

# Forest based biorefinery



Skogsindustridagarna 2014

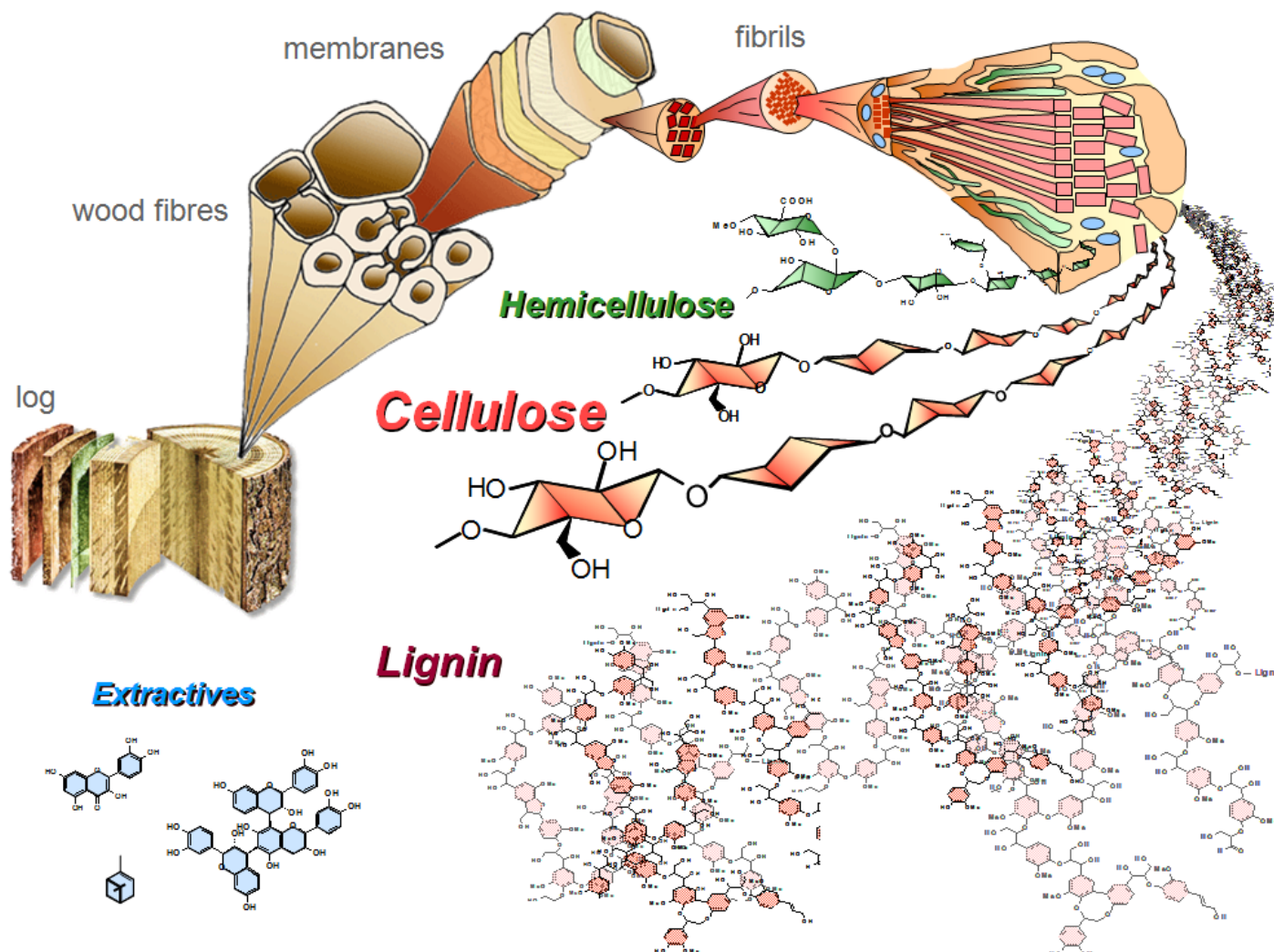
Christian Kugge, SCA R&D Centre

The Sky is the Limit!

Back to the Future!

