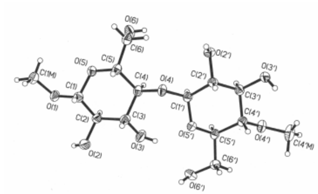
Biorefinery scenarios for the future

BOKU network „Bioconversion of Renewables“



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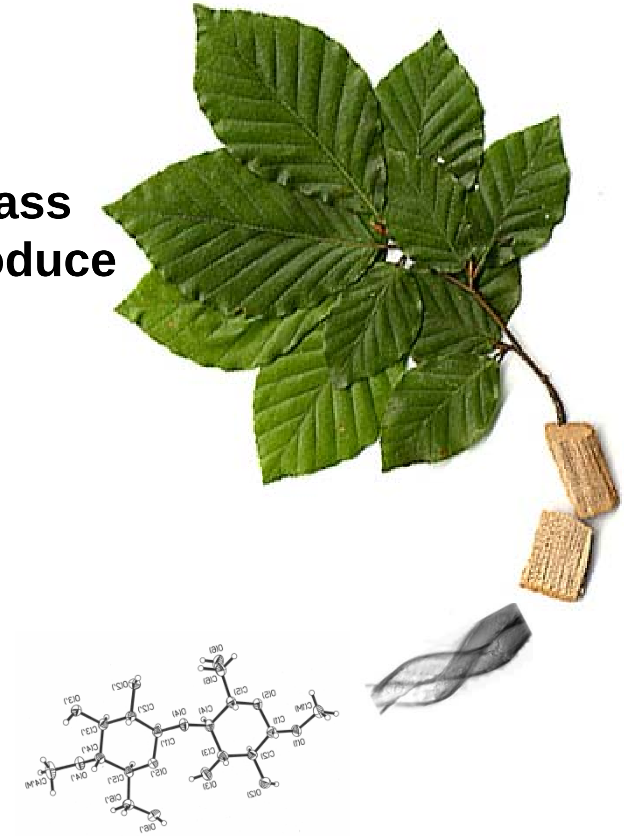
Definition: Biorefinery

