Biorefineries

What do we know? Where are the problems?

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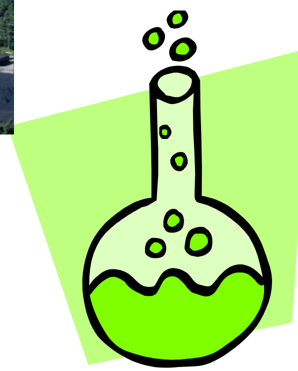
Bioeconomy – a contradiction per se?

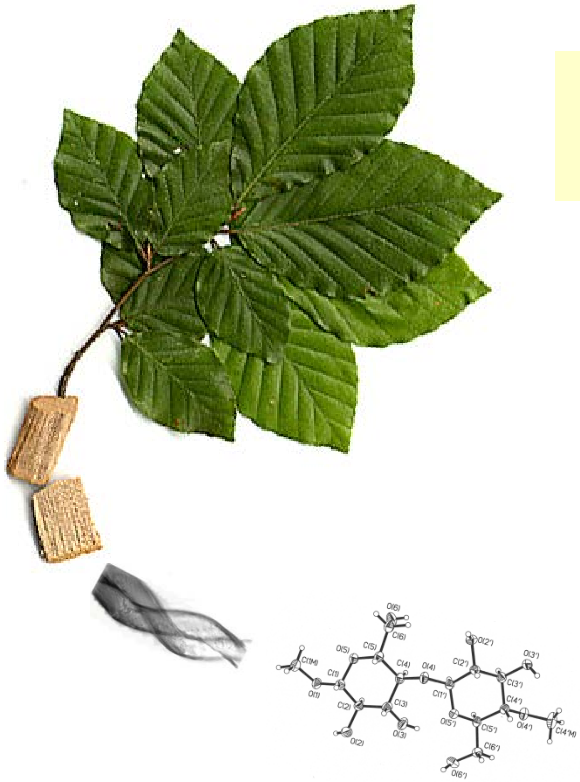


„CHEMISTRY“

„NATURE“

BIOECONOMY & GREEN CHEMISTRY ?

Biorefineries

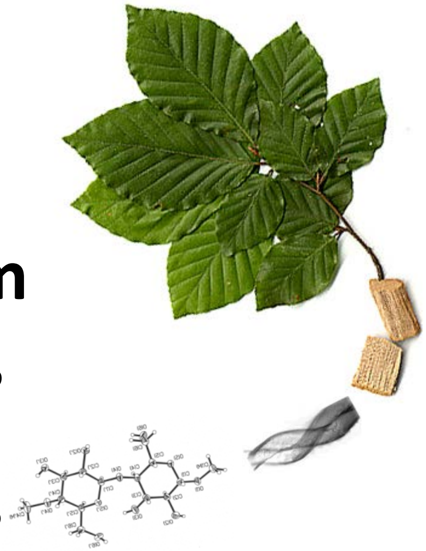


Biorefineries – some background

The problems of today´s
biorefineries (the „sixpack“)

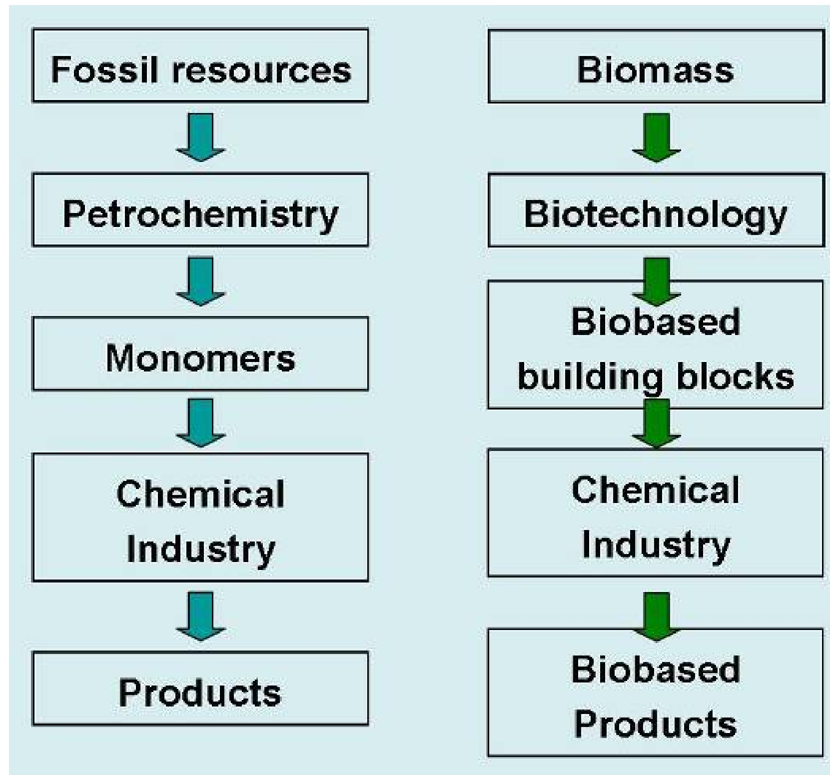
Three examples
(for a more optimistic ending)

Products from bio-refineries



1) Bio-polymers
   (Bio-materials)
2) Bio-chemicals
3) Bio-fuel
4) Bio-energy

Chemistry - Refinery | **Green Chemistry - Biorefinery**

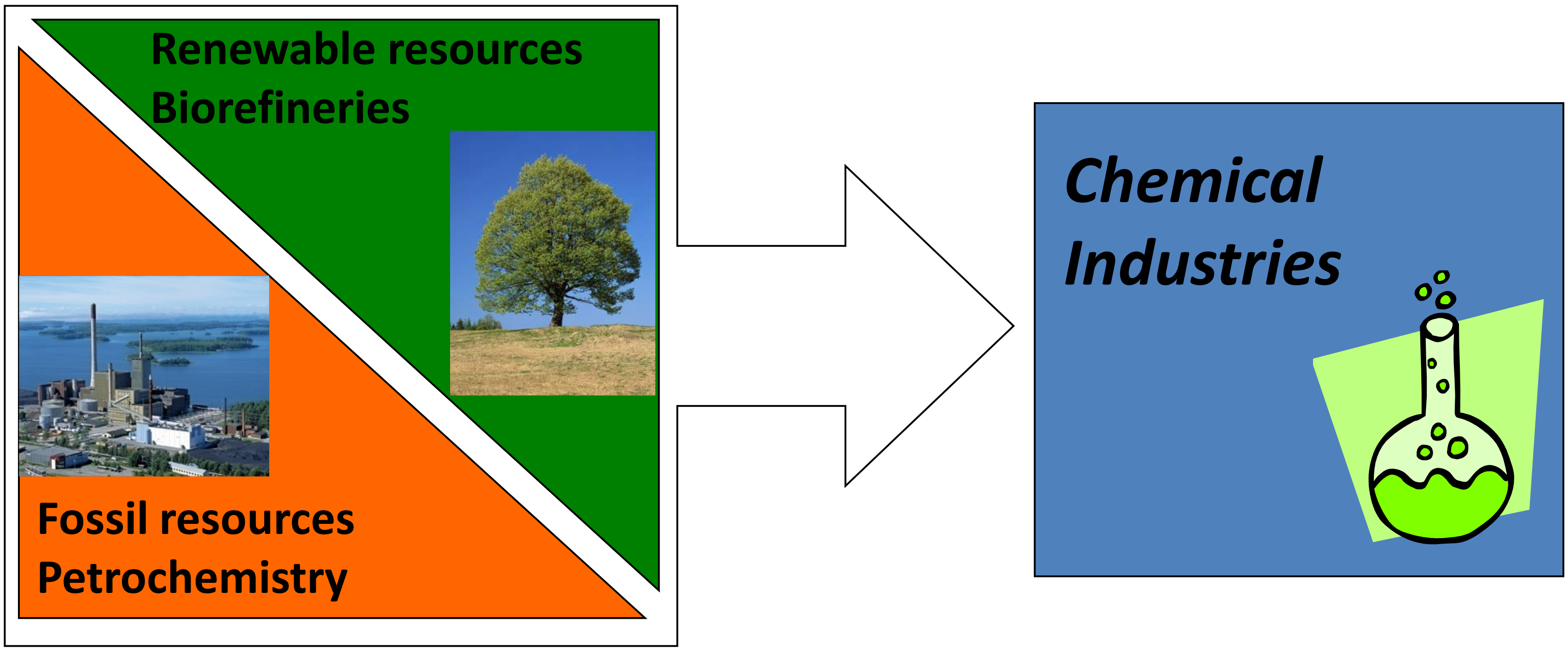


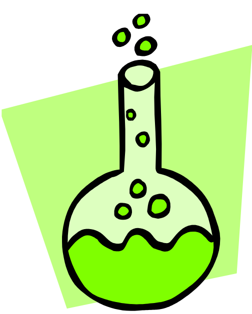
Definition: refinery / biorefinery

Fractionation (separation and purification) of fossil resources / biomass into its main components that are used further to produce an optimum of balanced products