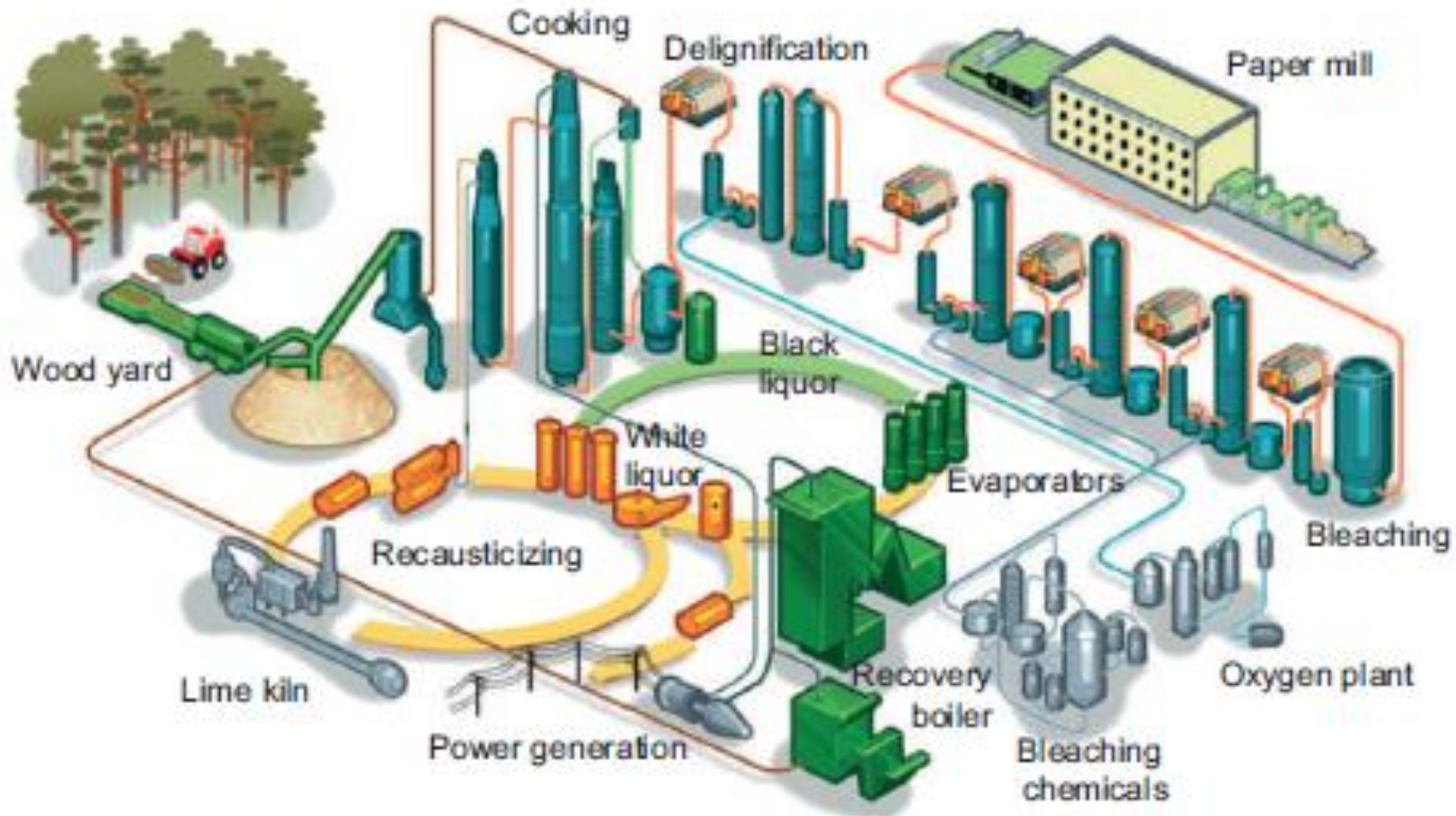


# The Beauty of Wood





# 1<sup>st</sup> Generation biorefinery – the kraft mill



Wood to cellulose fiber, hemicellulose, tall oil, turpentine, methanol, lignin and bark

# 1<sup>st</sup> Generation biorefinery – the kraft mill

- One timber truck = 40 m<sup>3</sup> wood, which gives:
- 8 ton bleached kraft pulp
- 12 m<sup>3</sup> bark (equals 0.6 m<sup>3</sup> oil).
- 16 tonnes black liquor (equals 4 m<sup>3</sup> oil).

... that is used for producing 8 MWh green electricity and the total need of heating for the production process.



# Cellulose and hemicellulose

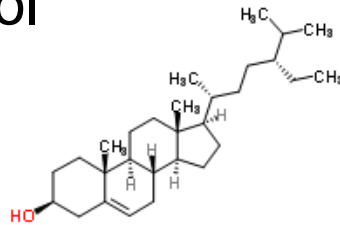


- 420k ton pulp/year at Östrand mill for products such as diapers etc.
- Hemicellulose is present in many process water and in the black liquor
  - ◆ Not separated today
  - ◆ Possible to extract from black liquor and process water (kraft, CTMP, TMP)
  - ◆ Mainly galactoglucomannan (C6) from spruce/pine and xylan (C5) from birch
  - ◆ Many potential use of hemicellulose: thickener or rheology modifier, binder, animal feed, oxygen barrier, sugar source etc.

# Tall oil

- SCA – collect and isolate phytosterols from tall oil in the **1940's**  
e.g.  $\beta$ -sitosterol for the pharmaceutical industry

b.p. 502 °C



- Structurally similar to cholesterol and limit human absorption of cholesterol
- 2014: tall oil to biodiesel

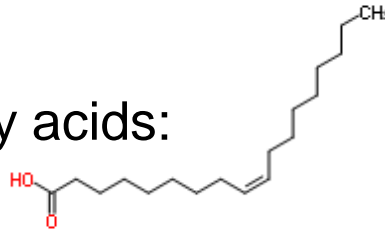
# Tall oil

- Tall oil soap is often removed in the black liquor evaporation by skimming and acidified by  $\text{H}_2\text{SO}_4$  giving crude tall oil (CTO)
- CTO production is ca: 30-50 kg/ton pulp, 50-70% yield.
- CTO is mainly fatty acids (20-40%) and resin acids (25-35%) but also some light oil (sterols) and pitch residue resin

Common fatty acids:

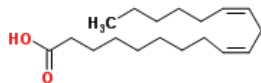
Oleic acid

Linoleic acid



C18, b.p. 360 °C

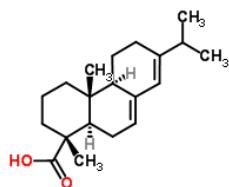
C18, b.p. 230 °C



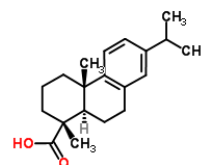
# Tall oil

## ■ Common resin acids:

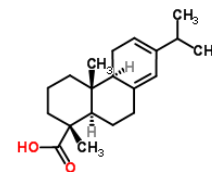
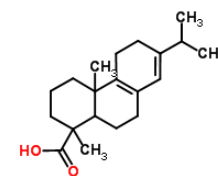
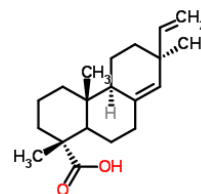
- ◆ Abietic acid
- ◆ Dehydroabietic acid
- ◆ Pimaric acid
- ◆ Palustric acid
- ◆ Levopimaric acid



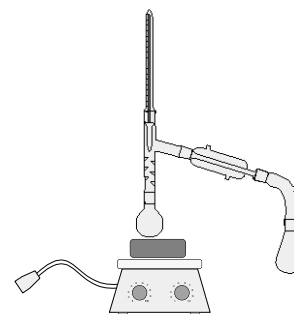
b.p. 440 °C



b.p. 429 °C



Tall oil substances separated by distillation





# Turpentine

- Turpentine , typically 5 kg/ton pulp

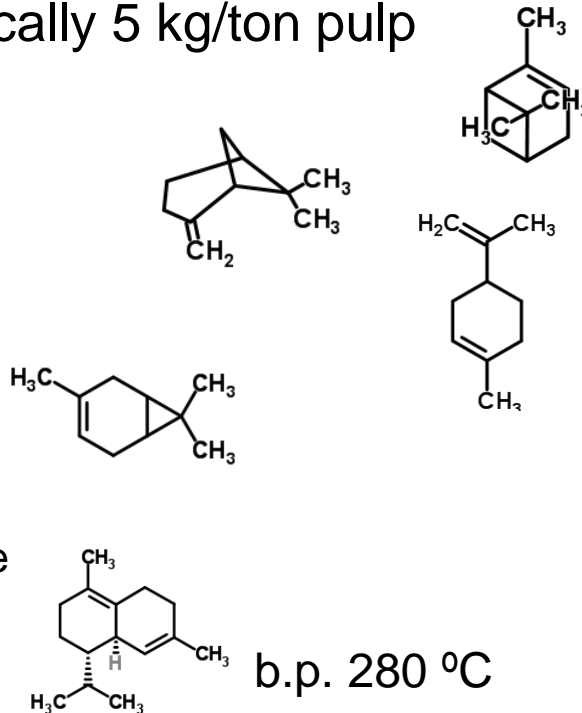
- ◆  $\alpha$ -pinene

- ◆  $\beta$ -pinene

- ◆ Limonene

- ◆  $\delta$ -carene

- ◆ Sesquiterpenes
  - e.g.  $\delta$ -cadinene



b.p. 280 °C

Plus many sulfur substances!

All low b.p. substances also called pine-oil

- ...but also sulfur-free turpentine from TMP mill Ortviken (1980's)