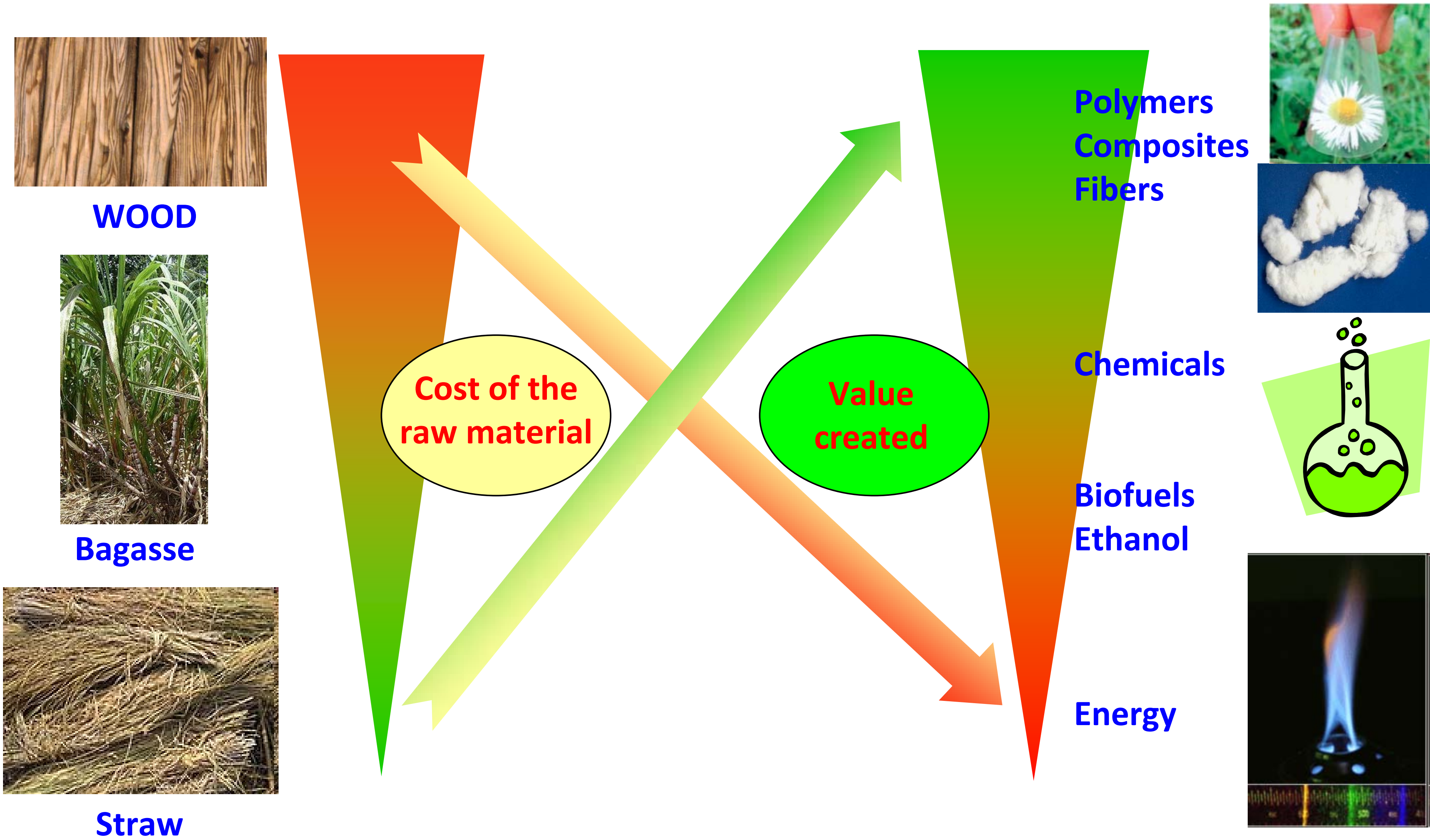
Fractionation (separation and purification) of biomass in its main components that are used further to produce an optimum of balanced products



1) **Biopolymers (Biomaterials)**
2) **Biochemicals**
3) **Biofuel**
4) **Bioenergy**