Looking into the (far) future

The basis of the chemical industries, present and future





In (far) future, fossil resources WILL be used up.
If mankind is not to fall back into a rudimental, pre-industrial state, the whole production and all flows of the chemical industries will have to be changed from a ***petrochemical basis*** to a ***renewable basis***.
This requires long-term efforts and fundamental research.

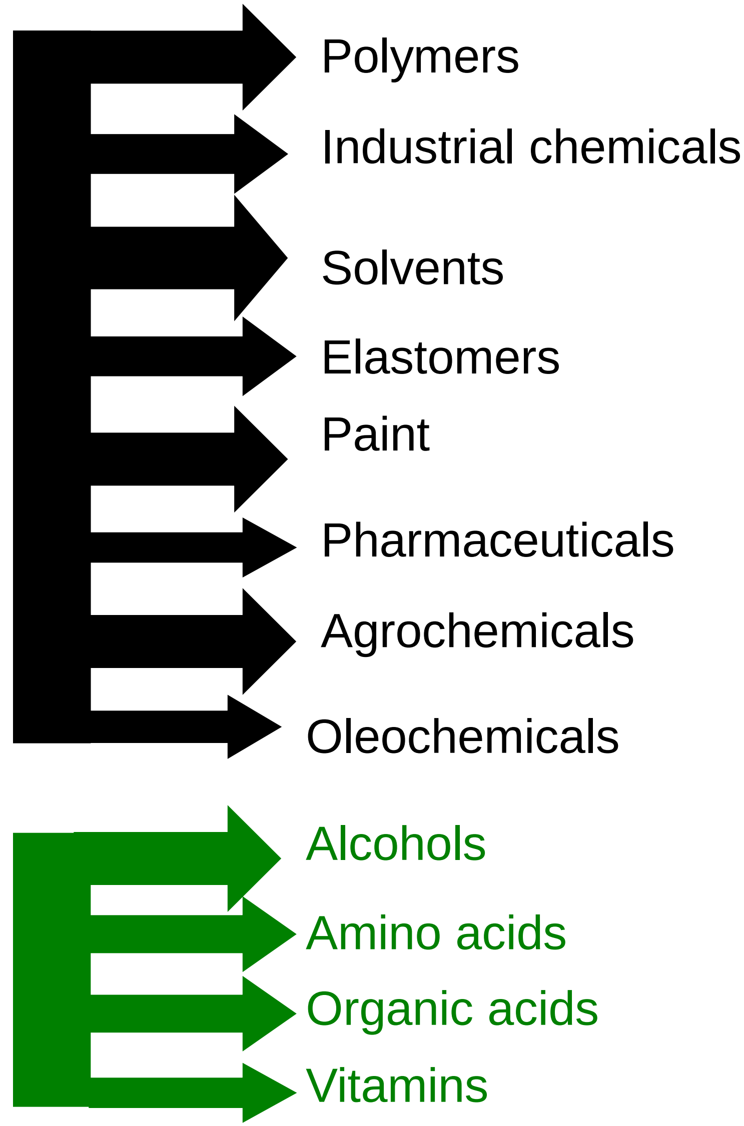
Either…

Or…

Product classes of today´s „classical“ chemical industry

- Products from petrochemistry

- Products from industrial biorefineries

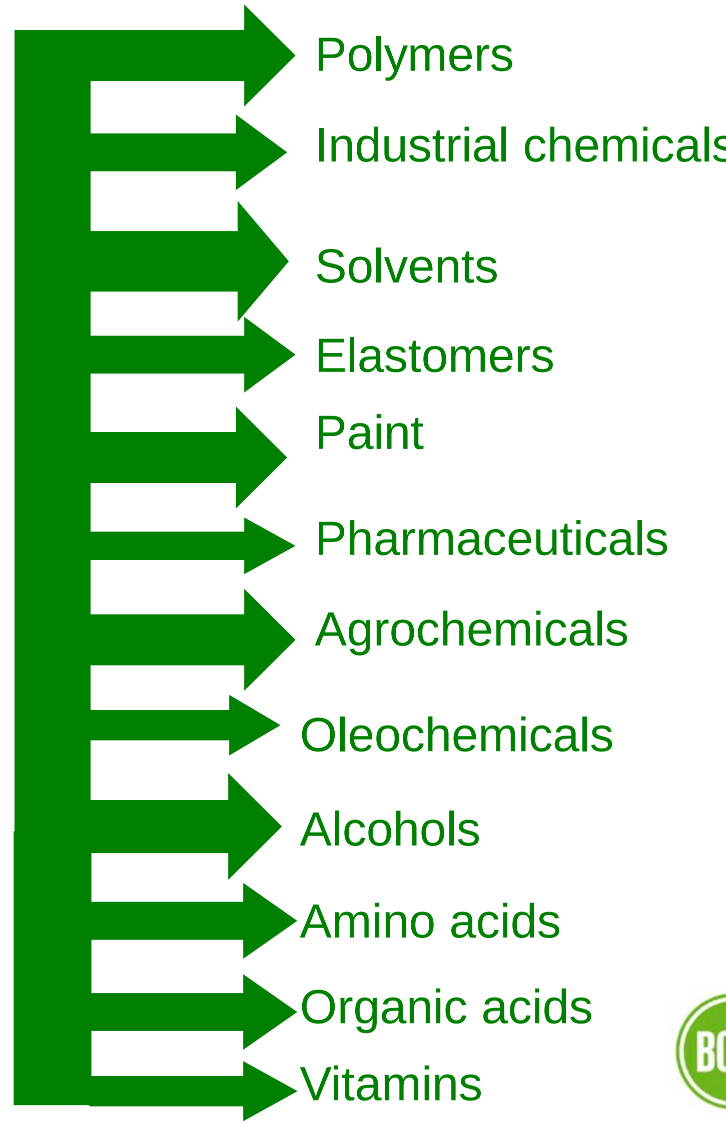


Product classes of the chemical industry in the far future

(Bio)chemical technologies producing all materials from renewables, which are nowadays mainly based on fossil resources