- ◆ Super-clean

- ◆ Smells spuce

- ◆ Potential applications towards high-end perfumery industry

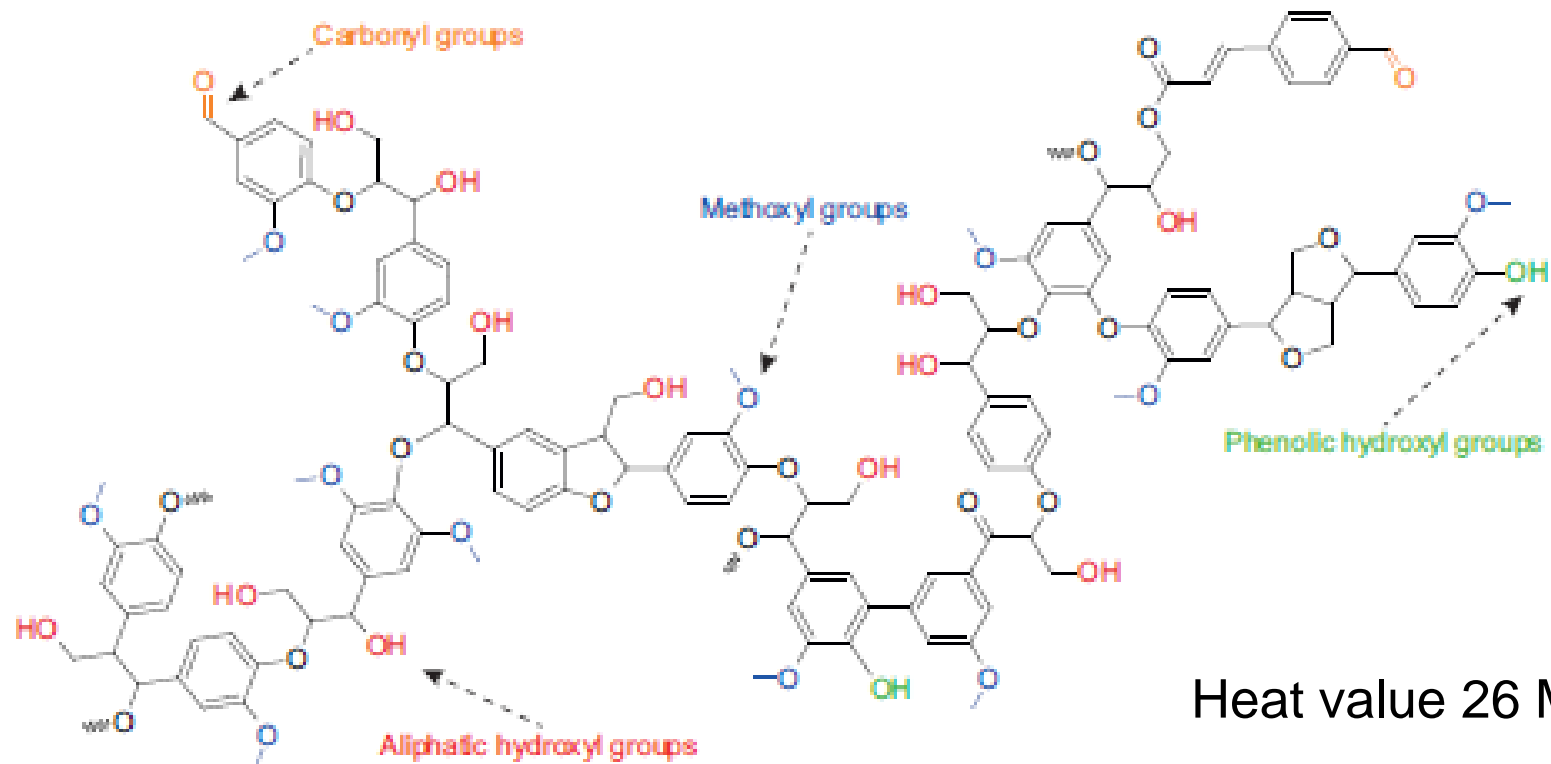
# Methanol



- 10-15 kg/ton pulp (softwood-hardwood)
- Contaminated by various sulfur substances, ammonia, turpentine and water.
- Advantage: limited availability of green methanol.
- The global market is 65 million tons.
- Use in the manufacture of paints, polymers, glues and other products.

# Lignin

x100 g/l in black liquor – burnt for heat and converted to energy  
Östrand mill produce 460 GWh/year

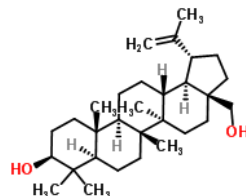


...there is the weak link?

## ■ X tonnes of bark is burnt today

### ◆ Birch

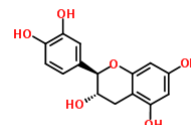
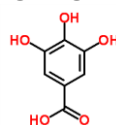
- Potentially extract betulin
- For pharmaceutical and cosmetica industry



”bet on betulin”

### ◆ Pine/Spruce

- Potentially extract tannins, water-soluble phenol based substances with Mw 500- 3000 g/mol
- Bioactive (protecting the tree)
  - Antioxidative and radical-scavenging power
  - E.g. gallic acid and catechin

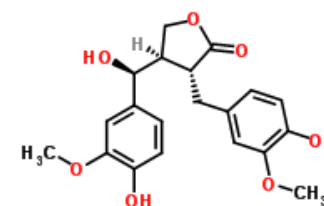


→ In your tea!

- Used in the tanning industry, tanning animal hides into leather
- Potential poly-ol source for further chemistry, replace phenols in resins and adhesives

# Wood knots

- Wood knots is cooked multiple times today
- Potential to separate from the process and extract chemicals
  - ◆ Wood knots are rich in lignans and 70-85% of the lignans is 7-hydroxymatairesinol (HMR)
  - ◆ Åbo Akademi baby (Prof. Bjarne Holmbom) – commercial in Finland
  - ◆ HMR is sold to the healthy food industry as food additive
    - Believed to prevent breast and prostate cancer
  - ◆ HMR is also present in low concentrations in process water (kraft, CTMP and TMP)

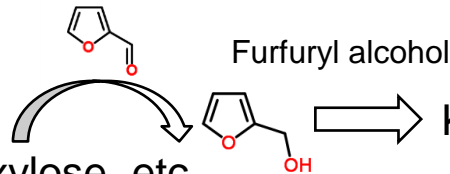




# 2<sup>nd</sup> generation biorefinery

## ■ C5 & C6 sugars

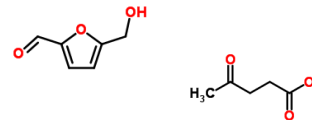
- ◆ Glucose, mannose and xylose, etc.



⇒ Kebony: softwood to tropical wood

## ■ Platform (building blocks) chemicals

- ◆ Hydroxymethyl furfural (HMF)
- ◆ Levulinic acid
- ◆ Butanol, iso-butanol
- ◆ Etc



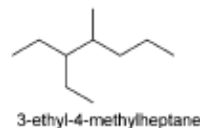
## ■ Fuels

- ◆ Drop-in fuels

- Ethanol 24 MJ/kg
- 2,5-dimethyl furfural (DMF)
- $\gamma$ -valerolactone
- Levulinic esters (biodiesel)
- Etc



- ◆ Cellulosic gasoline



# 2<sup>nd</sup> generation biorefinery

## ■ Novel kraft lignin applications after extracting lignin from black liquor

◆ Carbon fibres

◆ Lignin nanoparticles

◆ Lignin in advanced materials

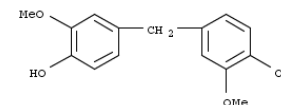
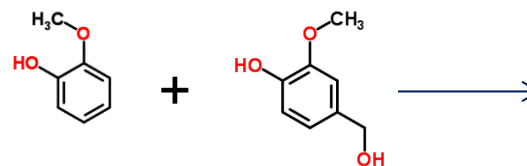
◆ Aromatics, e.g. vanillin, guaiacol