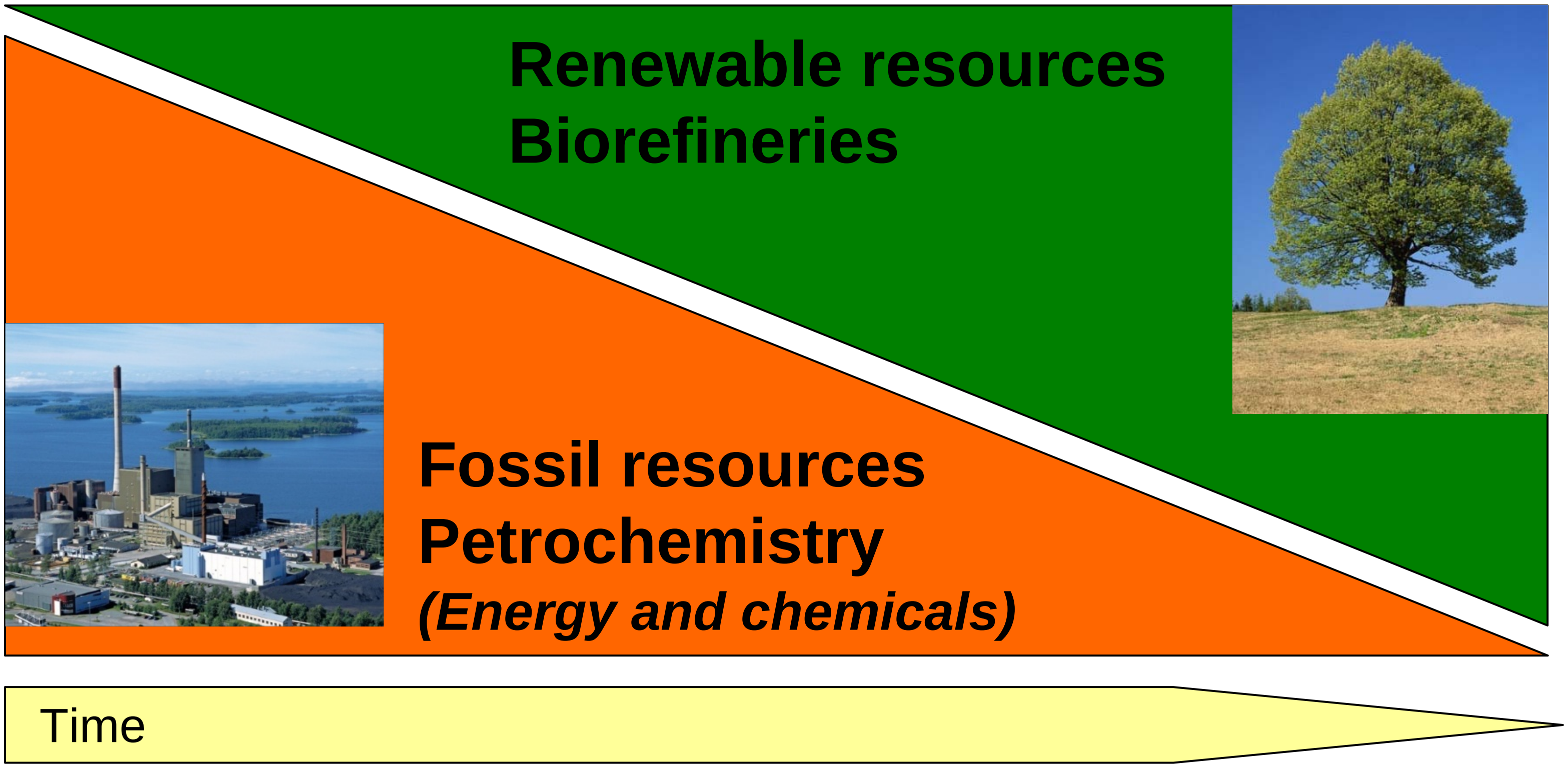
→ If possible: preserving the unique properties of the raw material – not destroying it!
→ Acknowledge and utilize the synthesis effort of nature !

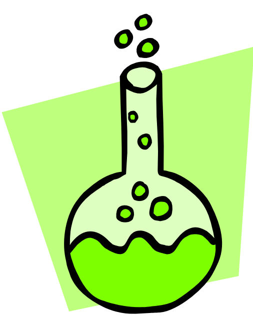
Creating value-added products ?!



Biorefinery – looking into (far) future

Where do the resources come from?

