimers....

Not a lot trees in my background....



Box elder



Cottonwood



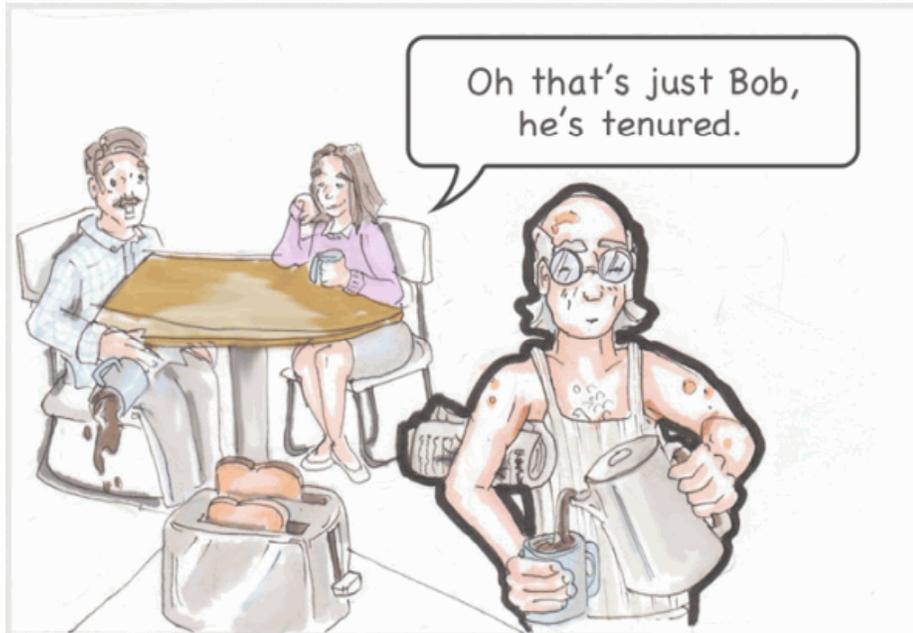
Evergreens

And, A Couple of Disclaimers....

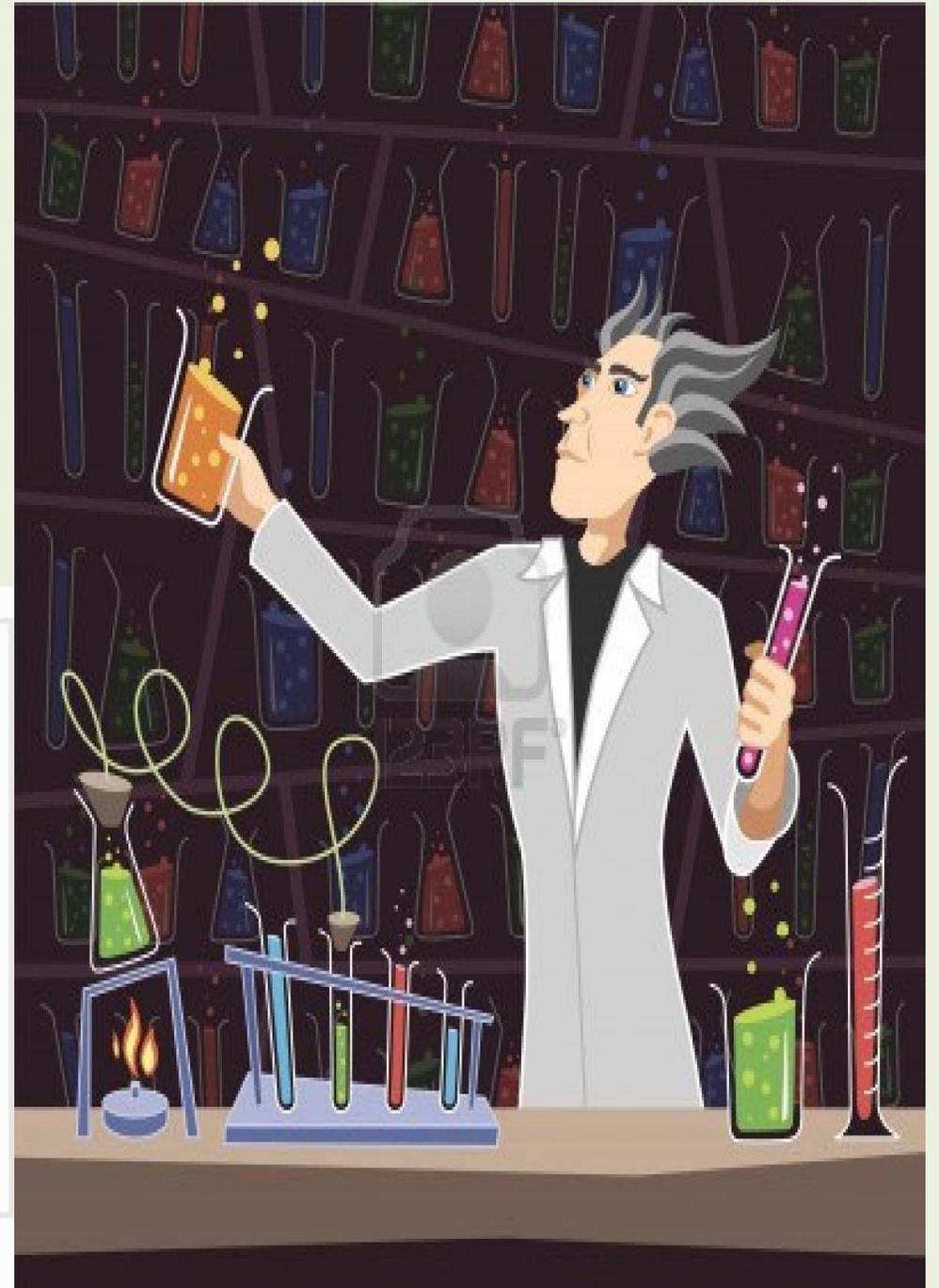
Not a lot trees in my background....

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

© AcademicKeys.com



"Tenured!"



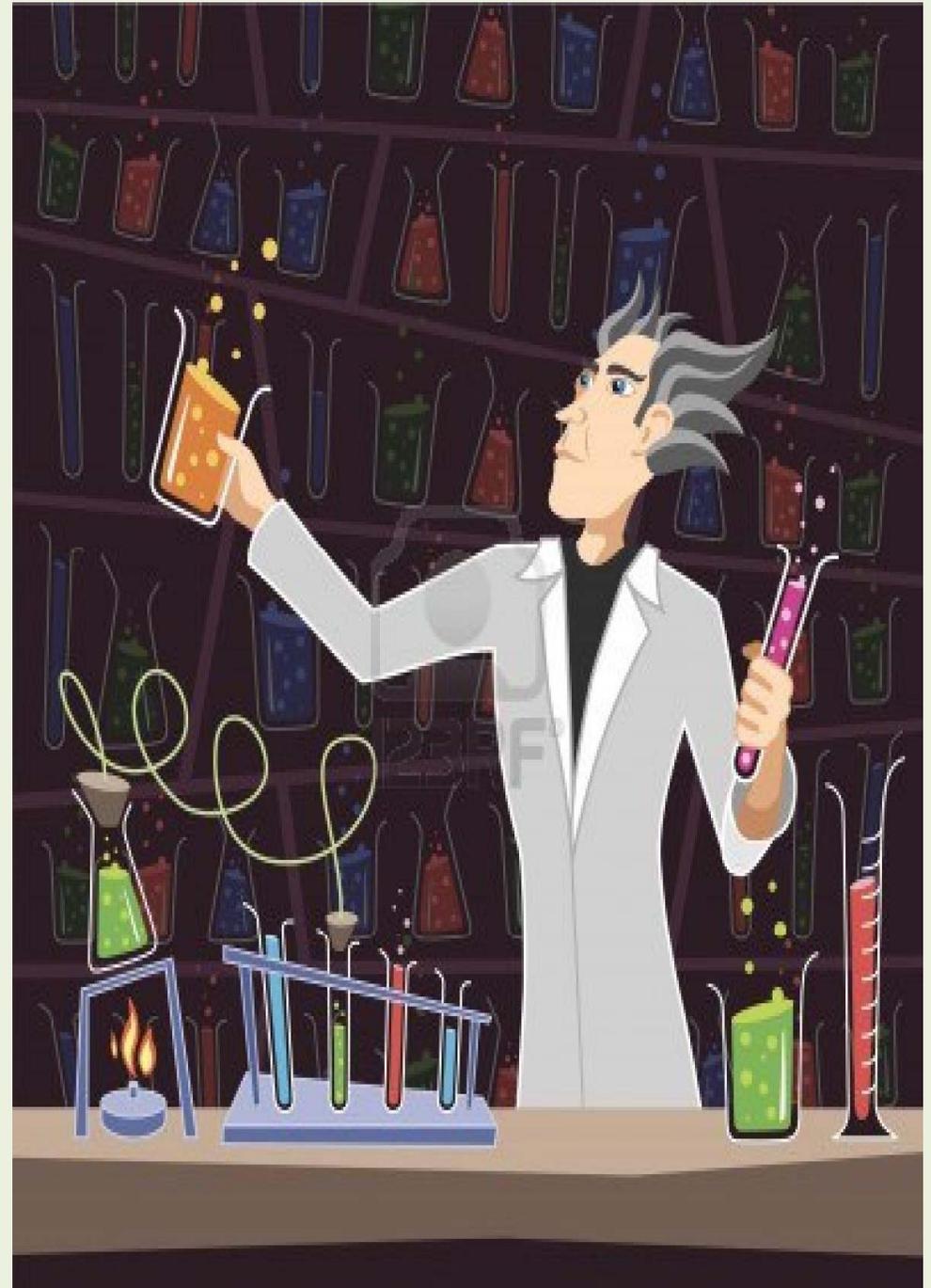
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(or recovering) research scientist....

Information and images in this  
presentation from public web sites...

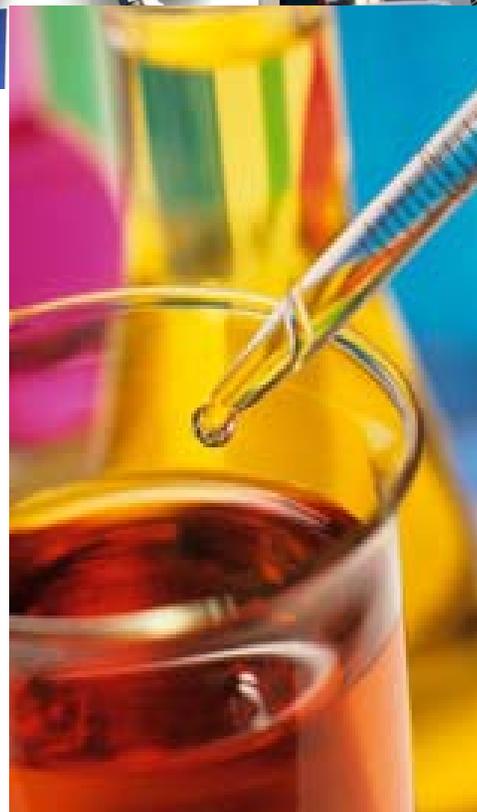
Descriptions of technology platforms  
and/or businesses does not infer  
endorsement....





So, where does all this “stuff” (fuels, plastics, and chemicals) come from?