◆ Liquified lignin as drop-in feedstock for an oil refinery

◆ Water-soluble cationic lignin

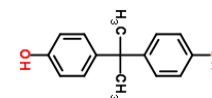
◆ Esterification of lignin – hydrophobic material

→ e.g. Lignoboost



Guajaform

Replace bisphenol A



ACS Dallas 2014

# Innventia activities at University of Tennessee

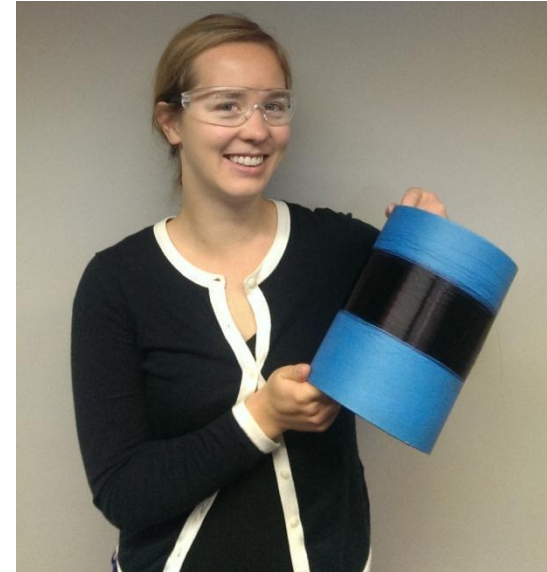
- Lignin multifilaments for carbon fibres



October/ November 2013

The first successful spool with  
lignin multifilaments produced  
from 100% softwood lignin

Work financed by: Stiftelsen Gunnar  
Sundblads Forskningsfond, Innventia  
& Valmet