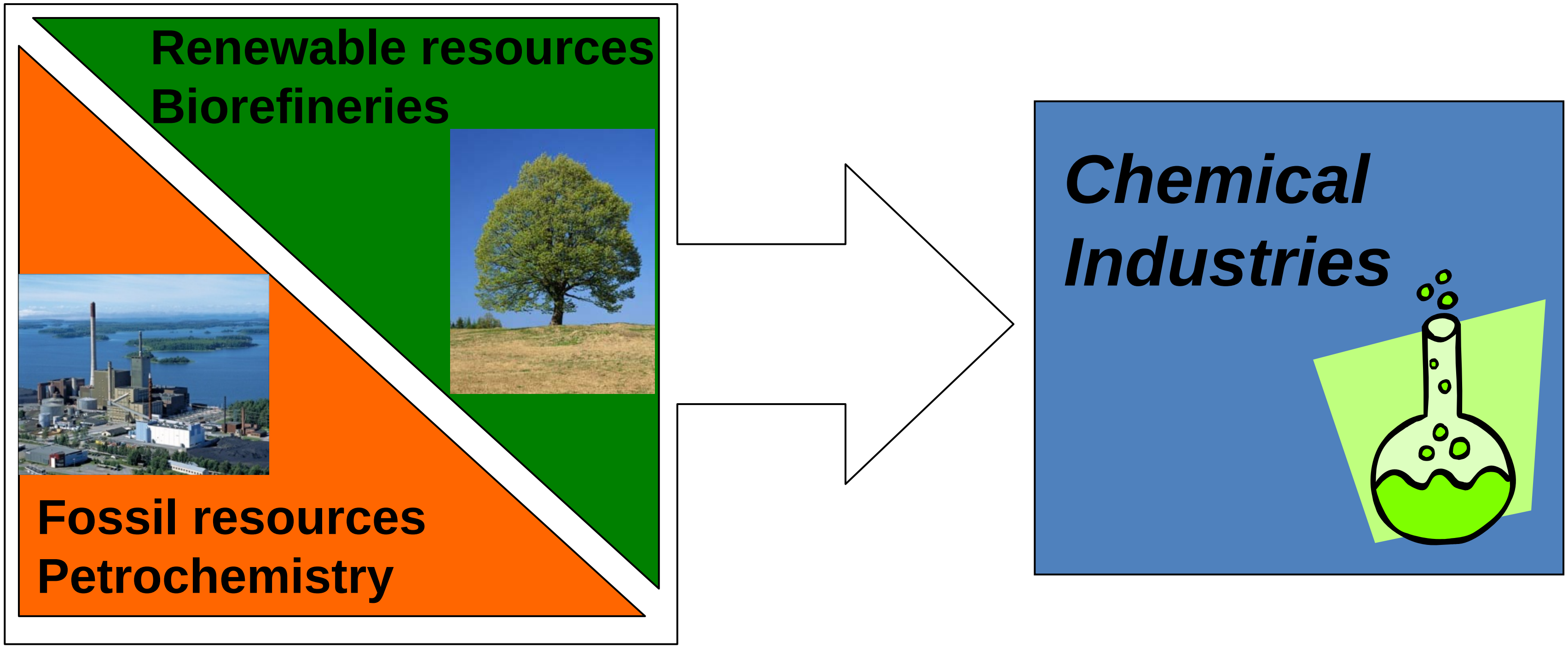


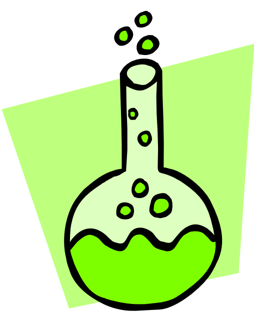


We need “**CARBON**” to produce materials and chemicals.
We don’t necessarily need “**CARBON**” for energy production (there are other and better alternatives) !

Biorefinery – looking into (far) future

The basis of the chemical industries, present and future

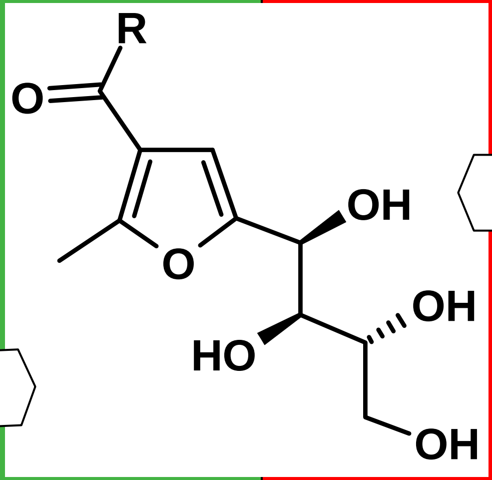




In (far) future, fossil fuels WILL be used up.
If mankind is not to fall back into a rudimental, pre-industrial state, the whole production and all flows of the chemical industries will have to be changed from a ***petrochemical basis*** to a ***renewable basis***.
This requires long-term efforts and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

What about “Green Chemistry”? Example: chemical from cellulose

“Green way”
- from cellulose (waste)
- 1 step
- yield 82%
- solvent water or ethanol
- microwave heating
- catalyst: clay
- 92% of atoms used
- 3 hours