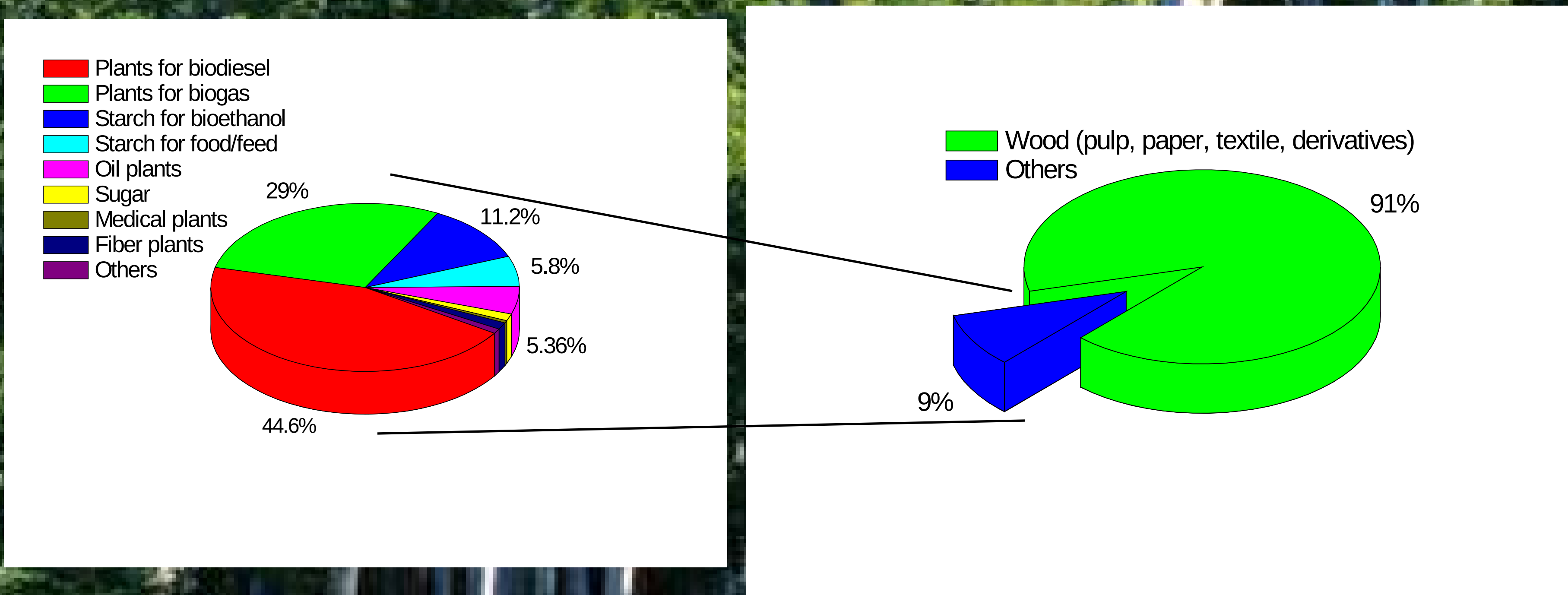
Change of the basis of chemical industries and all related production lines

Fossil → Renewables

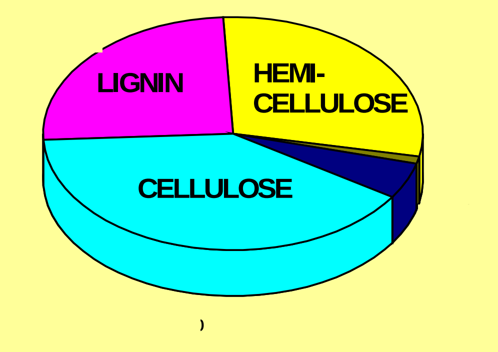


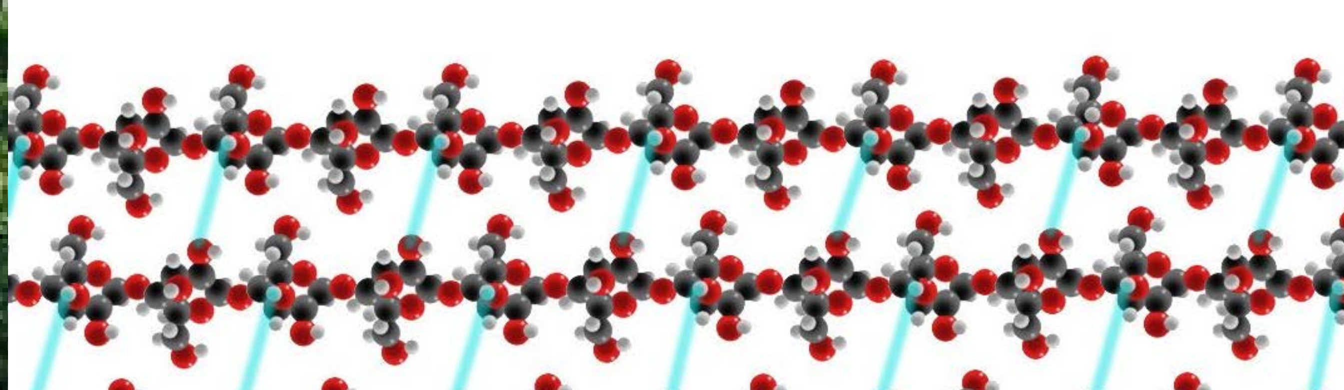
„Green“ starting materials for biorefineries today

Mass balance - current situation



Wood is - and will remain - the most important renewable starting material for future chemical industries („biorefineries“).

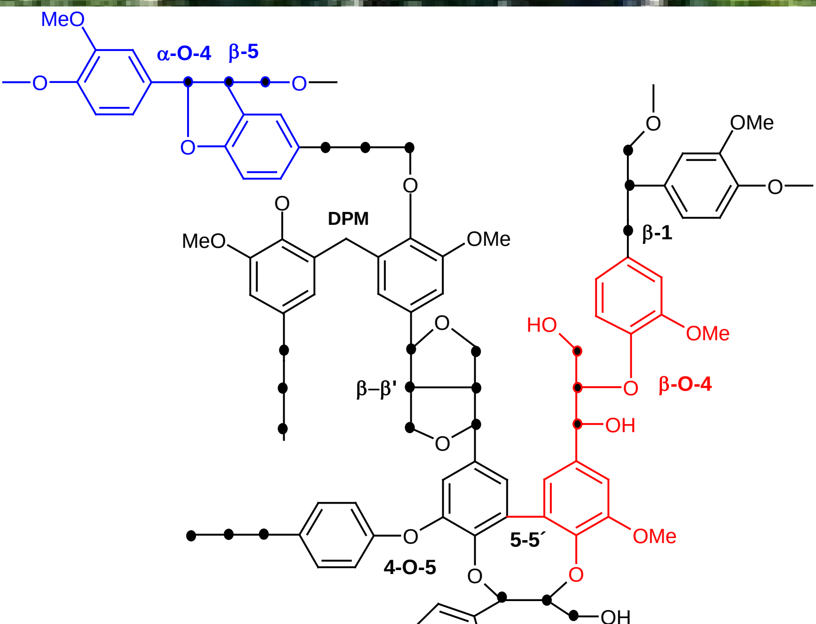




Anaximenes (ca. 550 v. Chr.):
… sind viele Dinge aus einem reinen Element [Feuer – Wasser – Erde – Luft] geformt, andere aus zweien oder dreien, nur das Holz jedoch bedarf aller vier.

ὑλη – Holz, Materie

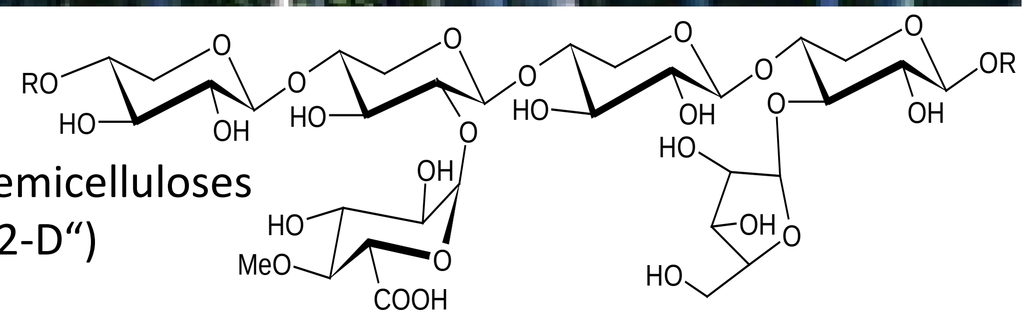
➡ Met**hyl**, Et**hyl**, Prop**yl**



Lignin („3-D“)