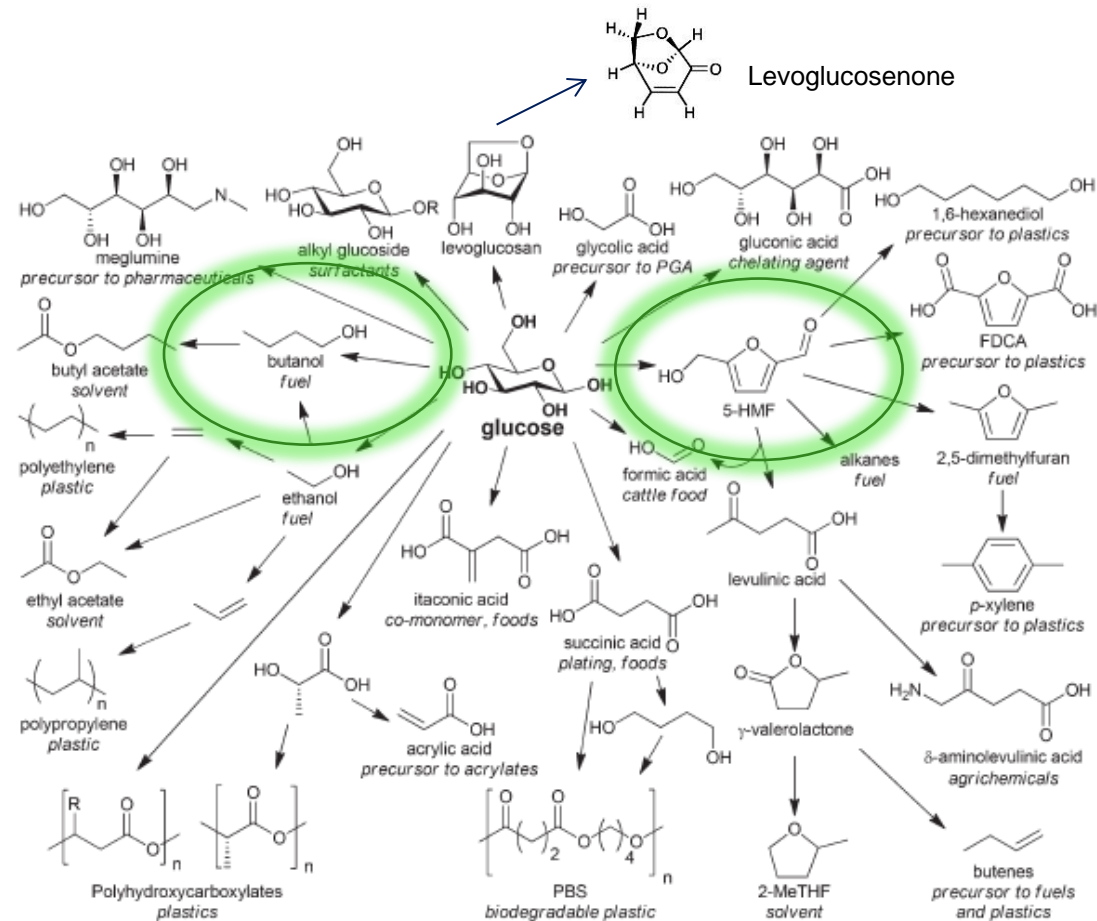


Grant to: Hannah Schweinebarth  
Supervisor: Per Tomani

# 2<sup>nd</sup> generation biorefinery

## ■ The sugar platform

- ◆ Sugar is the new oil



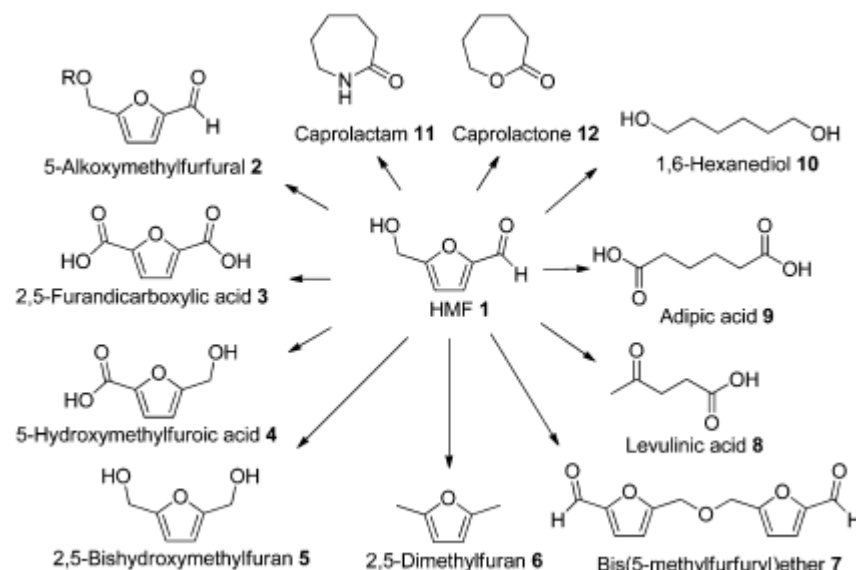
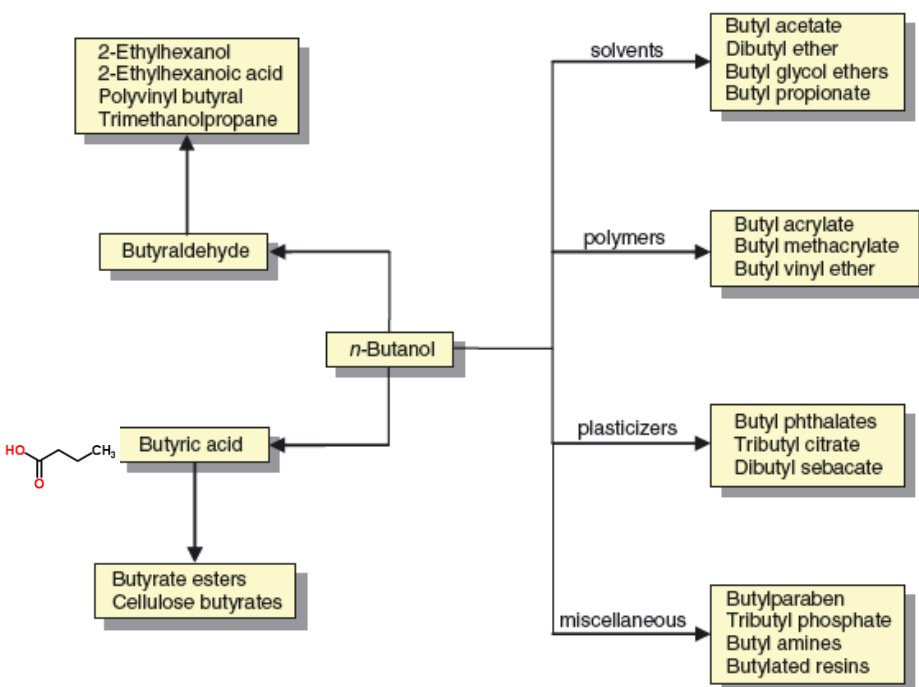
How? Old fashion biochemistry or novel catalytic chemistry or both?

# 2<sup>nd</sup> generation biorefinery



## ■ Platform chemicals

- ◆ HMF
- ◆ Butanol
- ◆ Etc...







# 2<sup>nd</sup> generation biorefinery



- Liquid fuels
  - ◆ Petrol or gasoline mainly C8
  - ◆ Jetfuel mainly C12
  - ◆ Diesel mainly C16
  
  - ◆ From C5&C6 sugars as earlier
  
  - ◆ From lignin (e.g. hydrothermal liquefaction and hydrogenation)
  
  - ◆ Or both (e.g. fast catalytic pyrolysis)