Well, it doesn't (currently) grow on trees

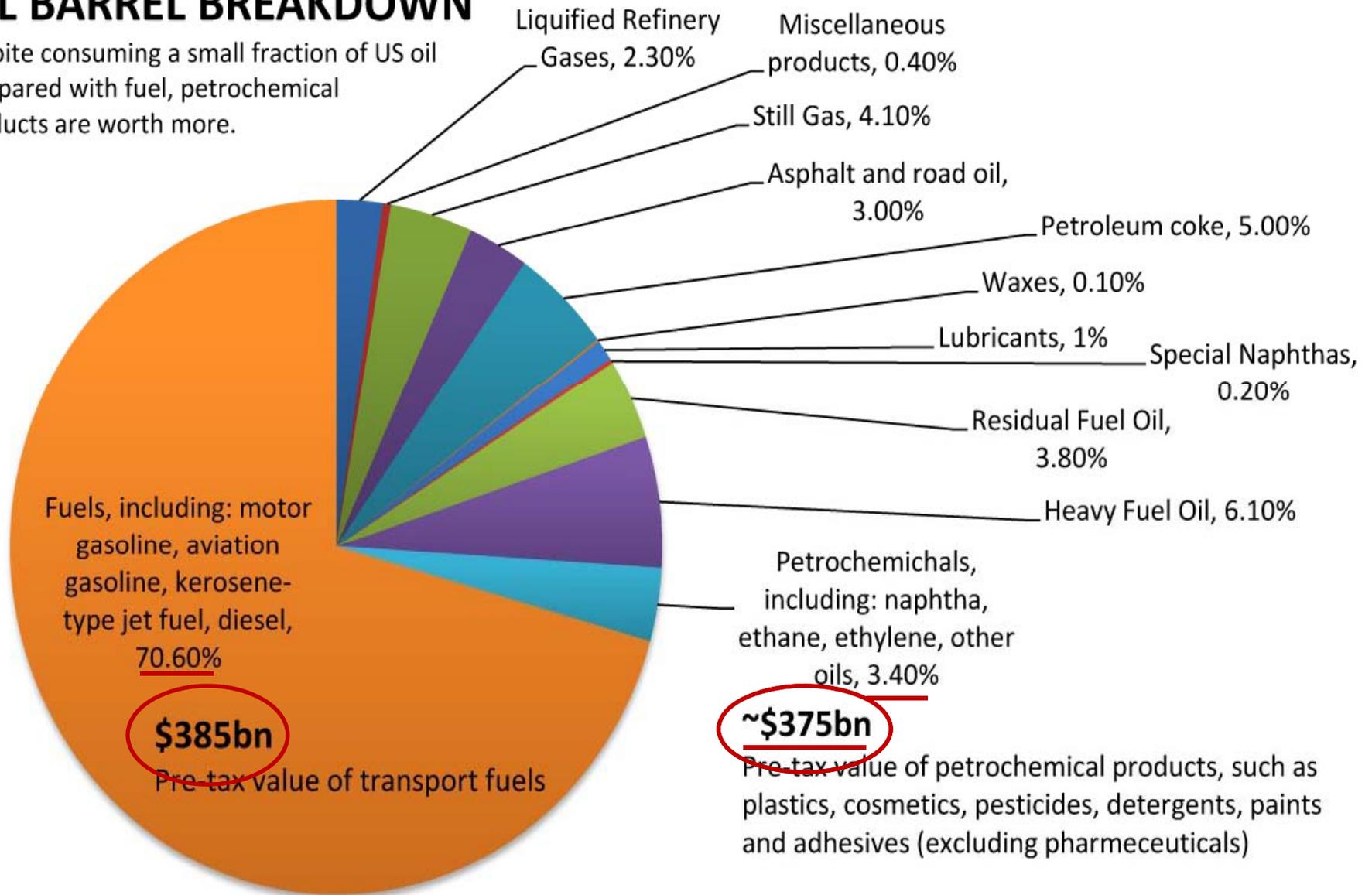


# A Petroleum Refinery



# OIL BARREL BREAKDOWN

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



SOURCE: U.S. DEPARTMENT OF INDUSTRY 2005, AMERICAN INSTITUTE OF CHEMISTRY

# The Petro-chemical “Leggo set”

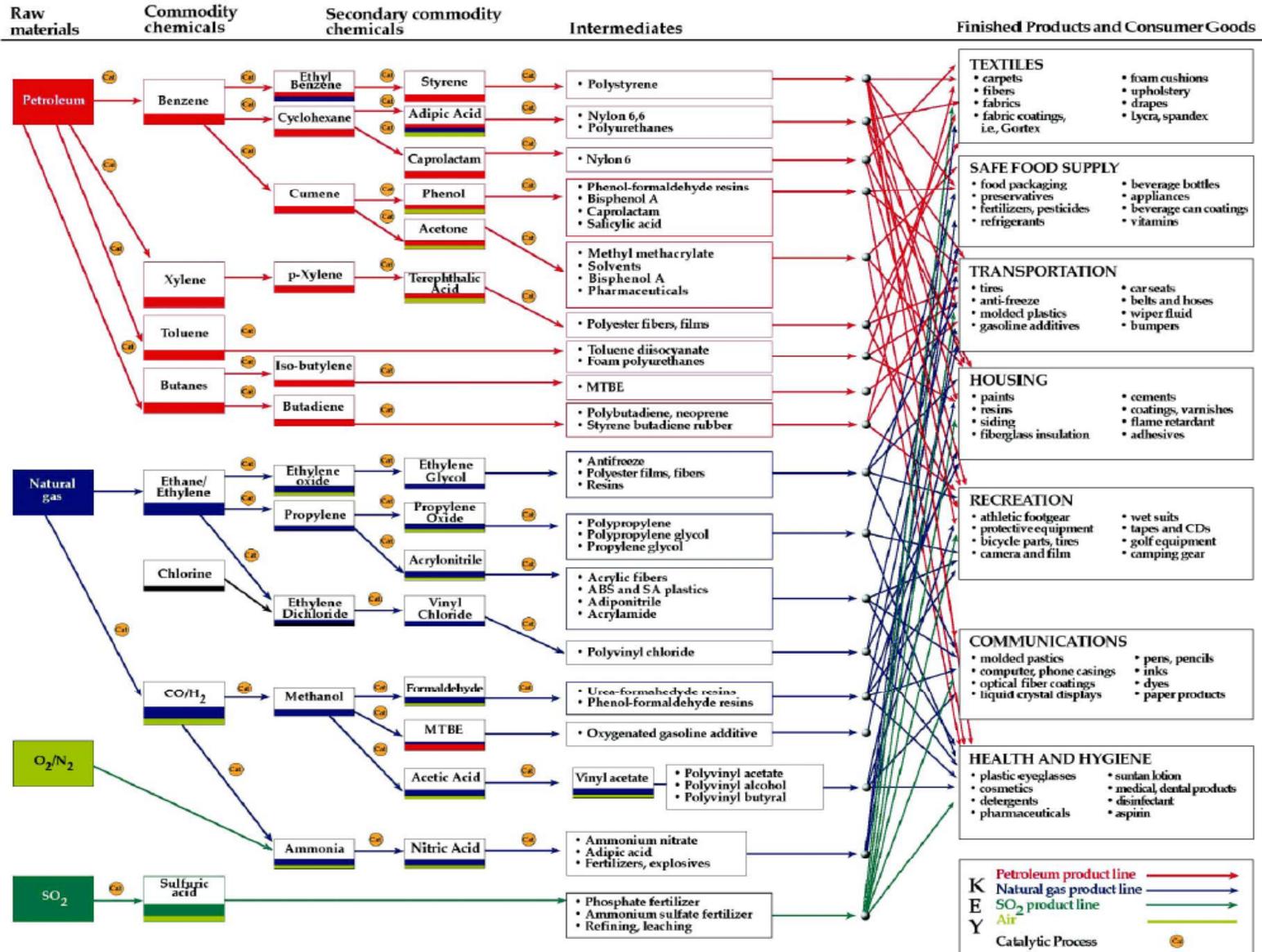
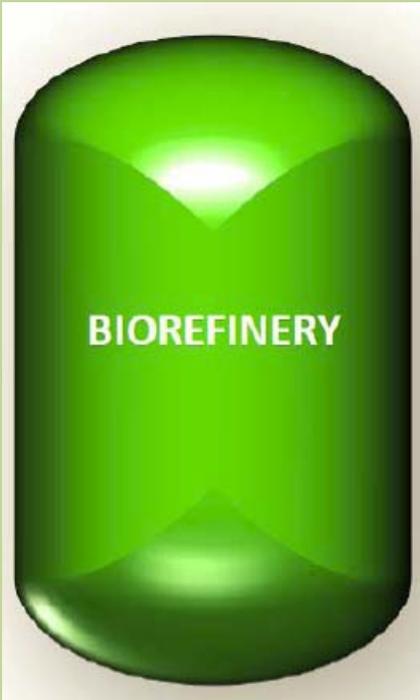
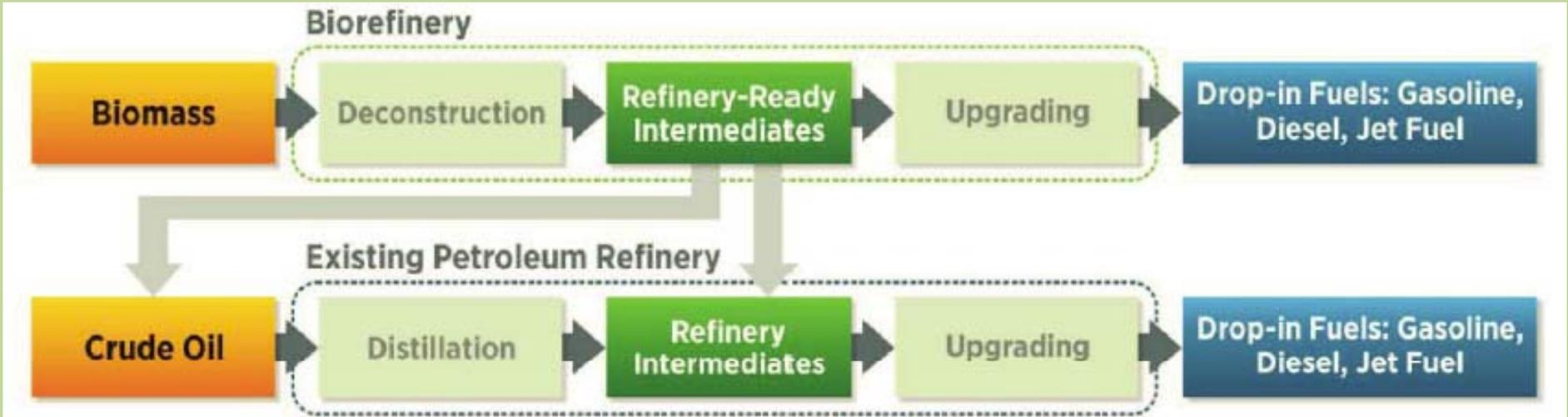


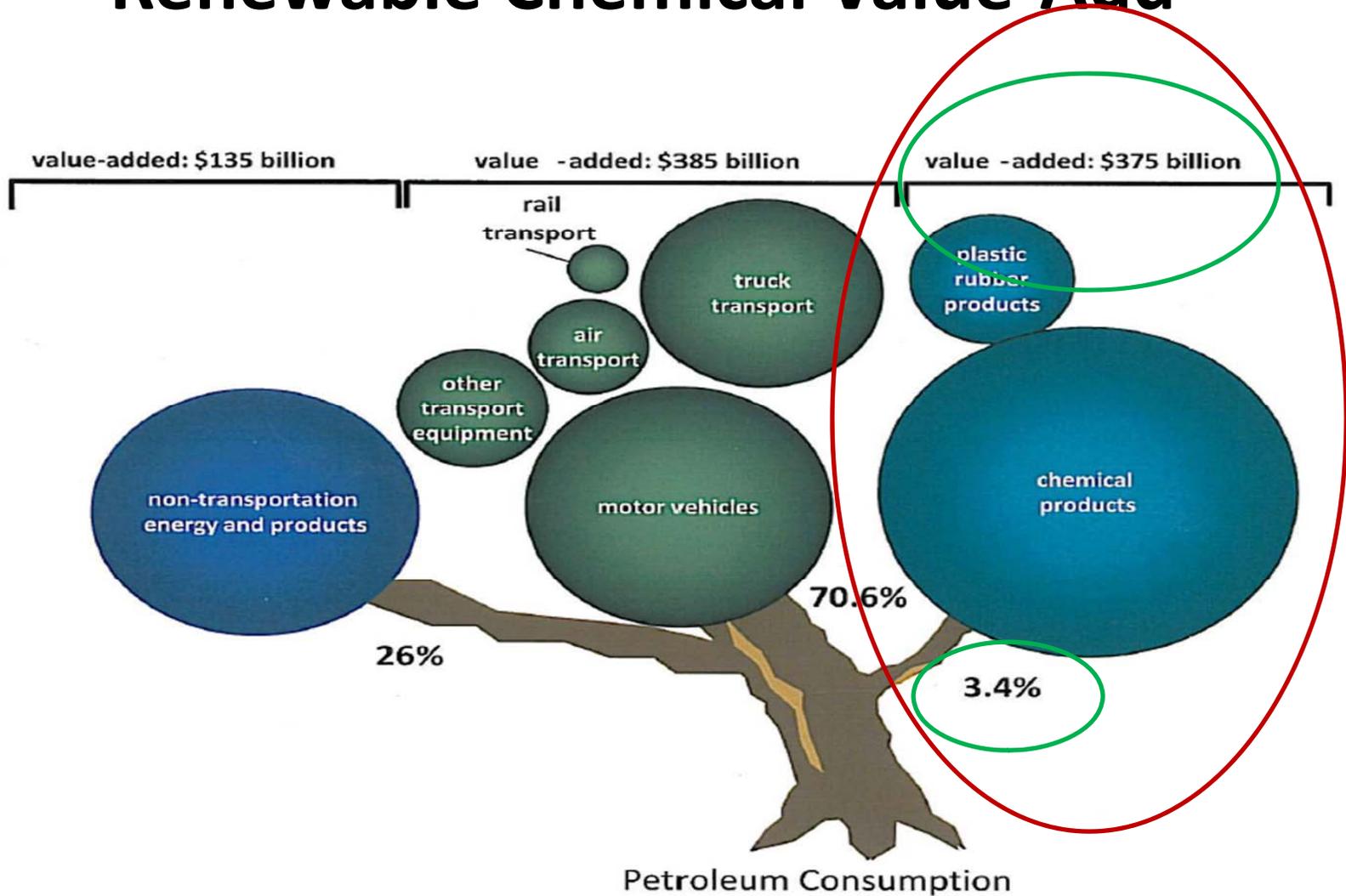
Figure 2 – An Example of a Flow-Chart for Products from Petroleum-based Feedstocks



A Biorefinery mimics a petrochemical refinery



# Renewable Chemical Value-Add



Adapted From: Vol. 1 No. 1. Spring 2005 Industrial Biotechnology; New Scientist 2007.