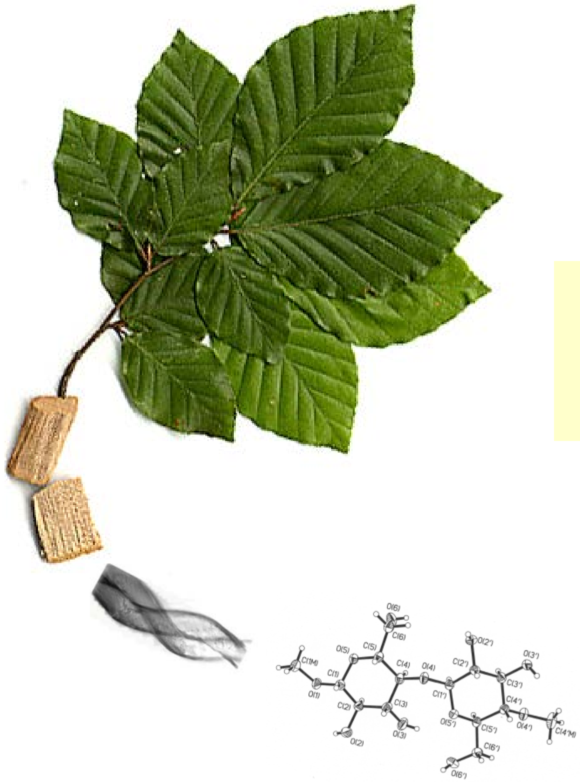
Other natural starting materials:

- Extractives (fats, oils, isoprenoids)
- Proteins
- Starch
- Other carbohydrates



Hemicelluloses („2-D“)

Biorefineries



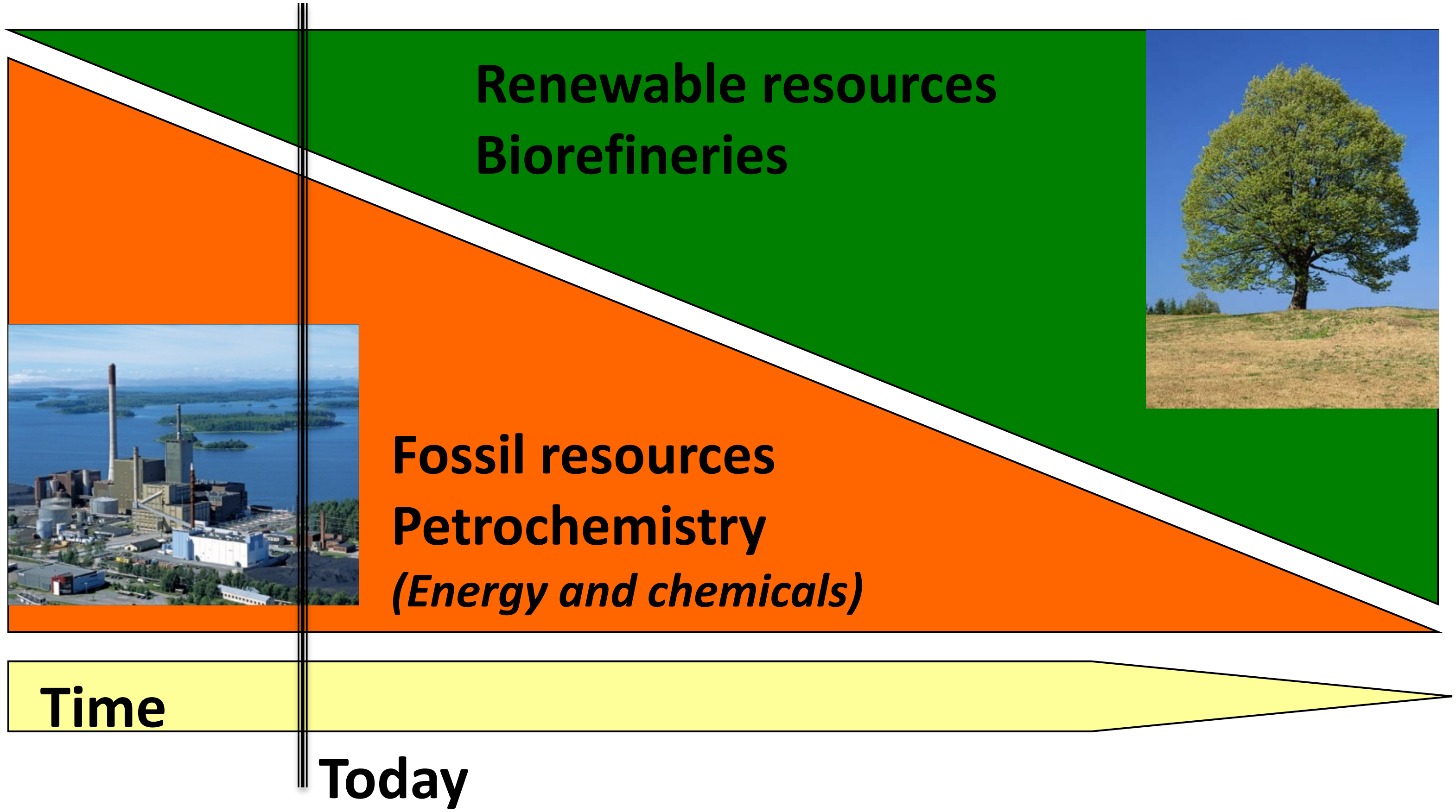
Biorefineries – some background

The problems of today´s biorefineries (the „sixpack“)

Three examples
(for a more optimistic ending)

The “time problem”

Time to grow: refinery 130+ years, biorefinery 25+ years only ?!

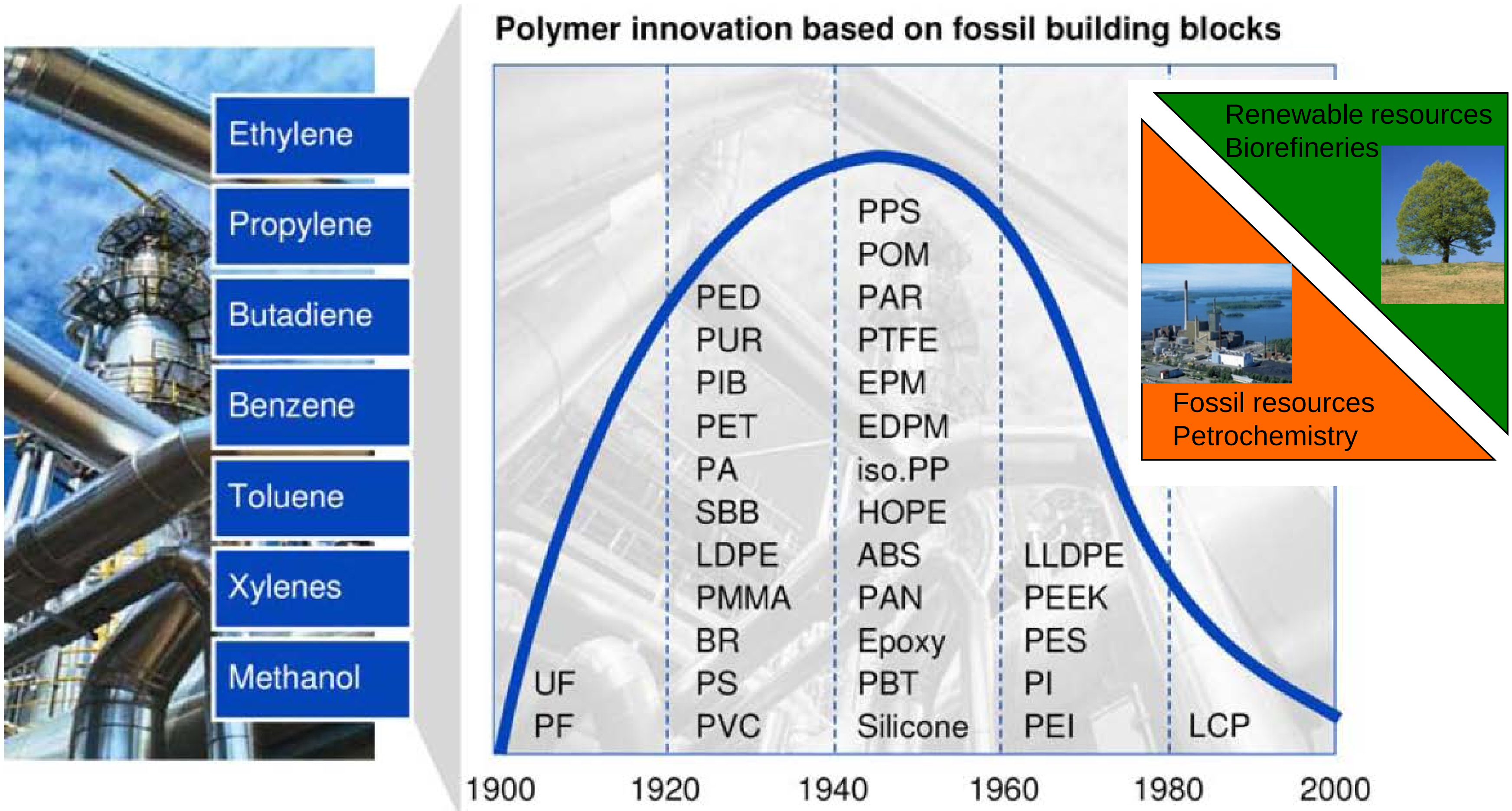


→ **Biorefinery is not an old science…**

→ **There are minimum time requirements for technological and socioeconomic developments.**