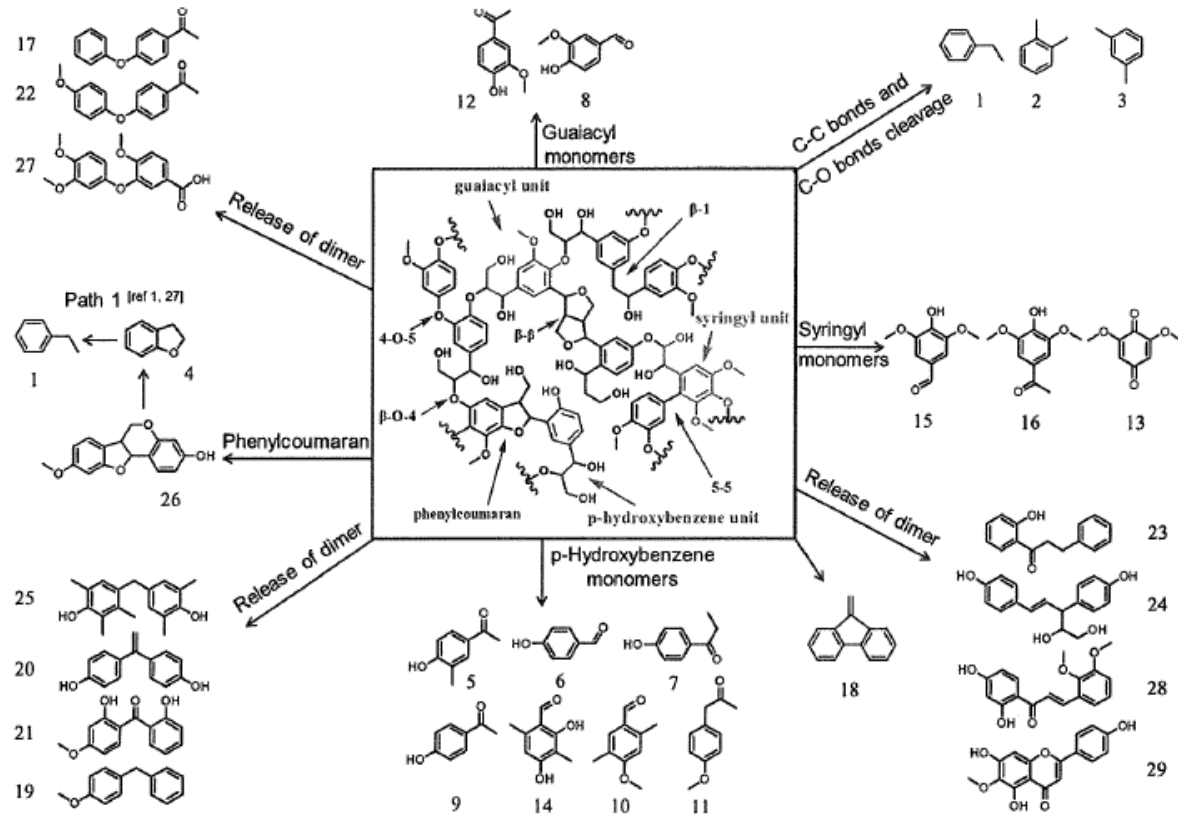
# 2<sup>nd</sup> generation biorefinery

## ■ Lignin

- ◆ Depolymerized lignin  
25-30% O<sub>2</sub>
- ◆ ...17% O<sub>2</sub> in phenol

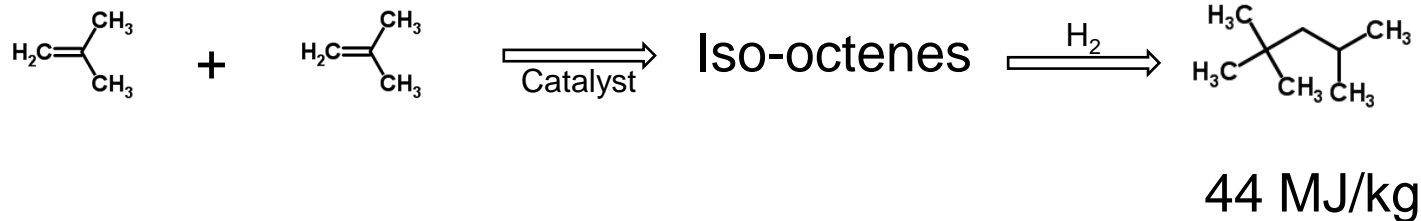
## ■ Many different technologies

## ■ Sometimes called the lignin soup



# 2<sup>nd</sup> generation biorefinery

- What about other fuels like 100% drop-in fuel (as cellulosic gasoline earlier)
  - ◆ Micro-organisms converts sugar to iso-butene (g) which is dimerized to iso-octane
  - ◆ Collaboration between Global Bioenergies and Audi

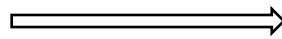


# 2<sup>nd</sup> generation biorefinery

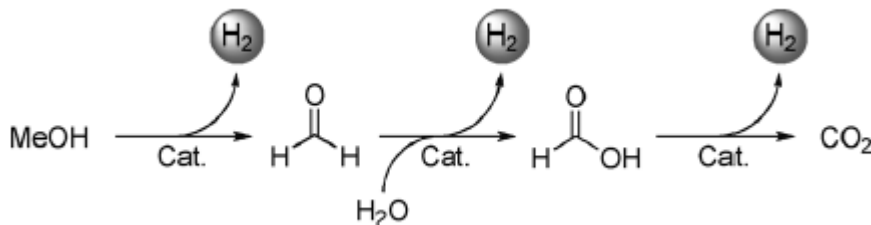
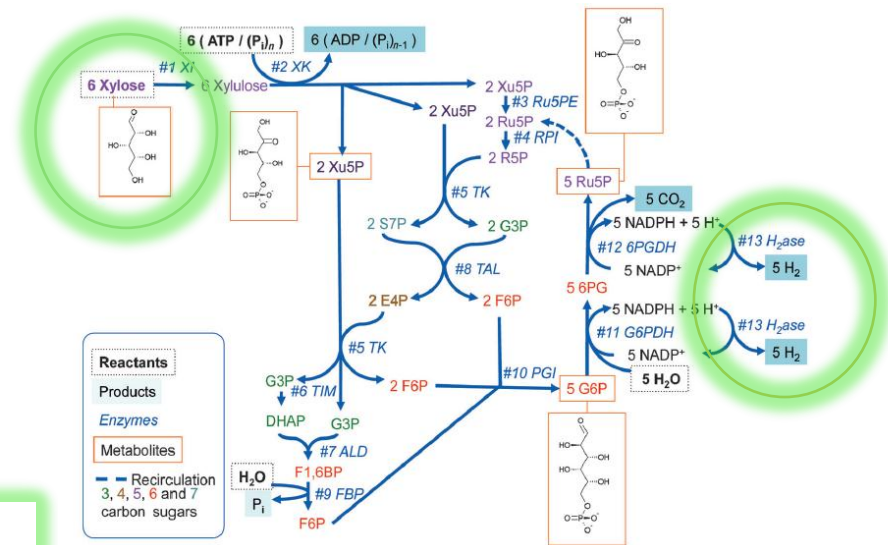
- Hydrogen is of increasing importance moving towards chemicals and fuels
  - ◆ Natural gas + steam
  - ◆ Water electrolysis (ok, green electricity)