“Classical way” (Synthese)
- from furfuryl alcohol
- 13 steps
- yield 8%
- six different (chlorinated) solvents
- heating, cooling (-78°C)
- Extensive purification
- 3% of atoms used
- approx. 5 days

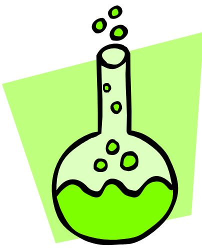
Selection from the „12 Principles of Green Chemistry“:

Avoid waste
Use renewables as starting materials
Maximize atom economy
Use innocent solvents
Design direct syntheses
Use catalysts
Boost energy efficiency

The “Green” in “Green chemistry” has to cover the whole reaction system, not just the starting material. This includes reagents, solvents, auxiliaries, experimental setup and technology, purification and separation steps, as well as energy aspects.

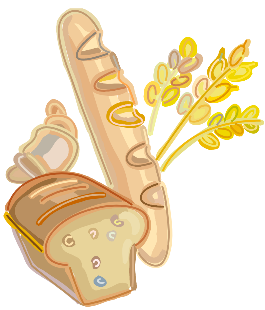
Important: development of new, direct syntheses,
minimizing the use of dangerous solvents and reagents,
utilization of the synthesis effort of nature

Biorefinery – looking into (far) future
General future developments



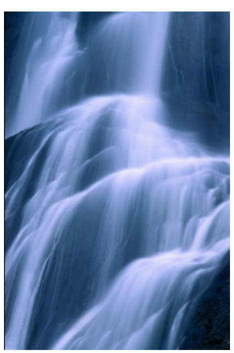
Material / chemical utilization

Energetic utilization



Food / feed if possible