Development time

Time to grow: refinery 130+ years, biorefinery 25+ years only ?!?

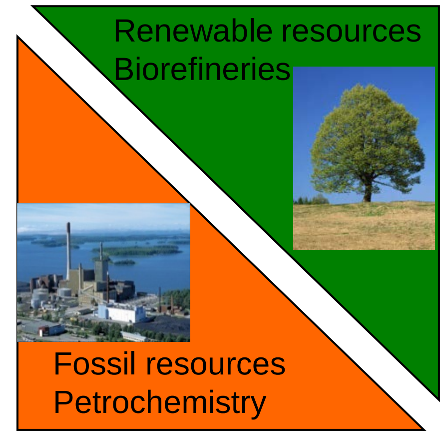


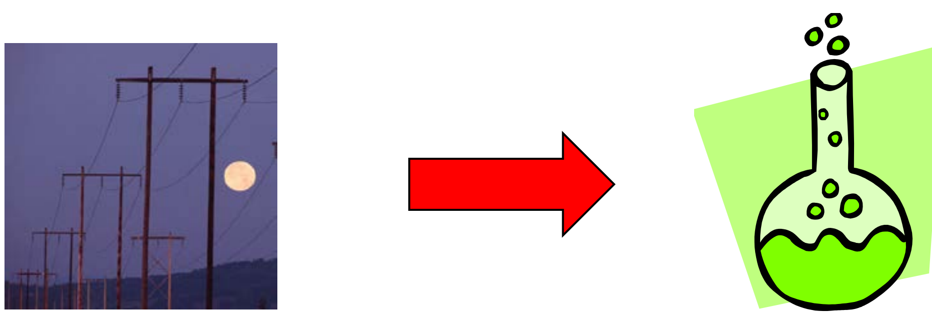
Development of polymers based on building blocks (McKinsey & Comp: Industrial Biotechnology, 2014)

The "energy *vs.* matter" problem

"Use as matter": chemicals, materials, food, feed

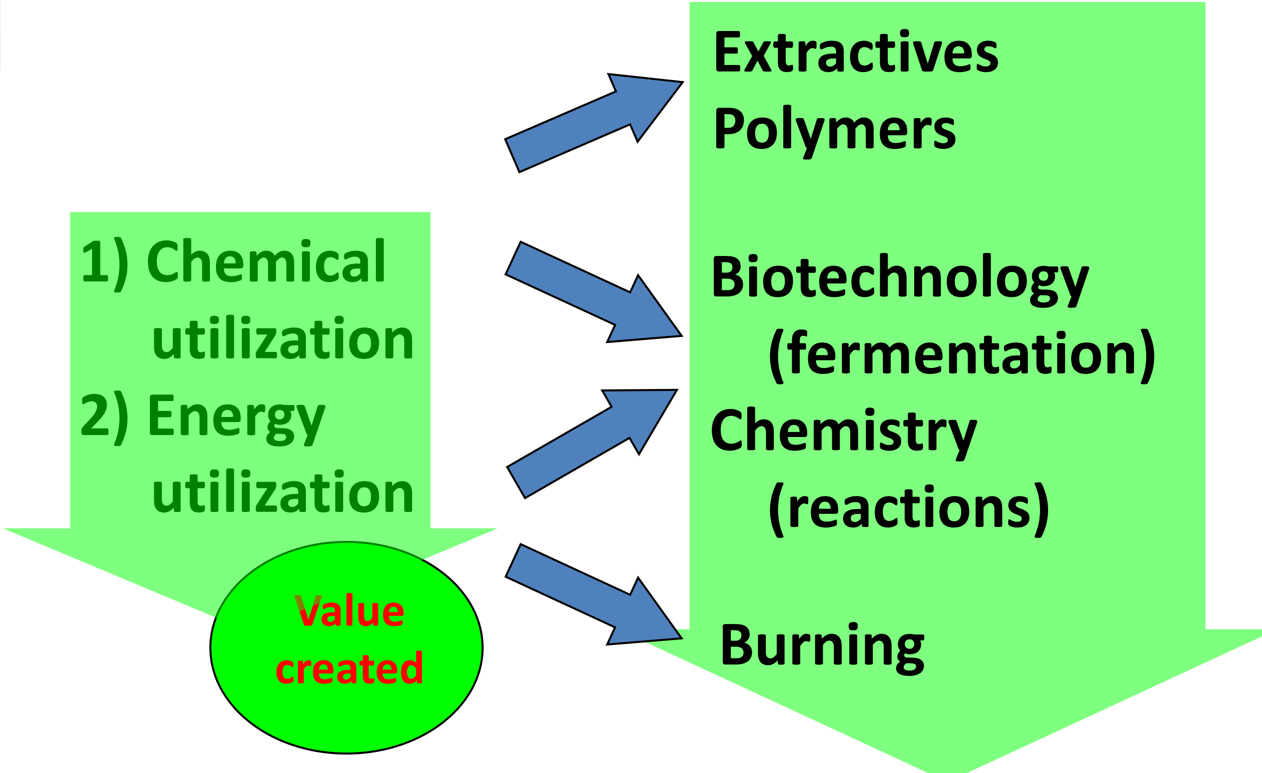
We need "**CARBON**" to produce materials and chemicals.
We don't necessarily need "**CARBON**" for energy production (there are other and better alternatives) !





The “energy *vs.* matter” problem

“Cascade utilization” as the logical consequence



→ “Do something with it first! If nothing works – you can still burn it!”
(George A. Olah, Nobel Prize Chemisty 1994)

→ Energy usage modes (biogas, pyrolysis oils, direct burning) should be operated only after value-added chemical utilization.

→ A major hindrance in cascade utilization is the insufficient advancement of separation technology and analytical capability today.

The „separation / analysis problem“

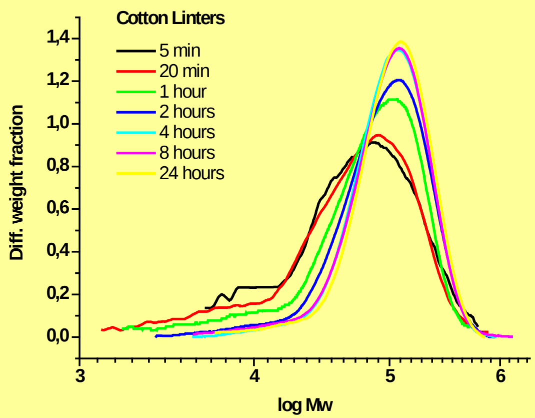
Natural products

- Extremely complex mixtures
- Natural variability
- Hard to process (consistency)
- Unknown components
- Mostly aqueous mixtures
- Often low concentration (fermentation)
- Unstable upon storage