## ■ What about green hydrogen? – intensive academic research

- ◆ Biogas + steam
- ◆ Syngas purification
- ◆ Biochemistry

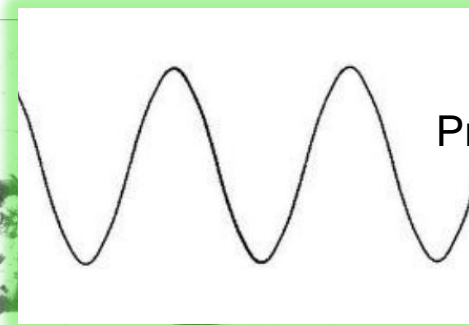
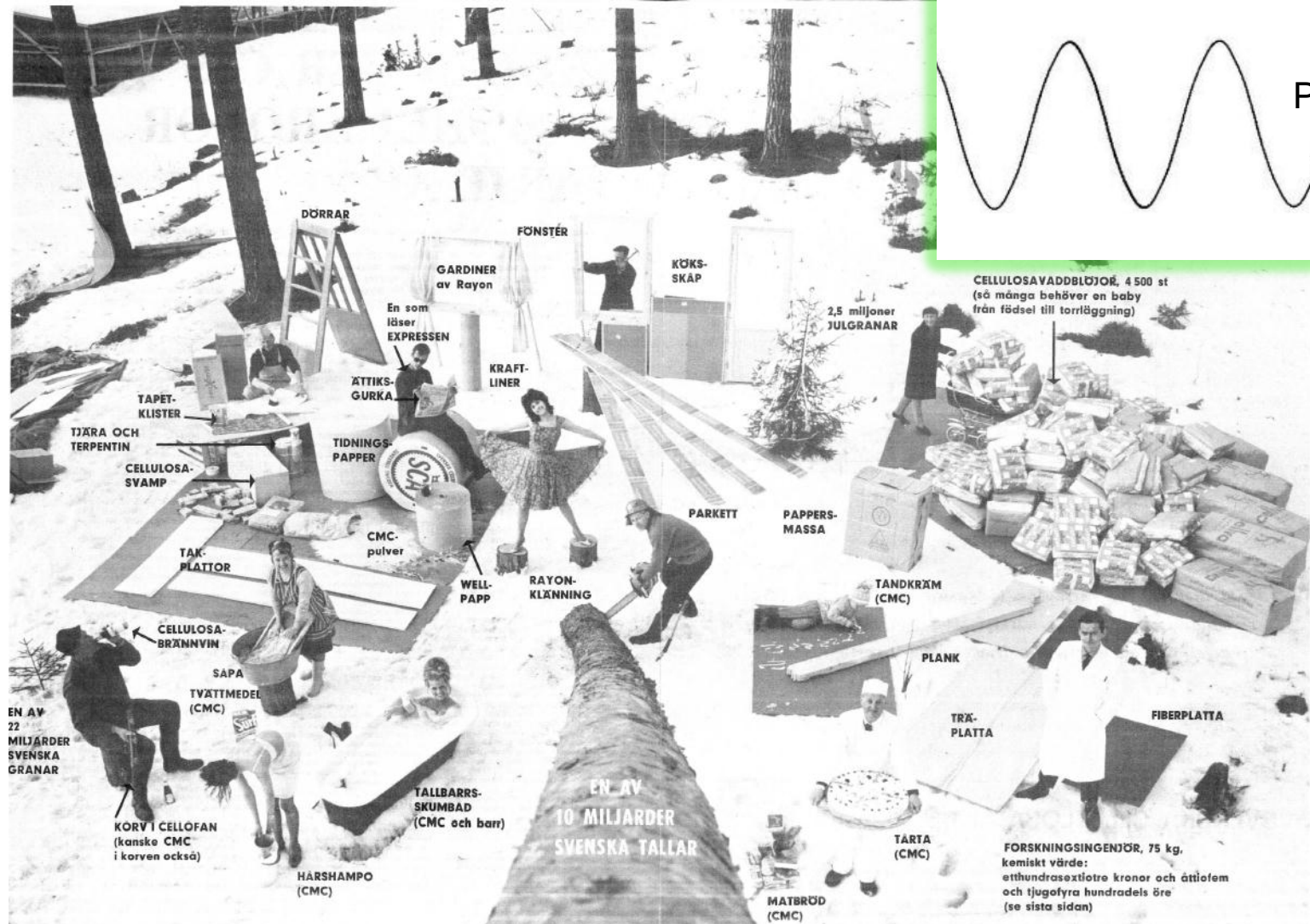


- ◆ Methanol





# Back to the future - wood products 1965 (Expressen)



Product cycle

# 2<sup>nd</sup> generation biorefinery



Is the sky the limit? – YES!

By 2020 the Green Chemistry market will reach \$98.5 billions



Walmart wants our trees!



**SCA**  
*Care of Life*

**Thank you!**

A decorative green wavy line that spans the width of the slide at the bottom.