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

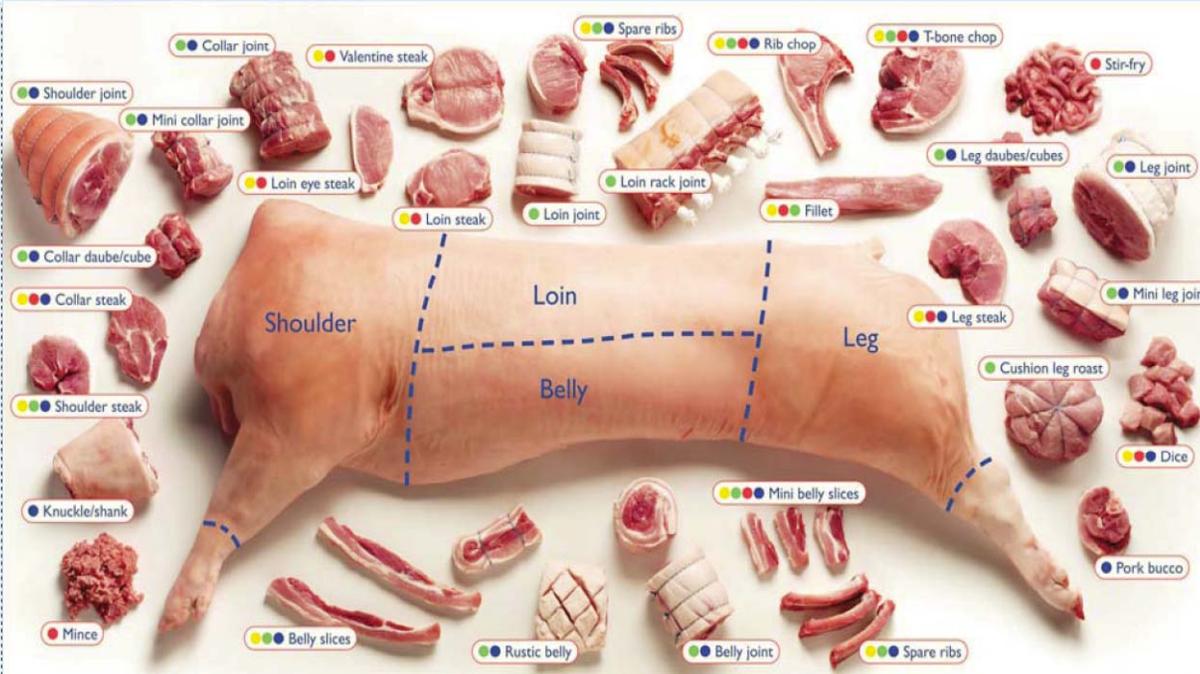
**6 Fabric softener:** Fatty acids from bone fat give colour

**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

**How a 16 stone 31b pig breaks down...**

**Bones**

**33lb**

15%

**Internal organs**

**31lb**

13.6%

**Miscellaneous**

**14lb**

6.3%

**Blood** 12lb 5.3%

**Fat** 12lb 5.3%

**Skin** 6.6lb 2.9%

**17 Wine:** Gelatine absorbs cloudy elements to give clear drinks

**Meat**  
**119lb**  
**52.1%**

**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 from bone fat 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

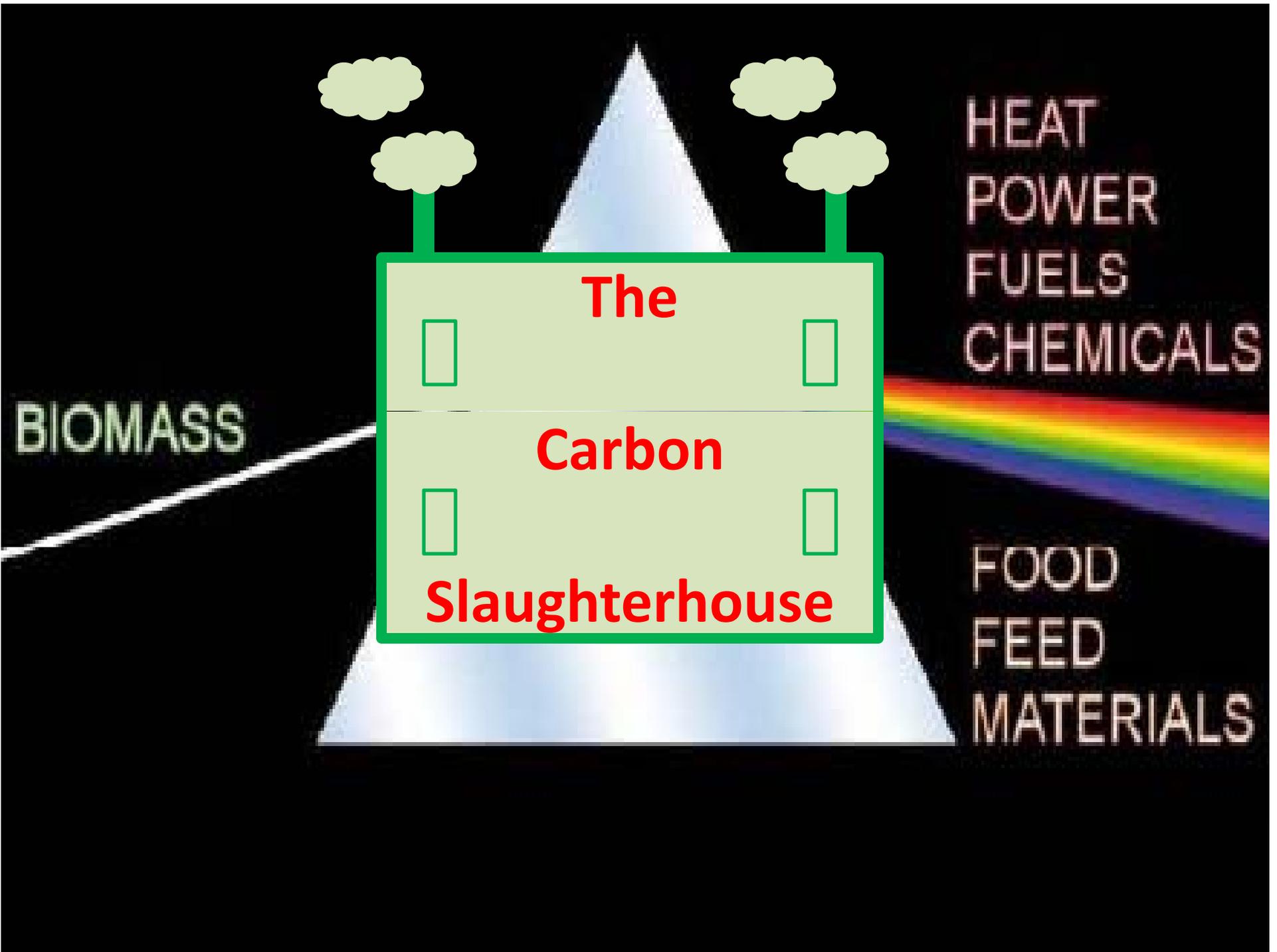
**37 Energy bar:** Treated collagen is cheap source of protein for body builders

**38 Cream cheese:** Gelatine used to make it stable

**39 Whipped cream:** Gelatine gives texture

**40 Sweets:** Porcine gelatine used as a binding and gelling agent and to ensure the right texture is found in the following: liquorice, wine gums, chewing gum





BIOMASS

The

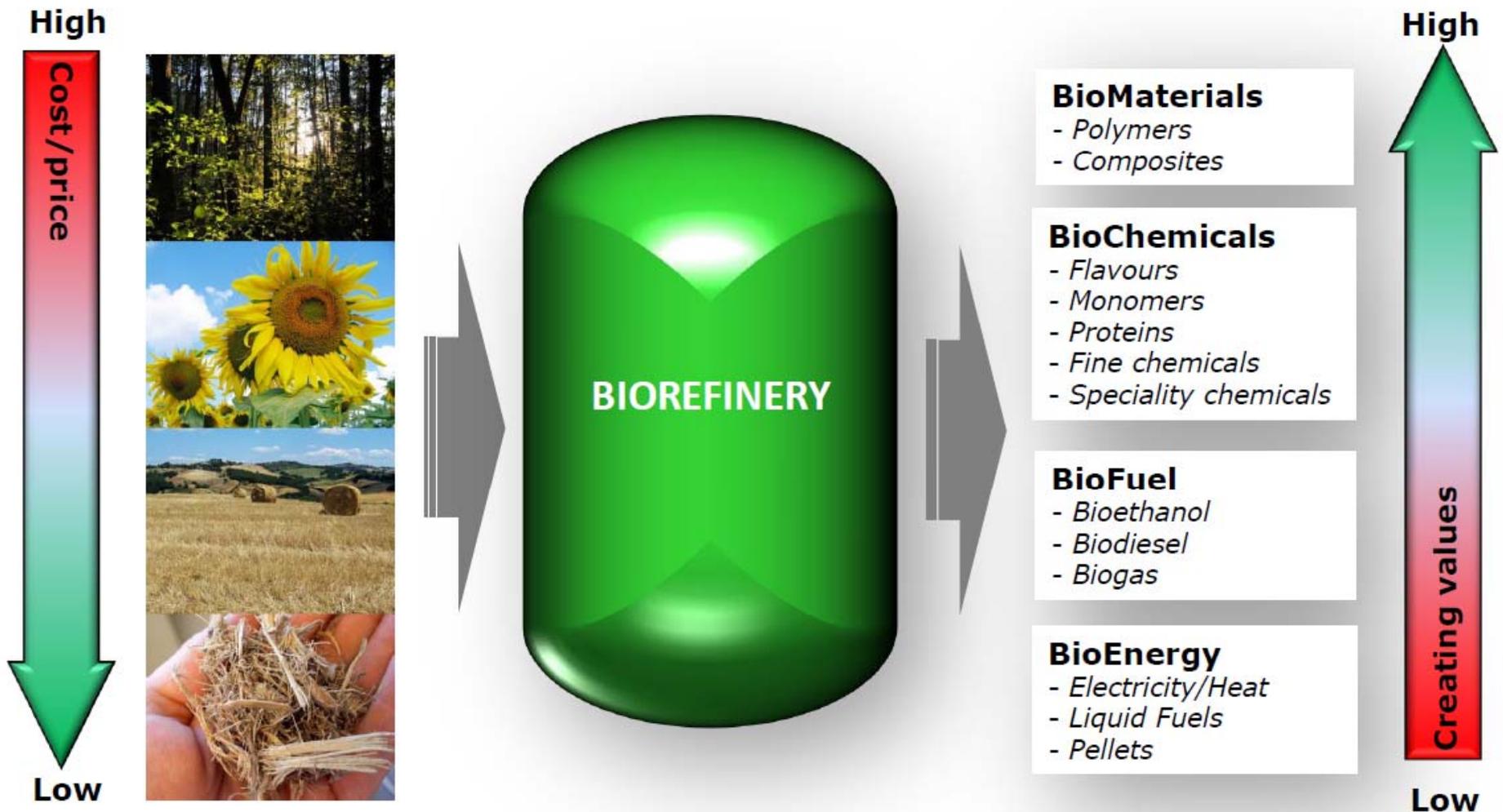
Carbon

Slaughterhouse

HEAT  
POWER  
FUELS  
CHEMICALS

FOOD  
FEED  
MATERIALS

# Further development of the biorefinery concept



# The Bio-based "Leggo set"

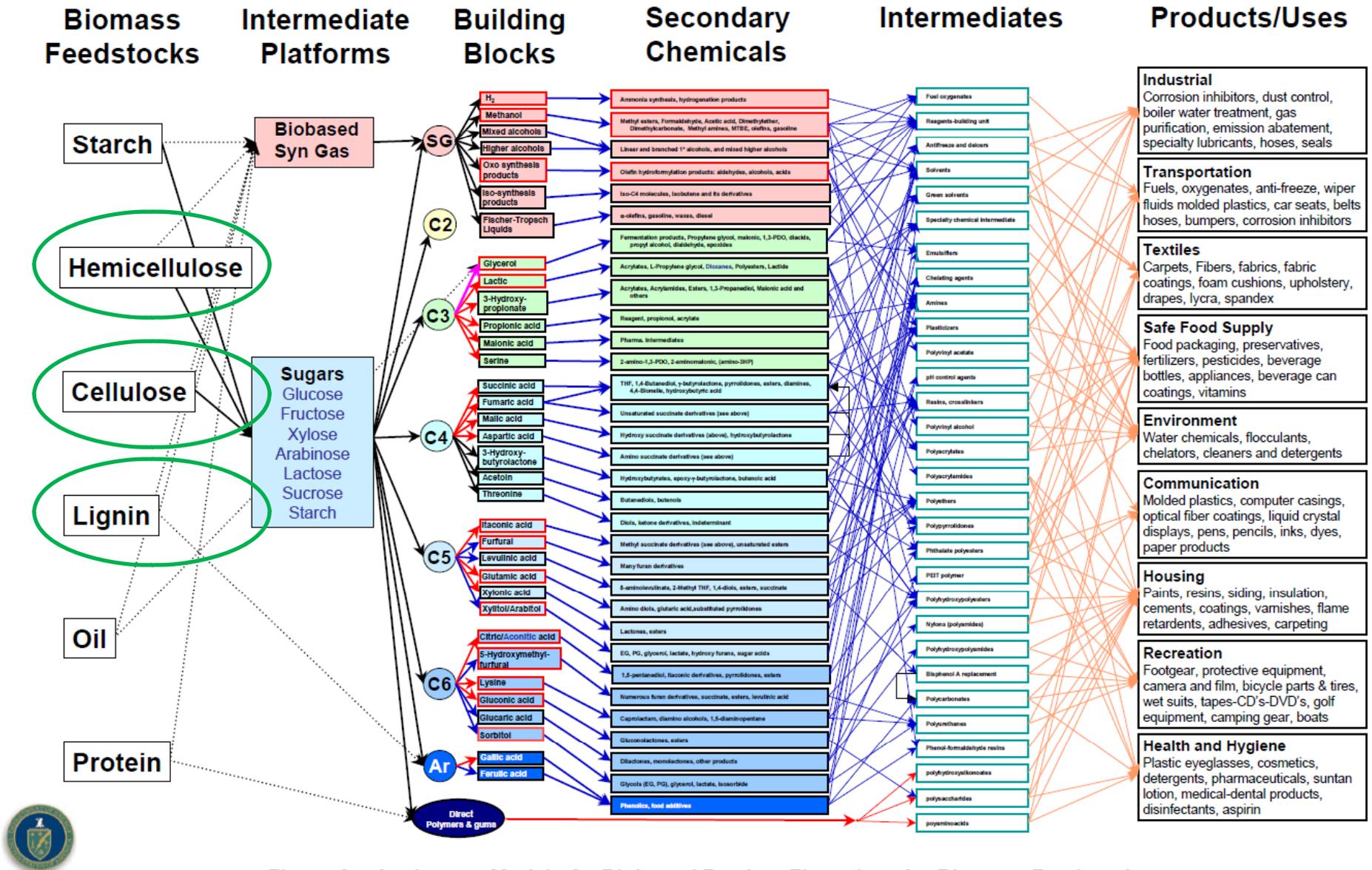


Figure 3 – Analogous Model of a Biobased Product Flow-chart for Biomass Feedstocks