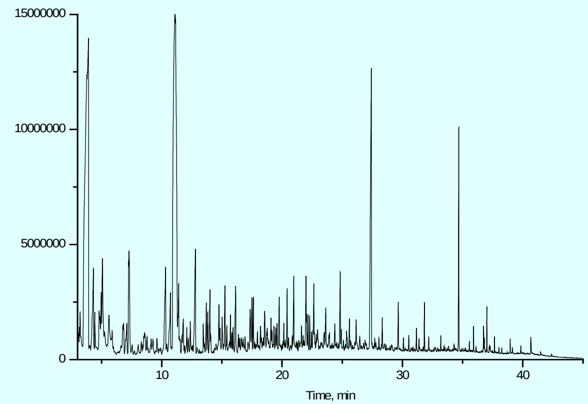
→ **Demand for new biorefinery-specific separation / purification / analysis techniques !!!**

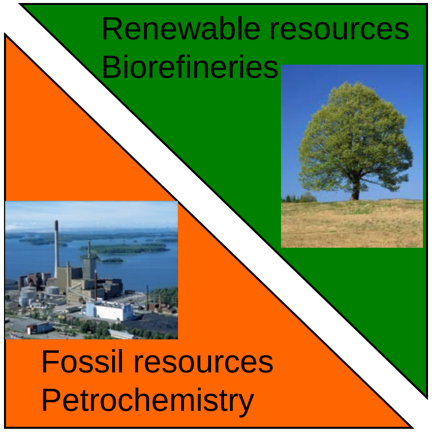
We need powerful „biorefinery analytics“

Carbohydrate (cellulose) analysis

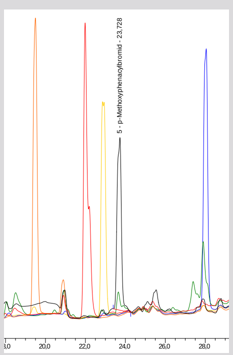


Lignin analysis





Analysis of byproducts

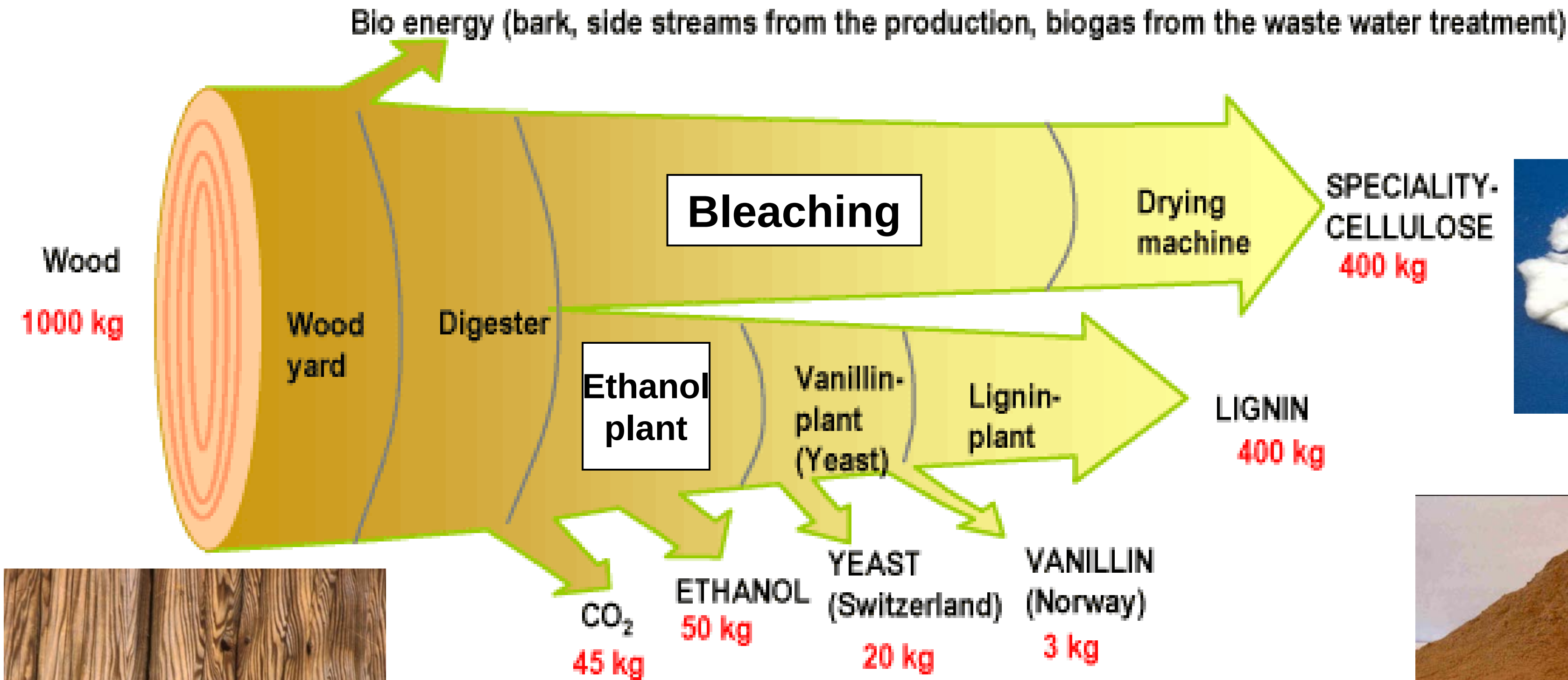


- GC-MS
- CE-MS
- NMR
- LC-MS
- DESI-MS
- GPC

Development of new products and technologies based on renewables must go hand in hand with the development of robust and reliable analytical methodology.

The “lignin problem”