# Petroleum Refinery vs. Biorefinery

## 20<sup>th</sup> Century

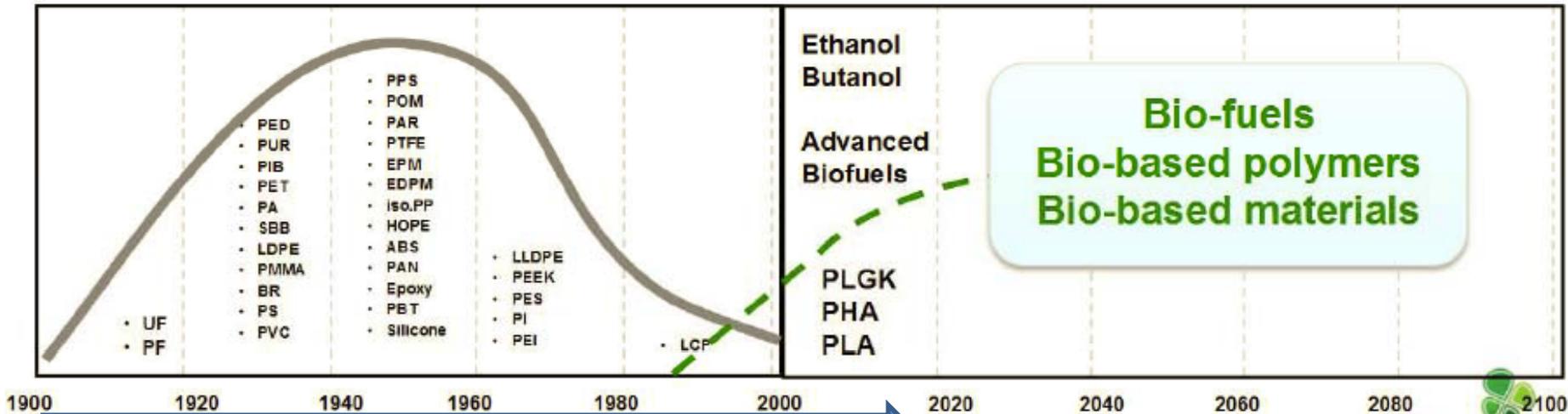


**Sustainability  
Self-reliance  
Climate**

## 21<sup>st</sup> Century



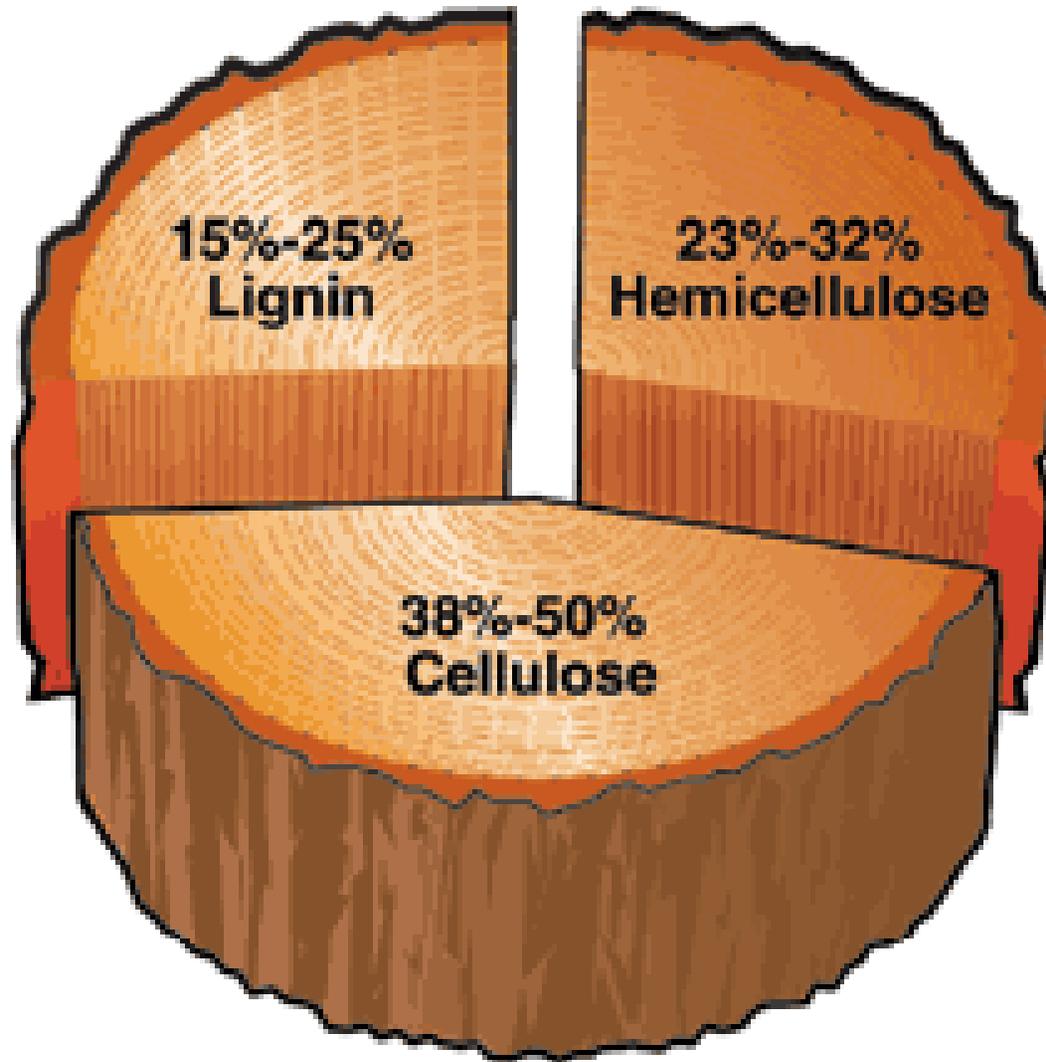
**Bio-fuels  
Bio-based polymers  
Bio-based materials**



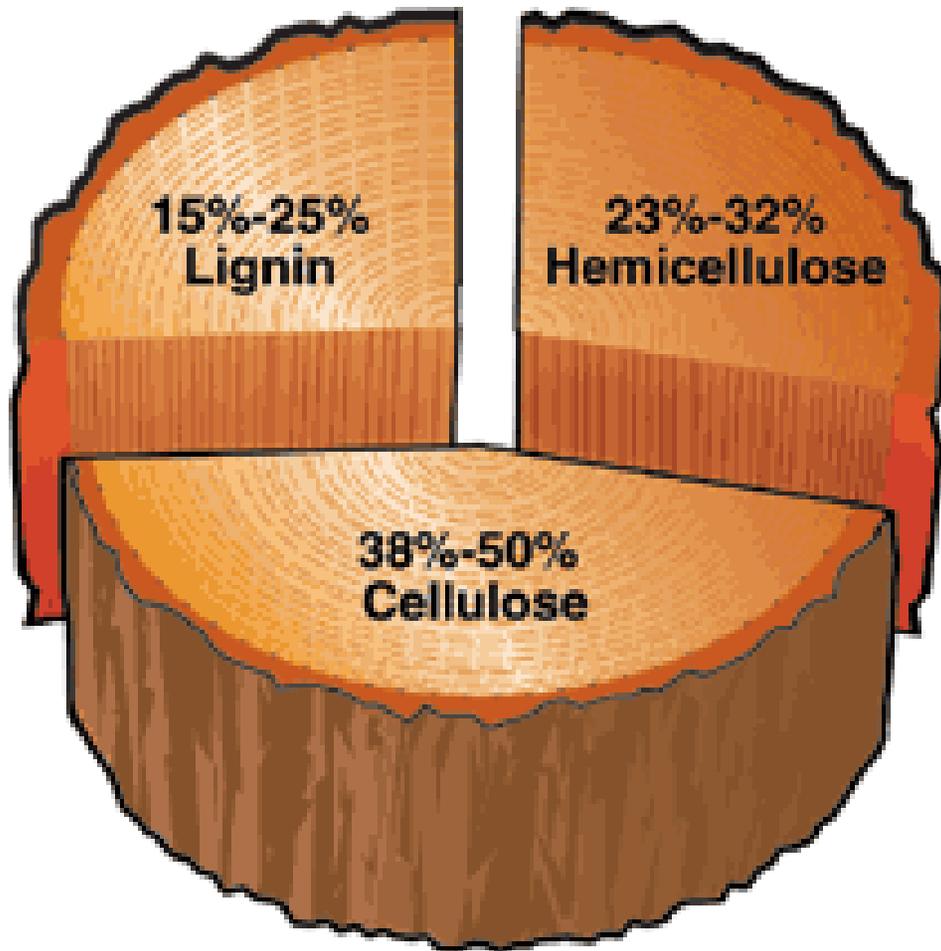
Source: McKinsey & Co., Segetis, Inc.



“It does grow on trees”



From this....



....to this

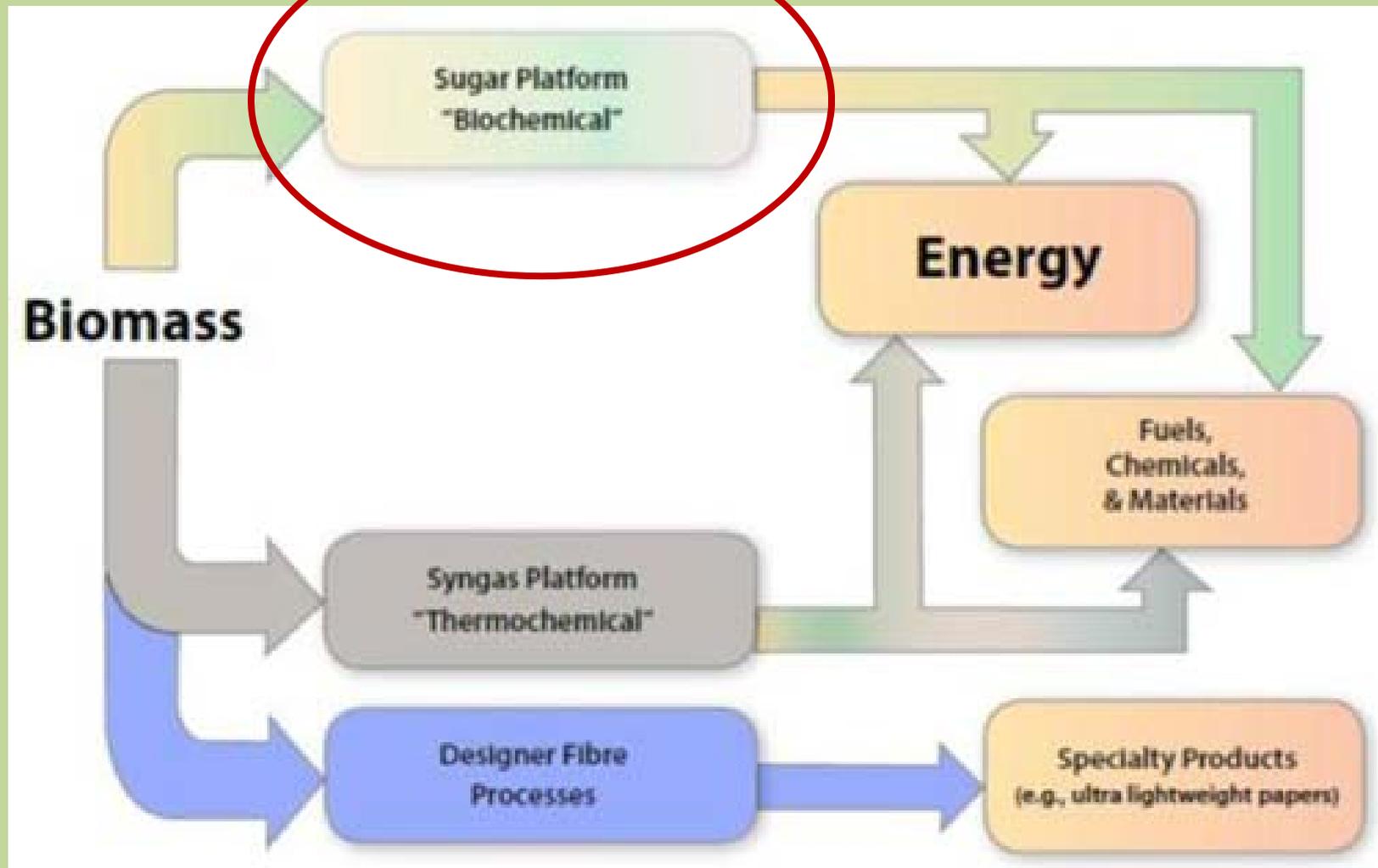
### Chemicals

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

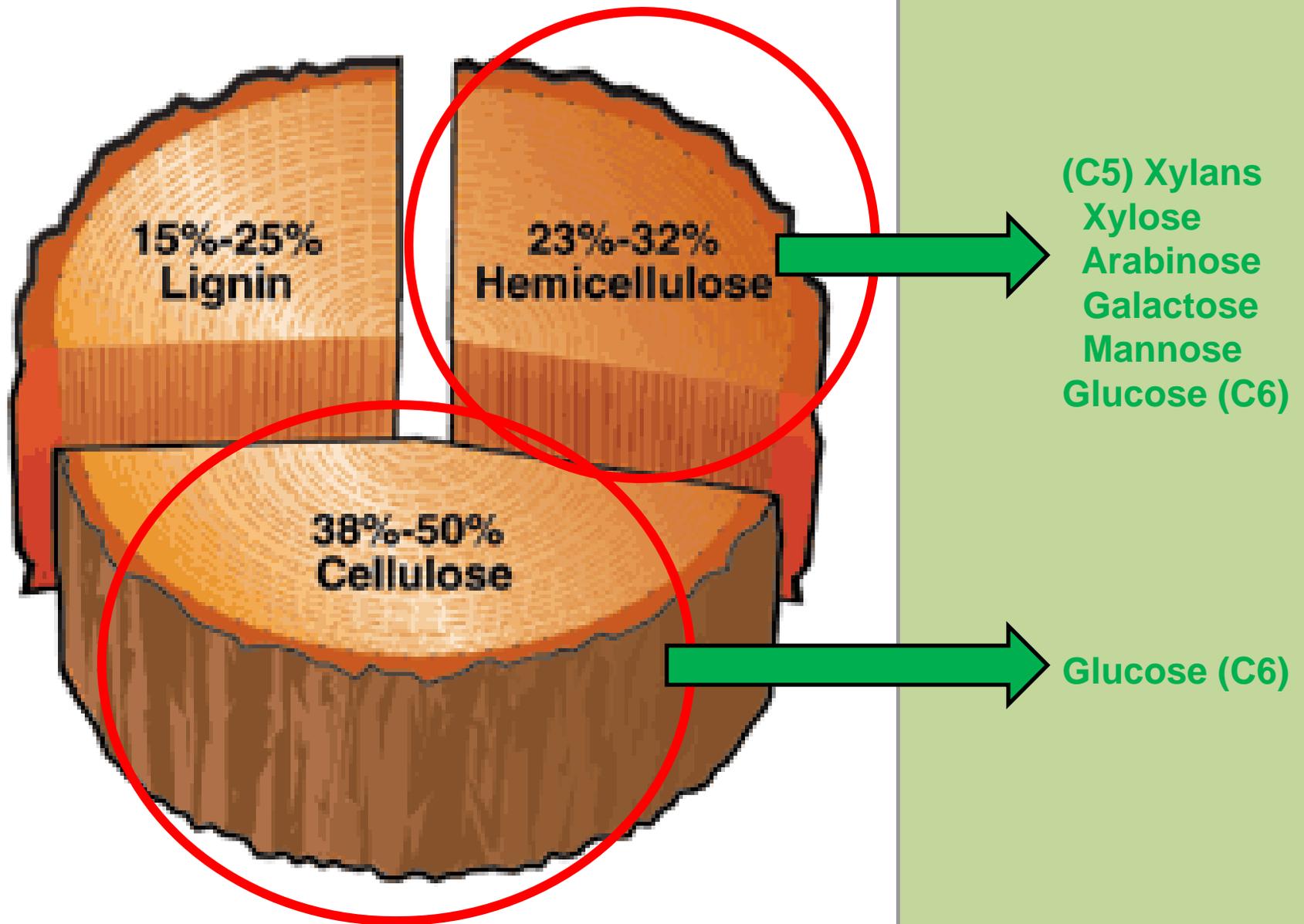
### Transportation Fuels

End Uses

## A Biorefinery.....



# Biochemical Route ("Sugar platform")



## Top Ten Sugar-Derived Building Blocks

1,4 diacids (succinic, malic, fumaric)  
2,5 furan dicarboxylic acid  
3 hydroxy proprionic acid  
Aspartic acid  
Glucaric acid  
Glutamic acid  
Itaconic acid  
Levulinic acid  
3-hydroxybutyrolactone  
Glycerol  
Sorbitol  
Xylitol/arabinitol

....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

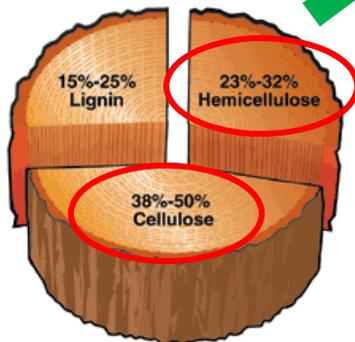
## Transportation Fuels

End Uses

## Sugar

Xylose  
Arabinose  
Galactose  
Mannose  
Glucose

From this....



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# Segetis L-Ketals – Renewable Platform Chemicals