Example: utilization of spruce wood

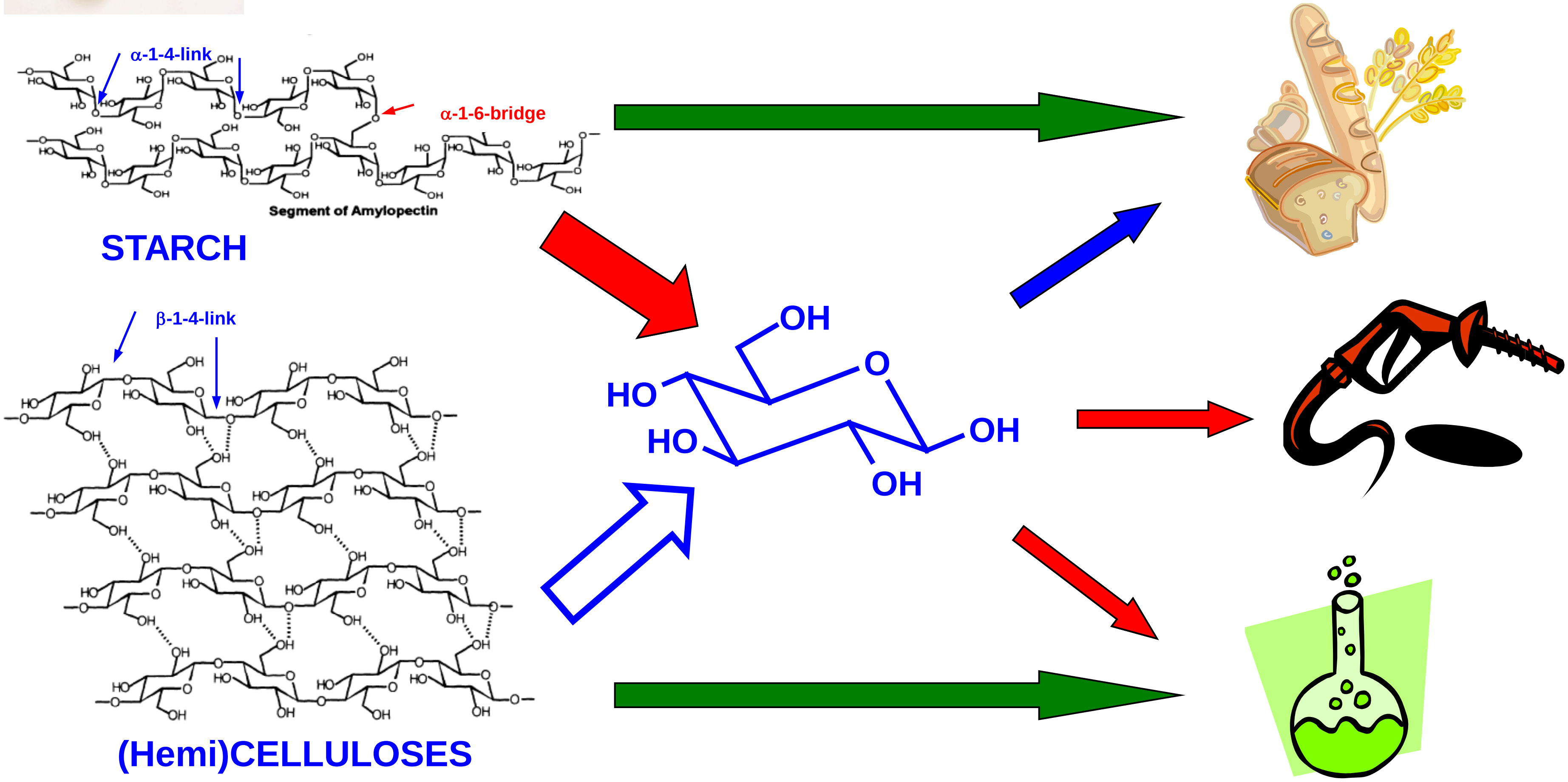


Thanks to: Borregaard, Norway / Finland

→ **Cellulose (and hemicellulose) can be nicely used today, lignin cannot.**

→ **<u>Meaningful</u> uses of lignin as general C-source for chemical industries are needed !!!**

The "alpha – beta" problem



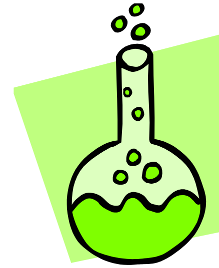
→ "Glucose from starch" is easy, "glucose from cellulose" is not.

→ On the long run, energy and chemicals / materials will be derived from natural resources that have no competitive utilization in the food / feed market.

→ This requires long-term research efforts (and might require some improved ethical thinking).

The “breakdown problem”

“Drop-in strategy” vs. “use-as-is strategy”



(Bio) Refinery — **Chemical industries**

Gas
Oil
Coal

→

Platform chemicals (commodities)

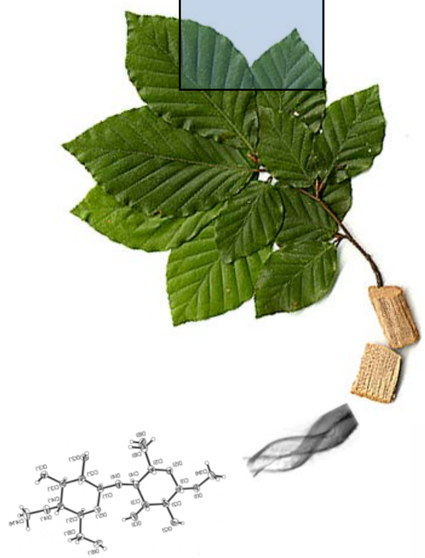
Fine chemicals (specialties)

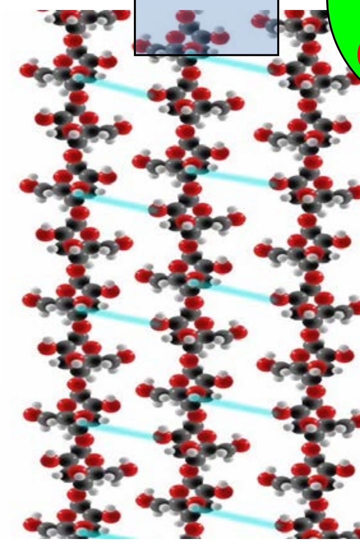
Synth. polymers, fibers, paints, pharmaceutics

Value created

Future renewable chemistry („biorefineries“):

Providing necessary chemicals (what the fossil fuels do today)
PLUS
Biogas by cascade utilization
PLUS
Providing special and novel materials by better use of the intrinsic properties



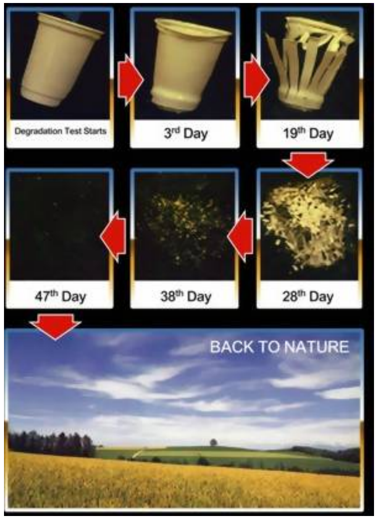


Is it wise to disregard the synthesis and optimization effort of nature?

→ Acknowledge the uniqueness of the raw materials – not just destroying them !

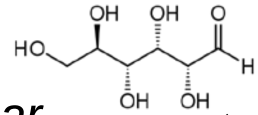
Example: poly(lactic acid) (PLA)

- Made from renewable recources
- Biologically degradable
- „Detour“: polymer → monomer → polymer



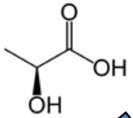
biomass

biorefinery



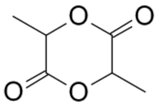
sugar

fermentation



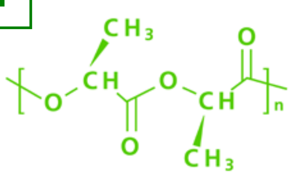
lactic acid

destillation



lactide

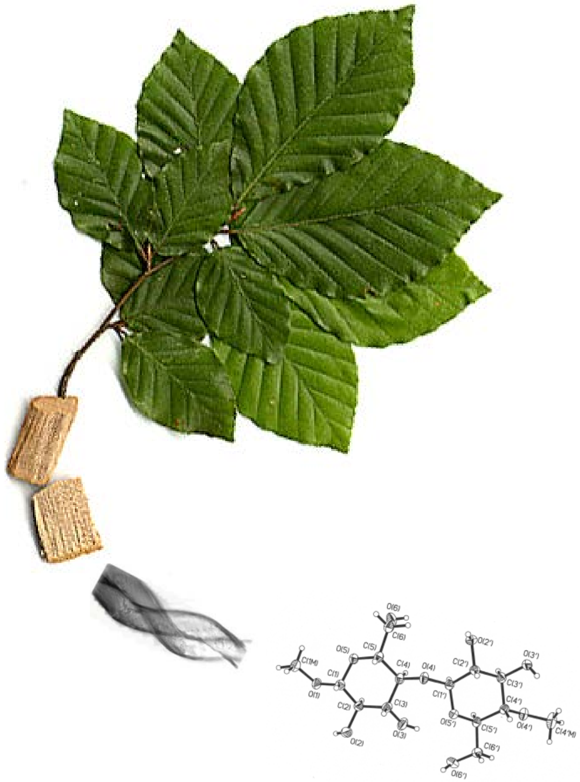
polymerisation



Polylactic acid (PLA)

www.boku.ac.at/bioconversion.html

Biorefineries



Biorefineries – some background

The problems of today´s biorefineries (the „sixpack“)

Three examples
(for a more optimistic ending)

Ammonoxidation of ligneous matter: *N*-lignins

Complex of dead organic matter

Lignin containing raw / waste materials

Topsoil
1-3 years: natural humification

Required chemicals
O_2, NH_3, H_2O (T, p)

Reactor
0.5-2 h: artificial humification

- Demethoxylation
- Demethylation
- Formation of quinones
- Oxidation of aliphatic side chains
- Cleavage of aromatic ring systems
- Nitrogen enrichment

Natural humus

Artificial humus, „*N*-lignins“

N-Lignins as multifunctional, artificial humic matter and soil improver

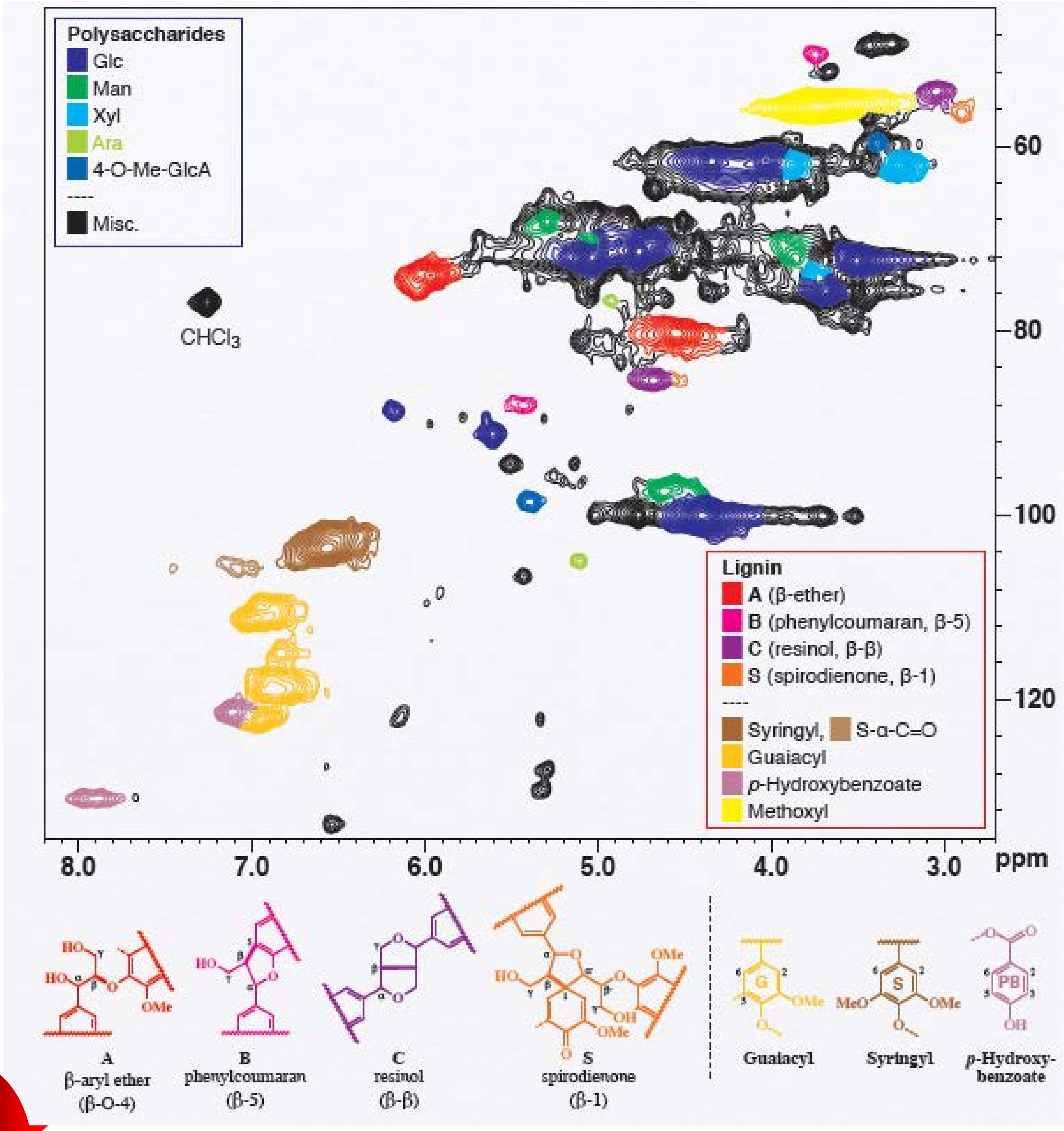
Chemistry largely identical to natural humic matter
C- and N-source, analogous to natural humic matter
Short-term, mid-term and long-term fertilizing effect
Matrix effect (water and nutrient reservoir)

Able to utilize bulk lignin amounts

Return of lignin into natural cycles (C, N) rather than burning it to CO_2

Additional CO_2 sequestration / mineralization (carbamate / urea)

Whole plant cell wall NMR



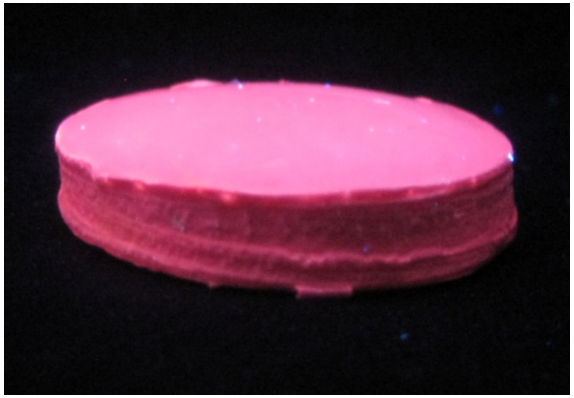
BOKU – Universitäts- und Forschungs-zentrum Tulln (UFT)

Analysis of:

- Celluloses
- Pulps
- Lignin
- Biopolymers
- Biomaterials
- Paper
- Historic celluloses

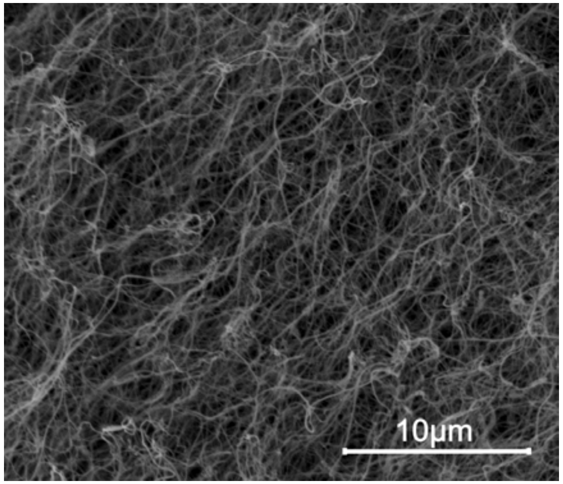
Novel analysis methods specific for green applications

Cellulose aerogels:
Functional materials with fascinating properties



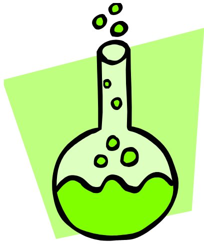
Selected properties

	cellulose aerogel	silica aerogel
density [mg cm^{-3}]	> 0.001	> 0.005
specific surface [m^2 g^{-1}]	250-800	500-1000
α (lin) [1/K 10^{-6}] at RT	0.029	0.030
sound propagation [km s^{-1}]	0.04	0.07-1.3



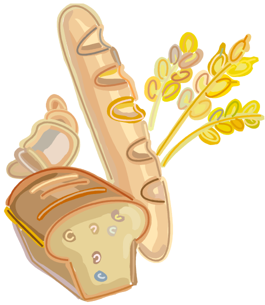
Ultra-leightweight cellulosic bodies for heat, sound and impact insulation and for medicine (cell scaffolds, bone replacement).

Summary: General trends in future biorefineries



Material / chemical utilization

Energetic utilization

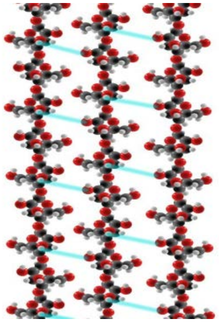


Food / feed: starch
Cellulose & lignin: chemistry

Energy / chemicals from food-/feedstock

Cascade utilization

Direct (one-step) „utilization“ by burning



Better use of nature´s ingenuity in synthesis and material production

Extensive breakdown of renewables „green-to-oil“

CO, H_2, CH_4, C_2H_5OH

Financial $upport

BOKU
Alma mater viridis

epnoe
European Polysaccharide Network Of Excellence

FWF

ÖZEPA

FFG

austropapier

National Institutes of Health
The Nation's Medical Research Agency

EVONIK INDUSTRIES

Roche

kemira

sappi

PRESERVATION ACADEMY

mondi

SCA

BASF
The Chemical Company

LENZING

Kelheim Fibres

fzmb

DSM

ISOVER

Norske Skog Bruck

heinzel pulp
ZELLSTOFF PÖLS AG

Thanks to the people who are actually doing the work…

Biorefineries
What do we know? Where are the problems?

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