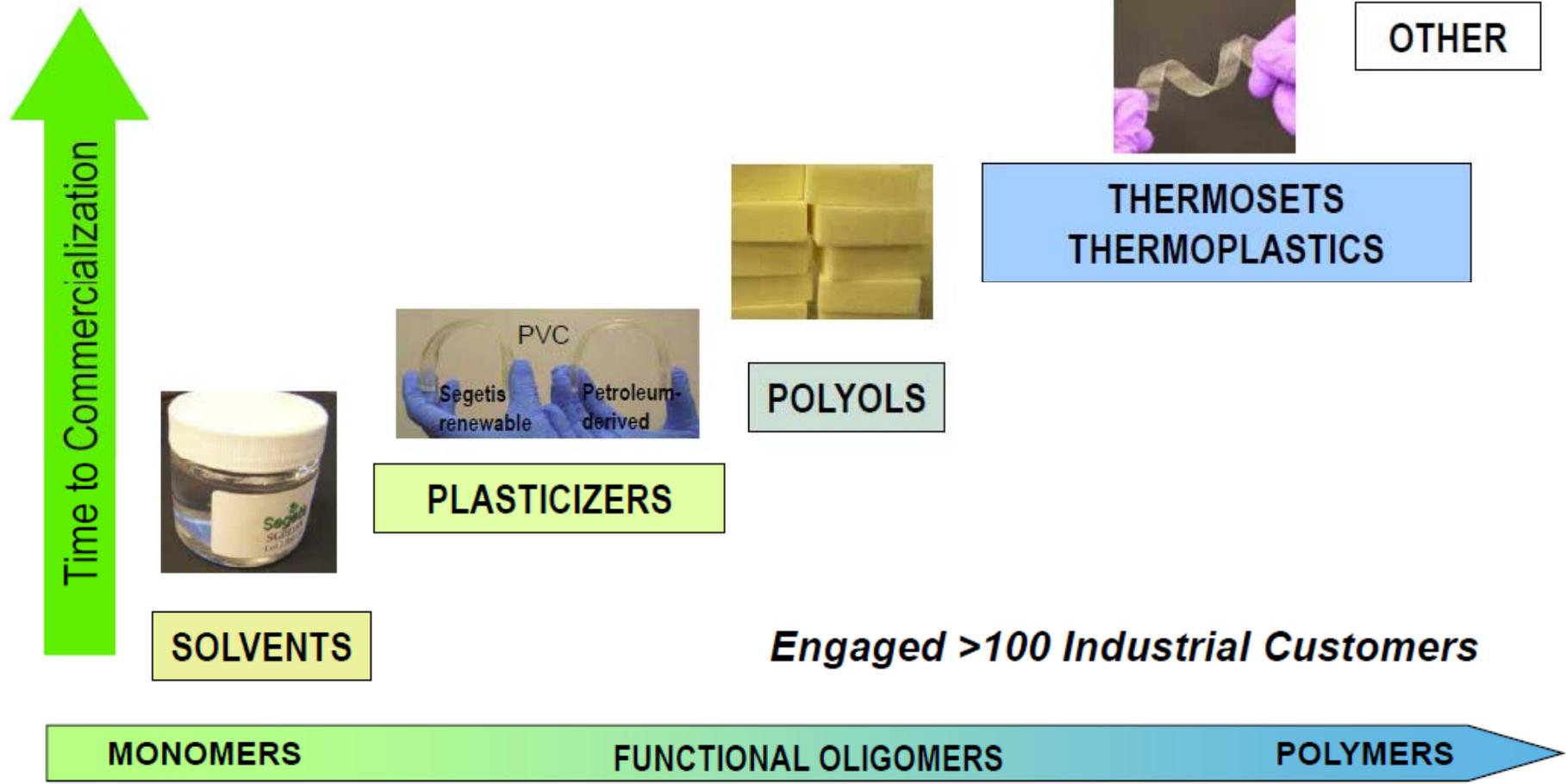


**Brian Tockman**

Nov 30 2010  
E3 Conference  
St. Paul, MN

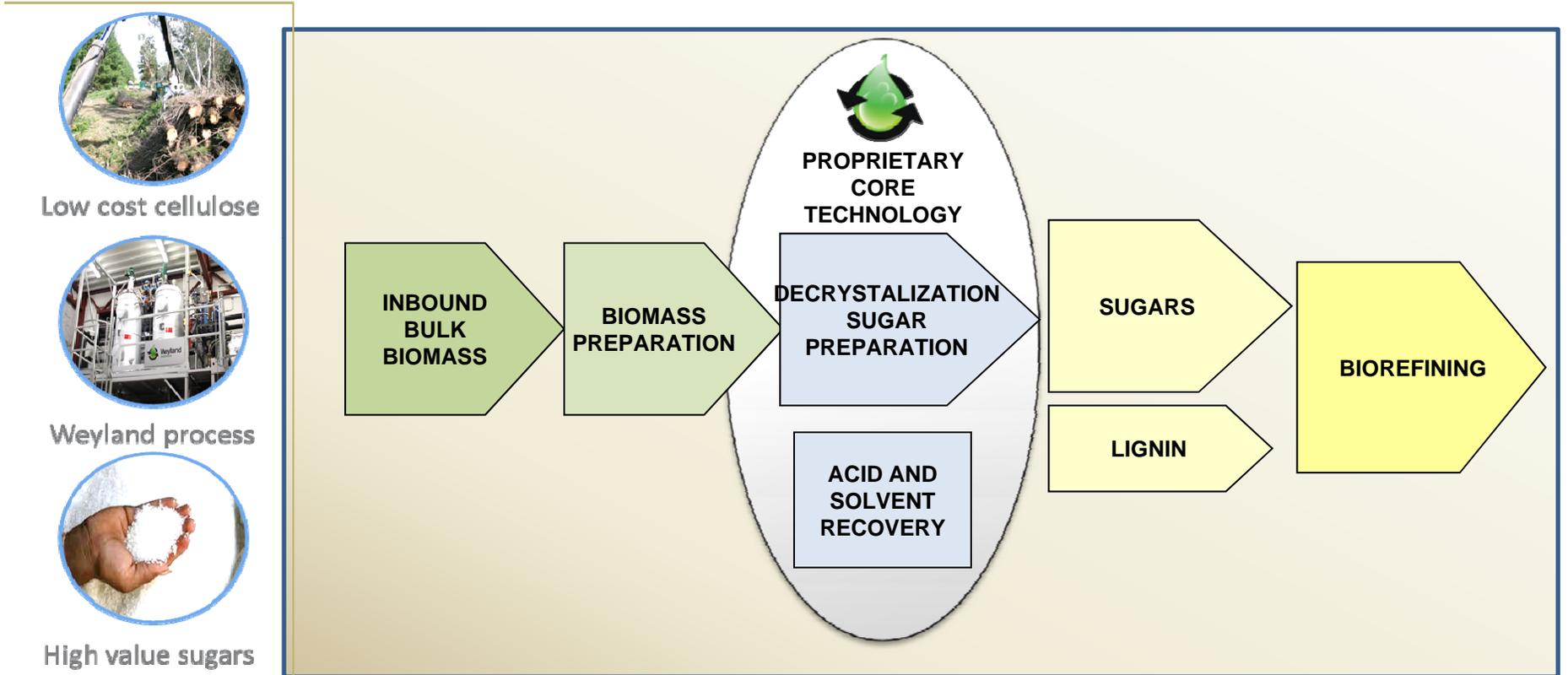


# Segetis L-Ketal Material Systems

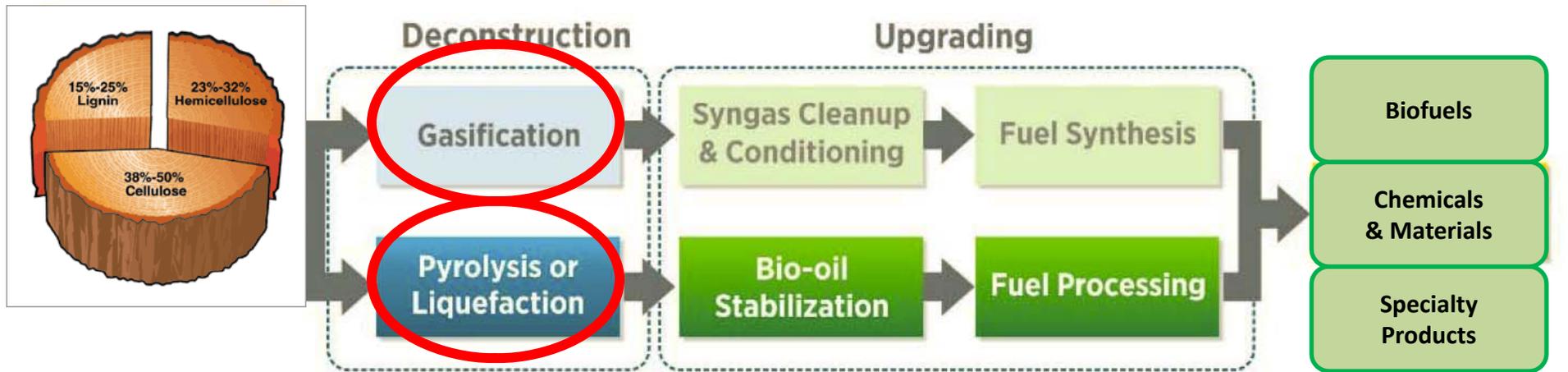




Weyland strong acid hydrolysis process converts woody biomass into fermentable sugars and high quality lignin



# Thermochemical Route



DME (Dimethyl ether): the (green) fuel of the future?



**A fourth line of business at Domsjö Fabriker - green fuels through Chemrec gasification technology**

1. Specialty cellulose



2. Ethanol



3. Lignosulfonate



4. Green fuels: DME & Methanol



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.

**CHEMREC**  
*Energy to succeed*

# Volvo Trucks Takes DME Plunge, Biofuel Or No Biofuel

Friday, June 7, 2013 5:57



**BIODME**





Biomass-derived pyrolysis oil

*Credit: Pacific Northwest National Laboratory*

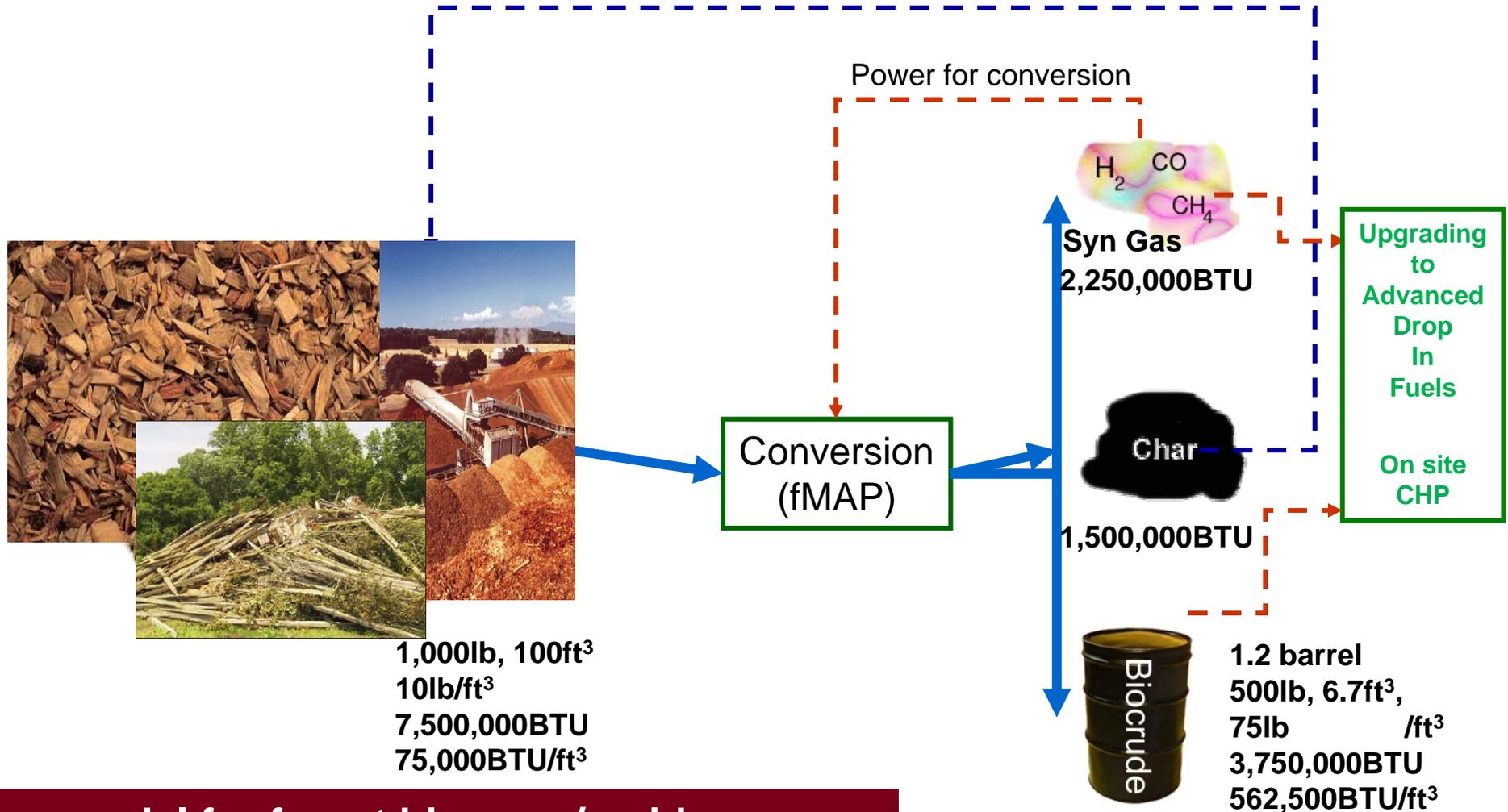
[Is it the future of fuel? New Battelle mobile pyrolysis unit nets 130 gallons of bio-oil per ton](#)

**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



1,000lb, 100ft<sup>3</sup>  
10lb/ft<sup>3</sup>  
7,500,000 BTU  
75,000 BTU/ft<sup>3</sup>

...a model for forest biomass/residues

# fMAP (fast) Microwave-Assisted Pyrolysis



Lab-scale  
2004



Continuous flow reactor  
2007



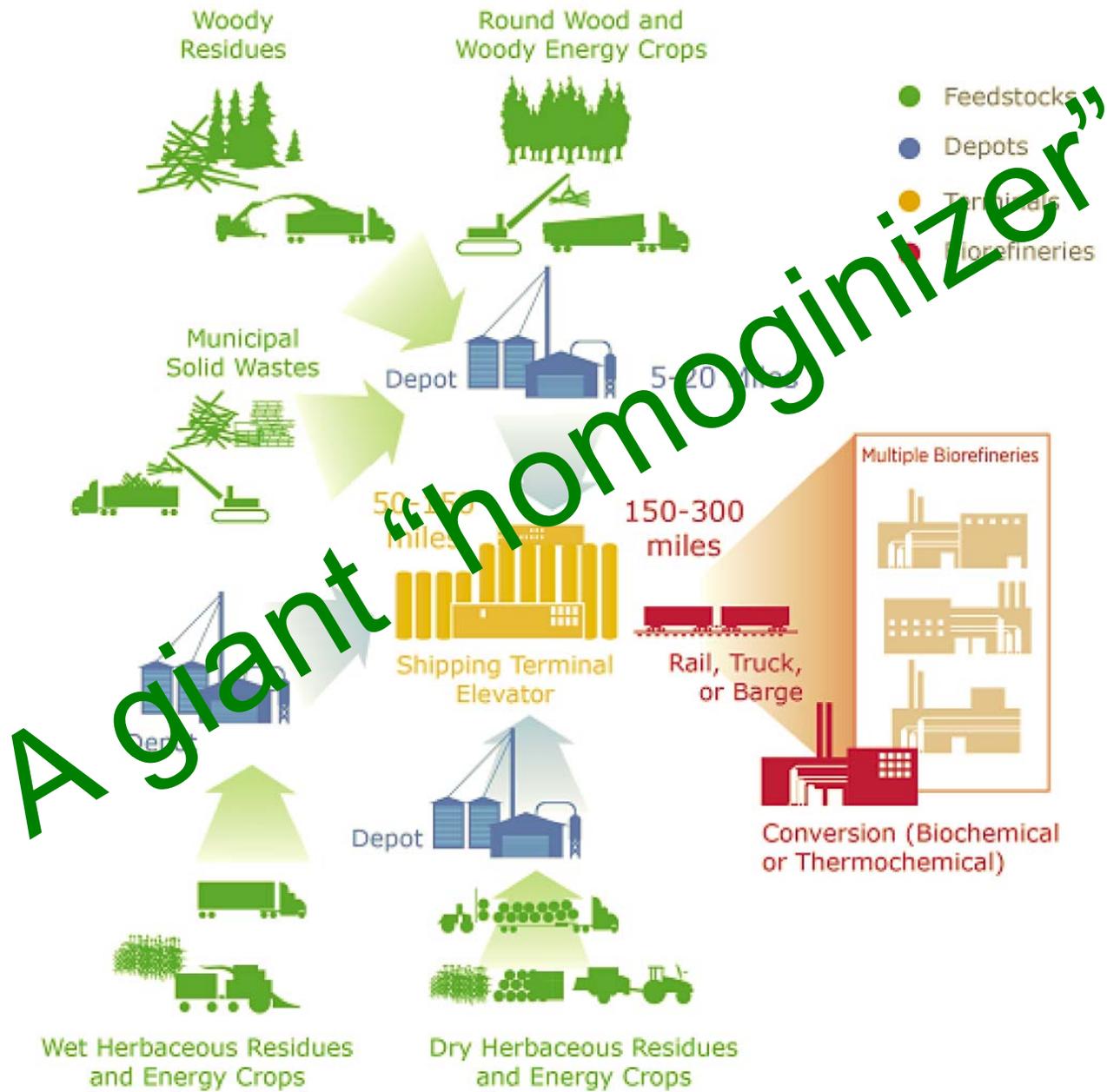
Aspen



Professor Roger Ruan



Portable unit  
2010



A giant "homogenizer"

*An example of the Advanced Uniform-Format Feedstock Supply System.*

# Integrated Torrefaction and Briquetting Demo Plant (12 T/day)

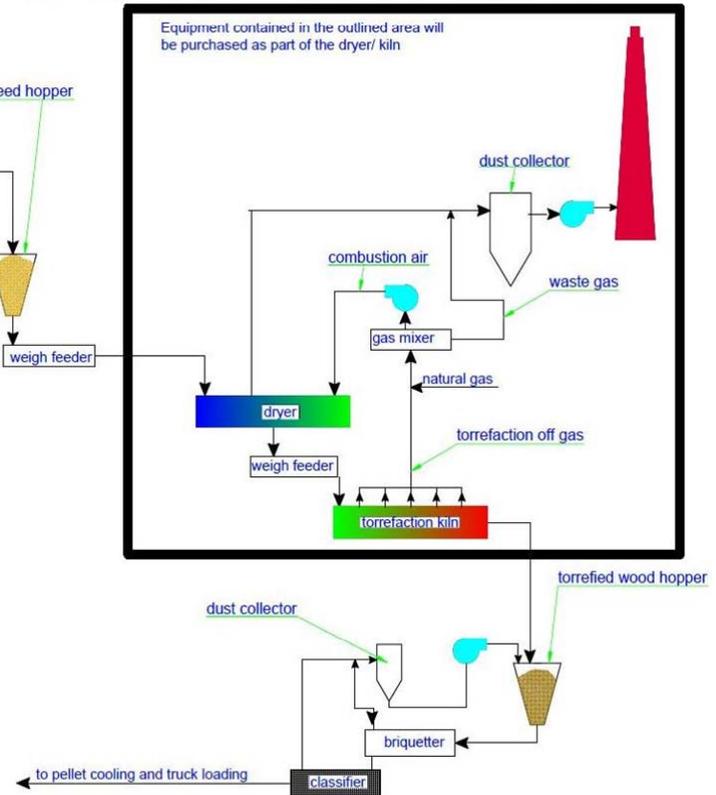
## Torrefaction

A thermochemical treatment process, similar to roasting or mild pyrolysis

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

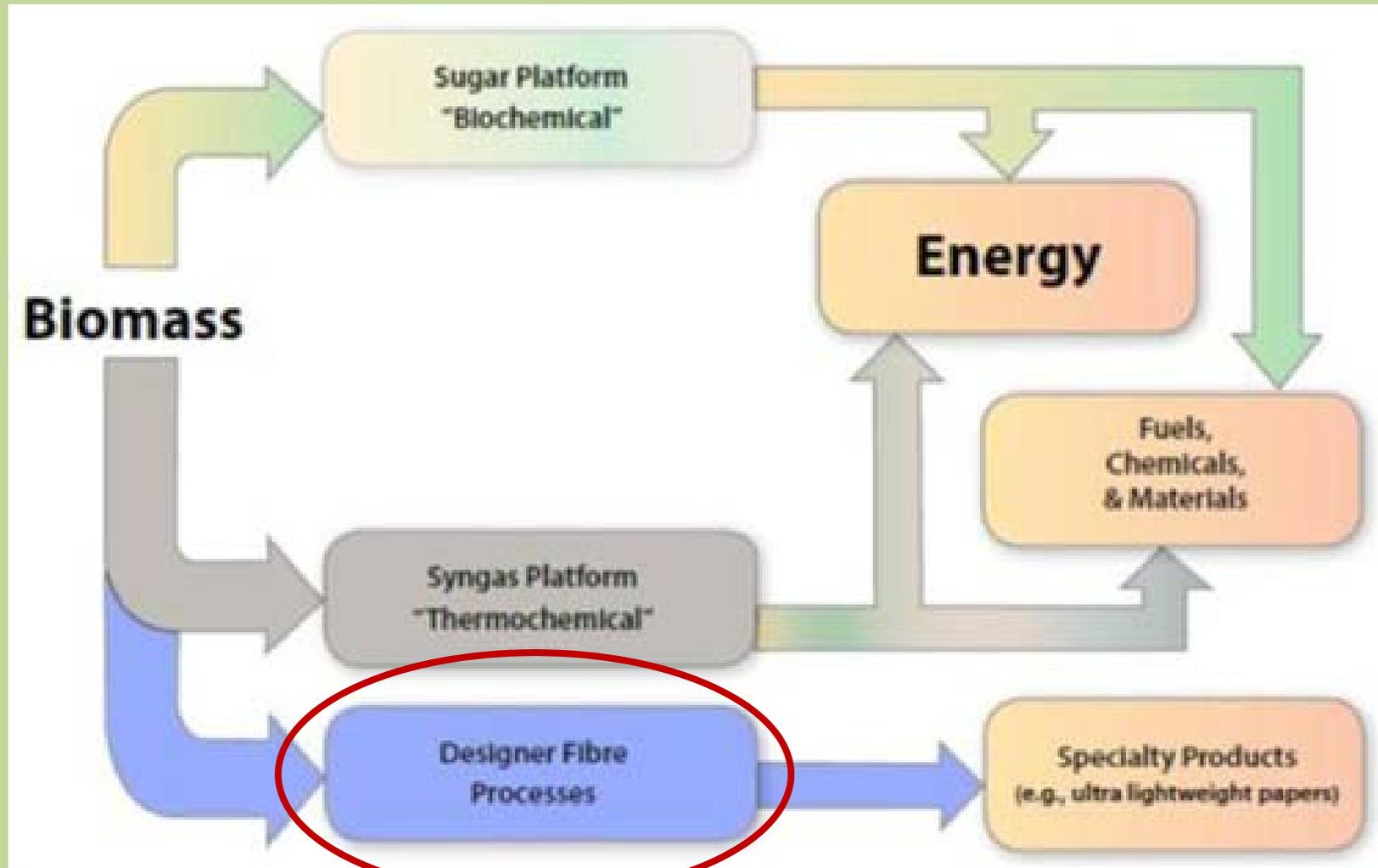


Demonstration Scale Kiln -12,000 kg/day

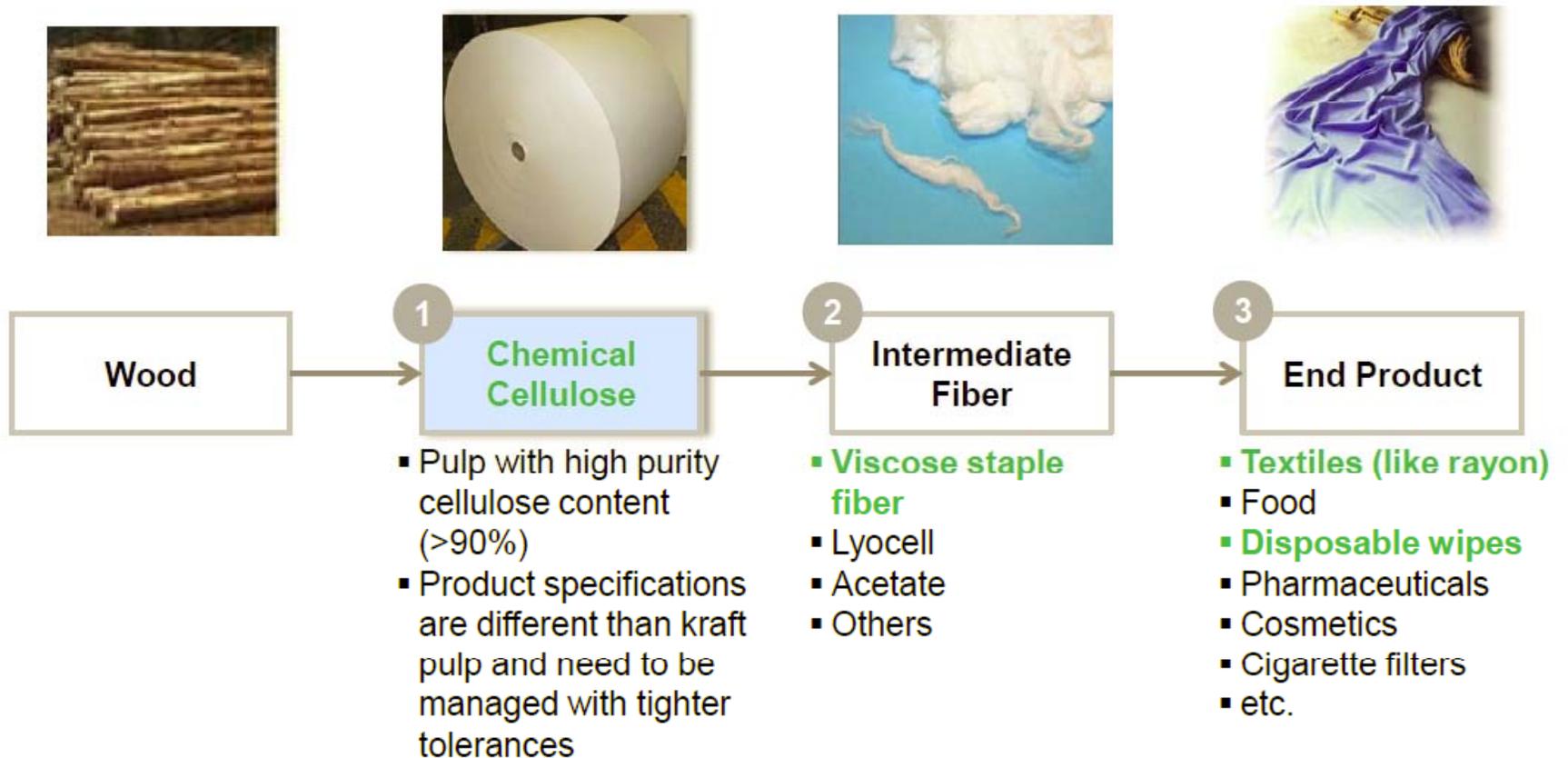


Komarek Briquetter

## A Biorefinery.....



## Specialized Cellulose Value Chain



# Sappi Cloquet Mill



# Nanocellulose ---

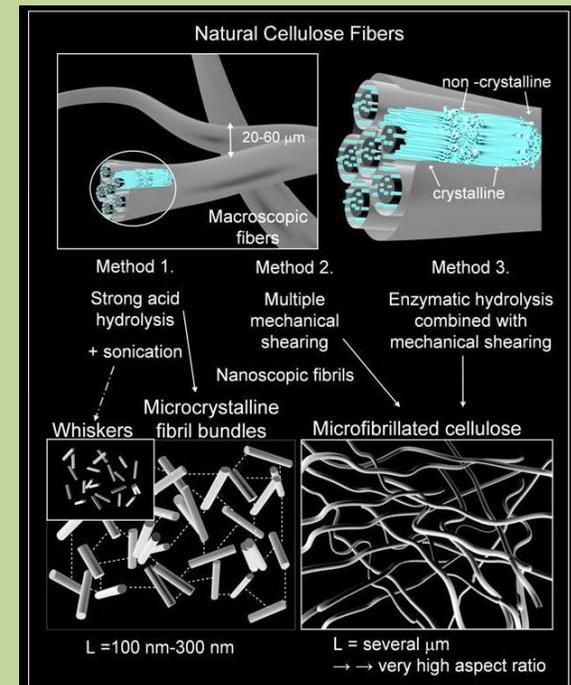
The next “wonder material”?

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



Nanocellulose 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

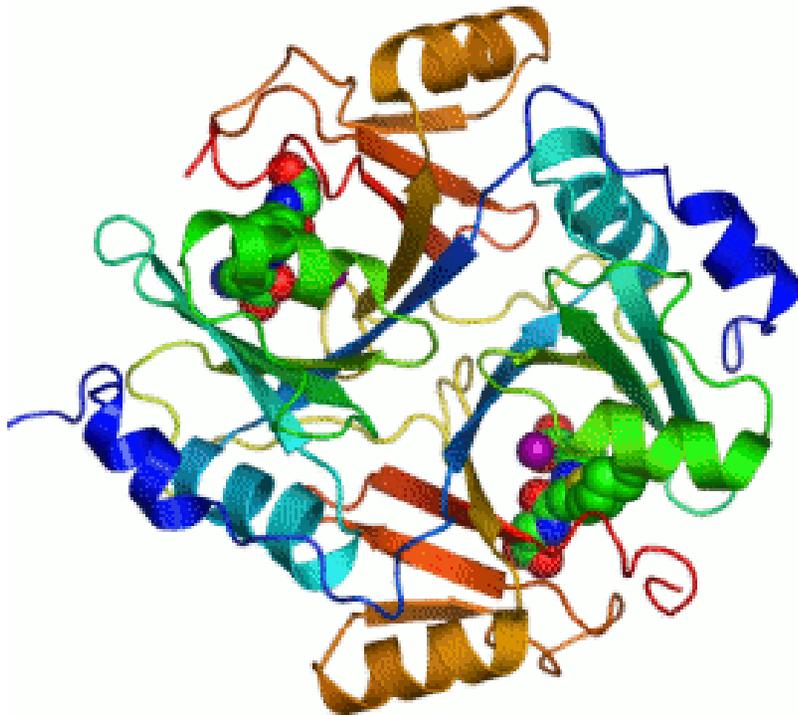
You can make  
anything you  
want out of  
lignin.....

..... Except

\$\$ MONEY \$\$



## 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.*”

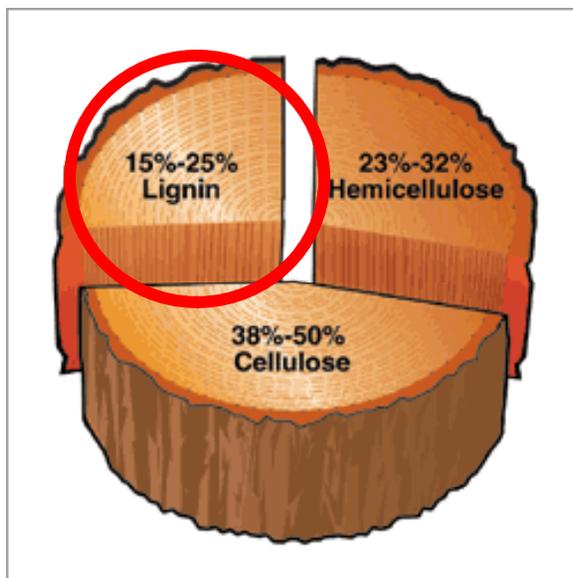


You know, we'd  
plant a lot more  
of you if you'd  
just ease back  
on the LIGNIN!





**Simo Sarkanen,  
Professor**



## 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.

low volume - high value market 10000 €/t

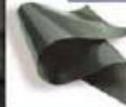


specialty chemicals



bio-plastics

bio-resins for wood-adhesives



activated carbon, carbon-fibres and carbon-black



fuel-additives



bio-bitumen for asphalt



bio-char for soil improvement

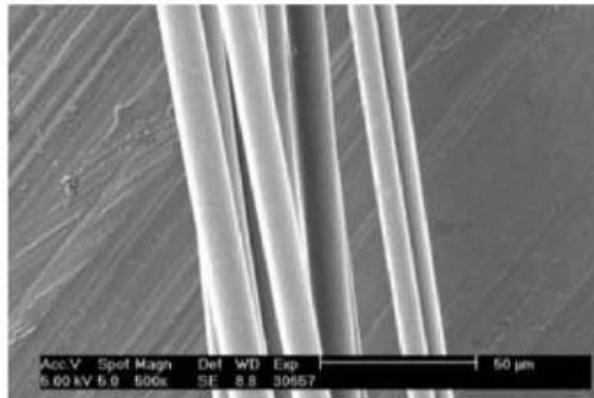
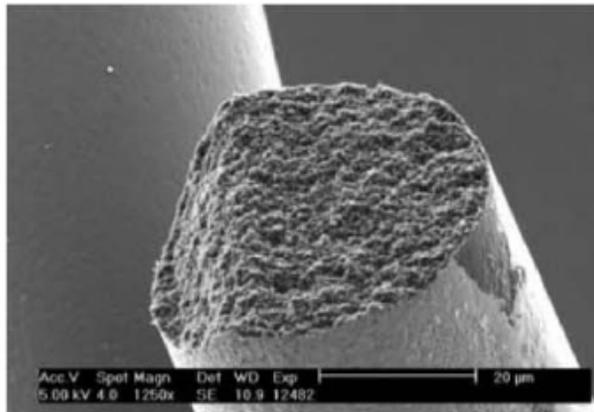


bio-fuel for CHP

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

high volume - low value market 100 €/t

# 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**

# The Coming Age of Wood

By EGDON GLIESINGER

With Graphic Illustrations by  
HENRY BILLING



Simon and Schuster, Inc. • New York • 1949

Forestry and Forest Products Division

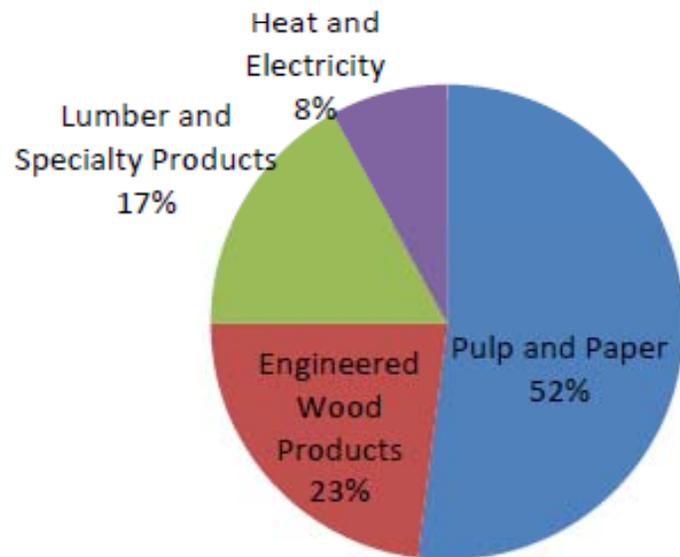


Food and Agriculture Organization  
of the United Nations

## Back to the future?

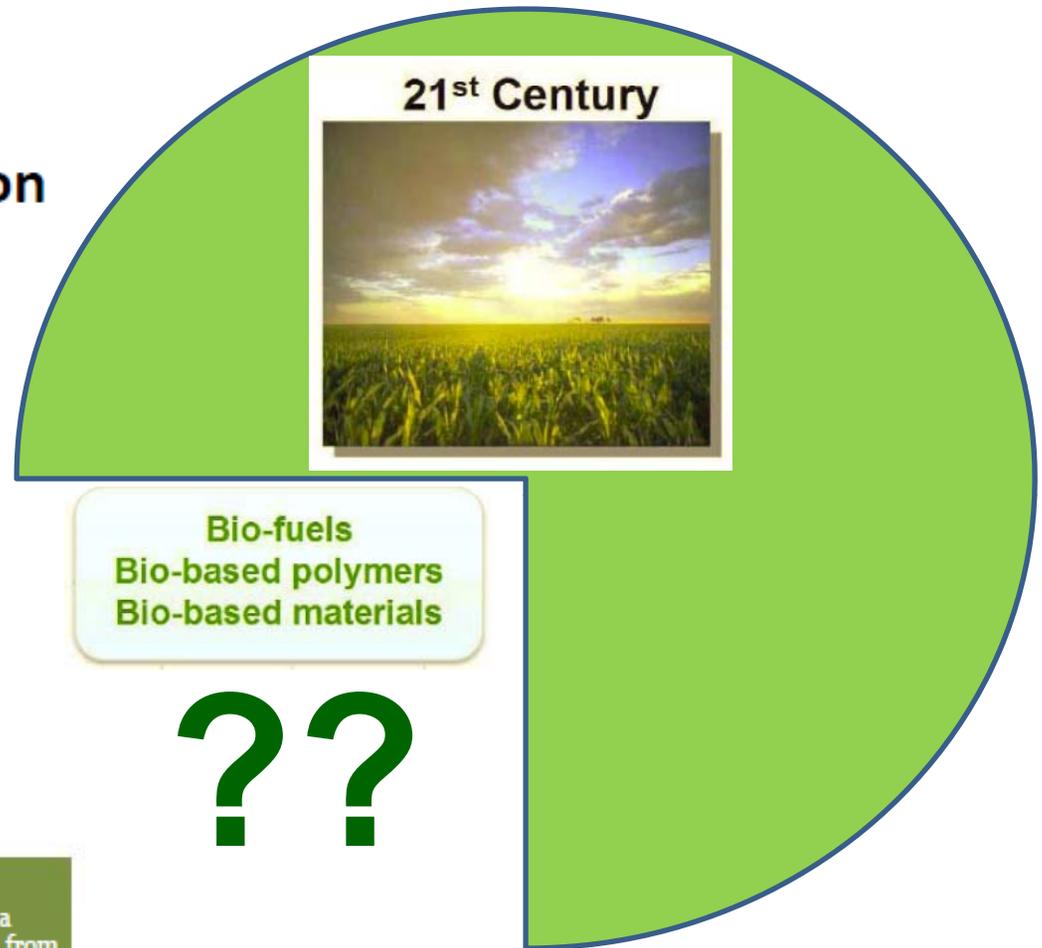
# Today

## Minnesota Wood Consumption



**Figure 5.5**

*Minnesota's forest resources 2009.* (2010) Saint Paul, MN: Minnesota Department of Natural Resources. Pg. 9. Retrieved on September 12, 2011 from [http://files.dnr.state.mn.us/forestry/um/forestresourcesreport\\_09.pdf](http://files.dnr.state.mn.us/forestry/um/forestresourcesreport_09.pdf)





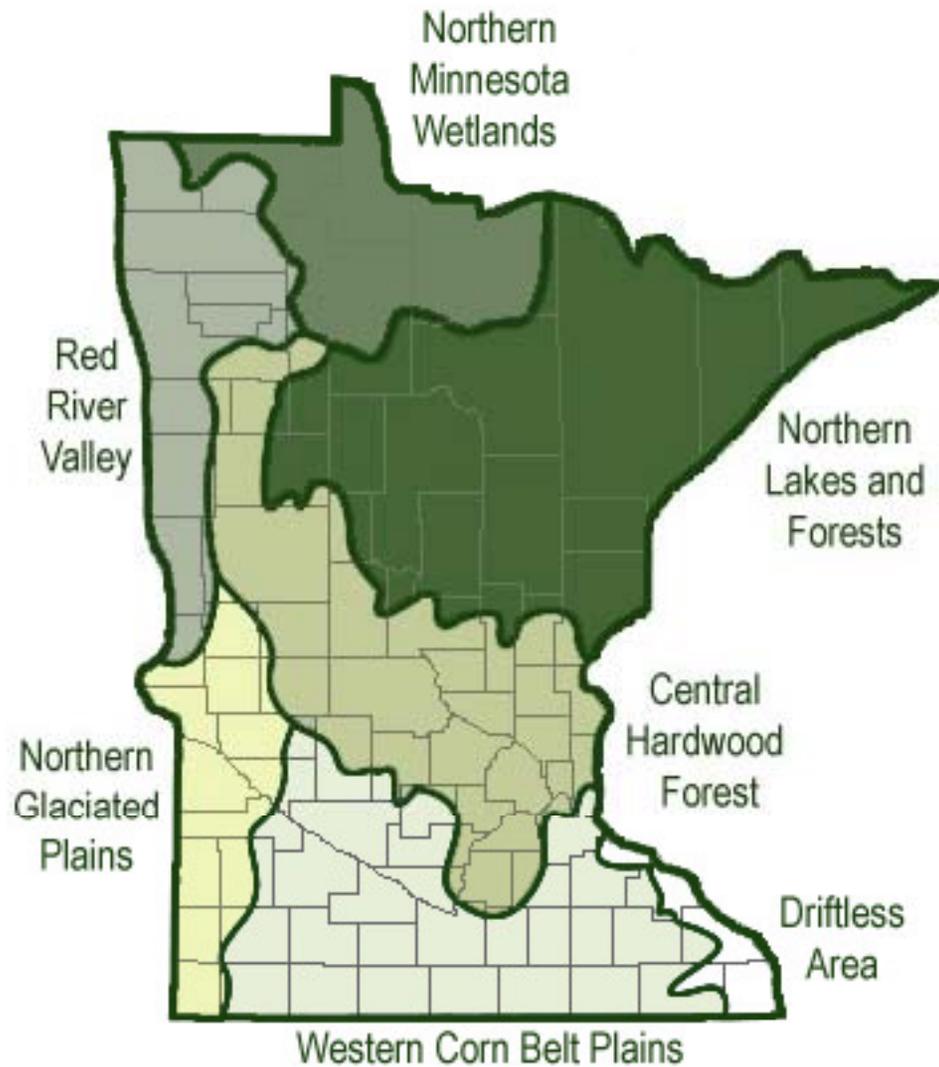
## **HF2465/SF2101: A bill for an act....creating**

- 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?

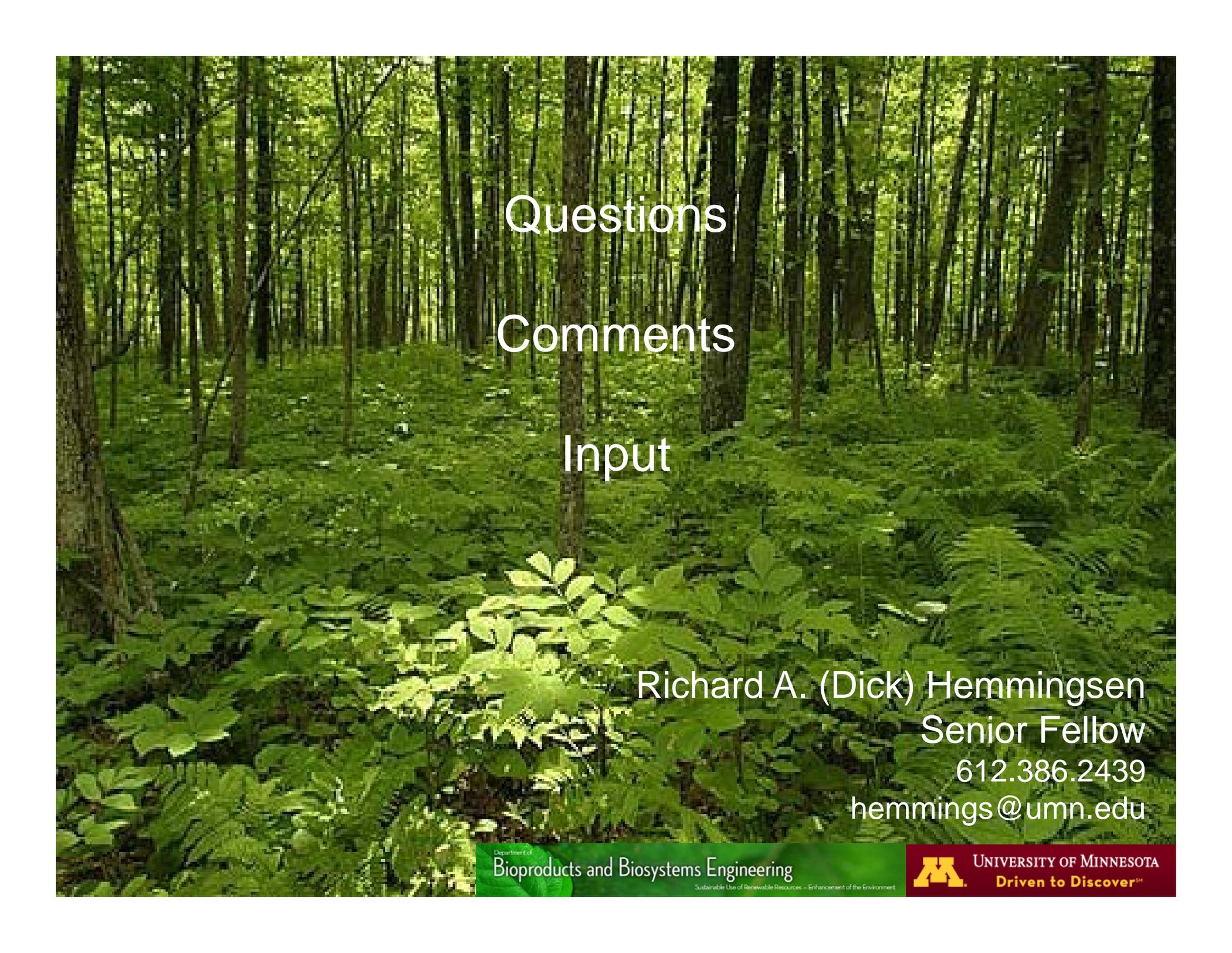


# Why Not

??



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



Questions  
Comments  
Input

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