Energy / chemicals from food-/feedstock

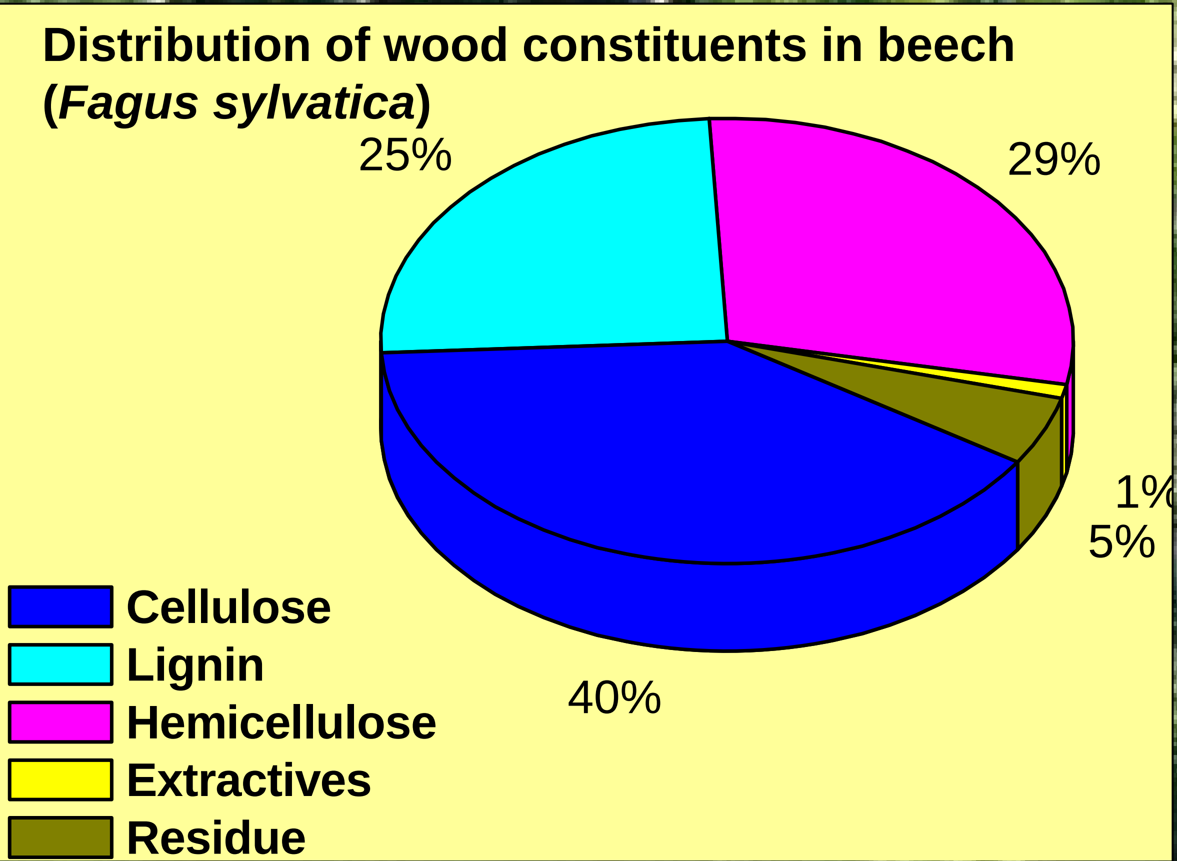


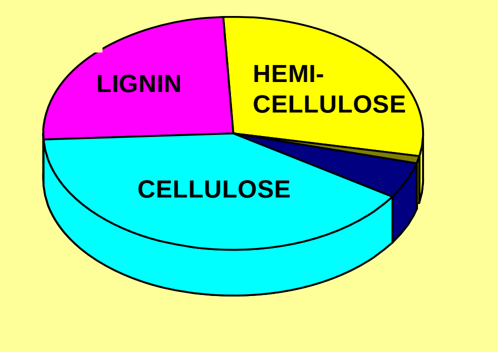
Cascade utilization

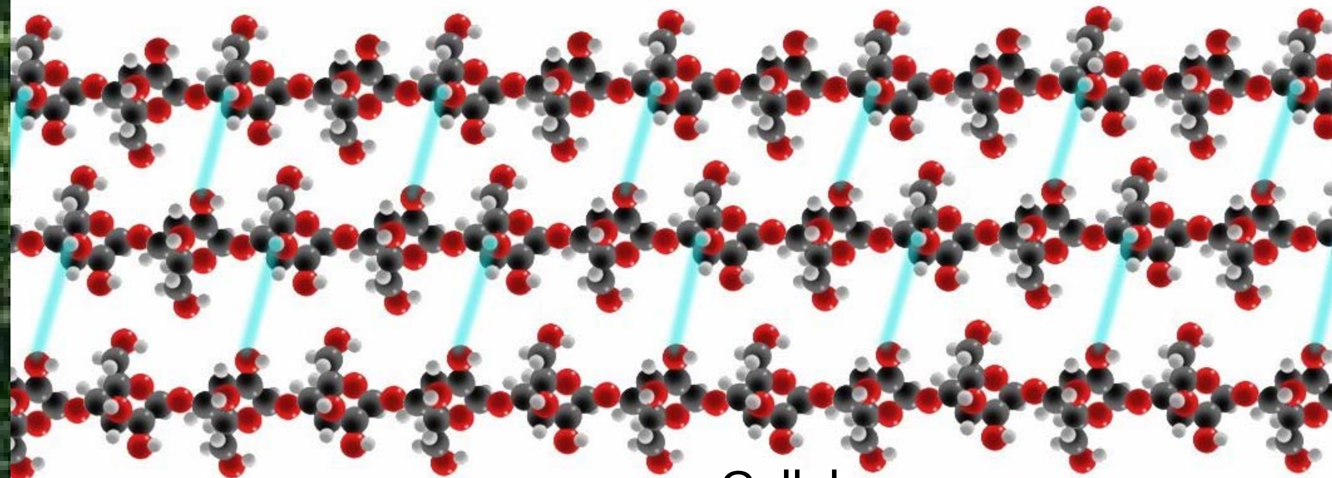
Direct (one-step) utilization

Wood - main constituents

Wood - main constituents



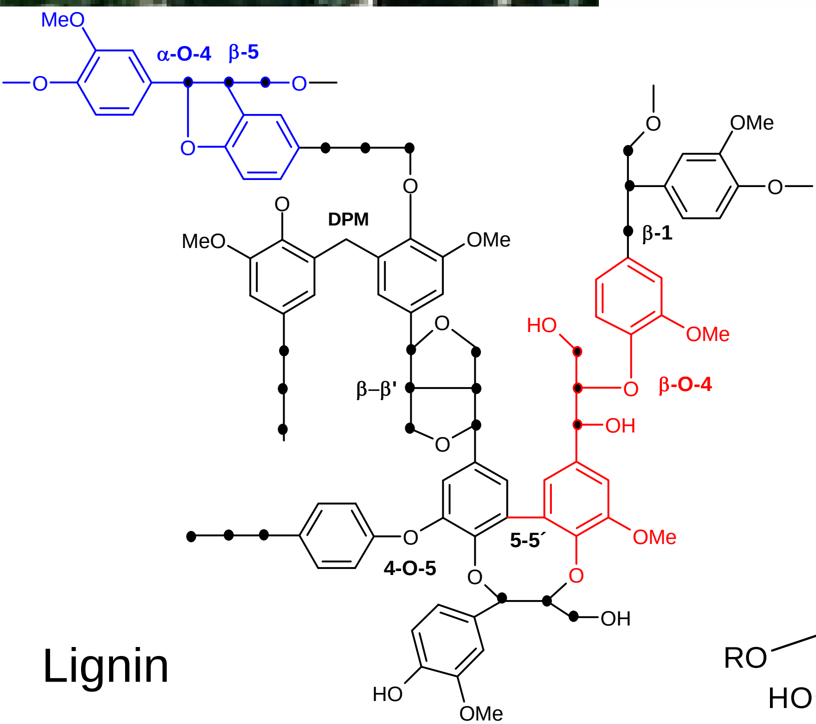




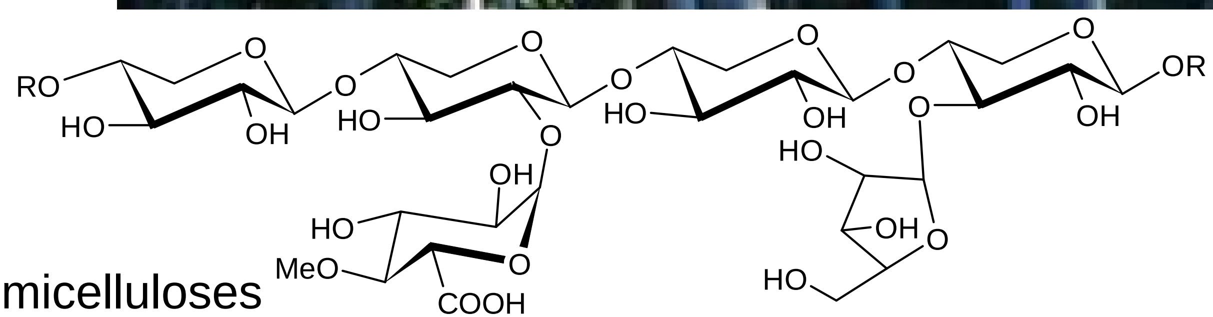
Cellulose

From other natural starting materials:

- Extractives (fats, oils, isoprenoids)
- Proteins
- Carbohydrates in general



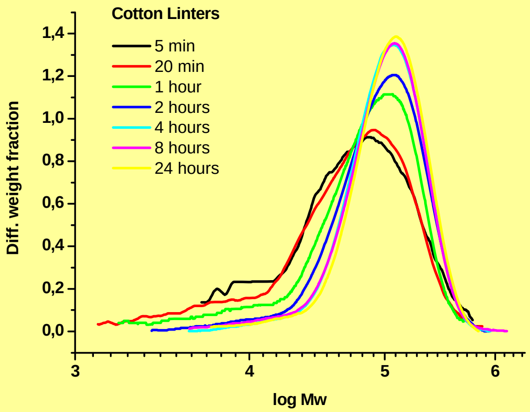
Lignin



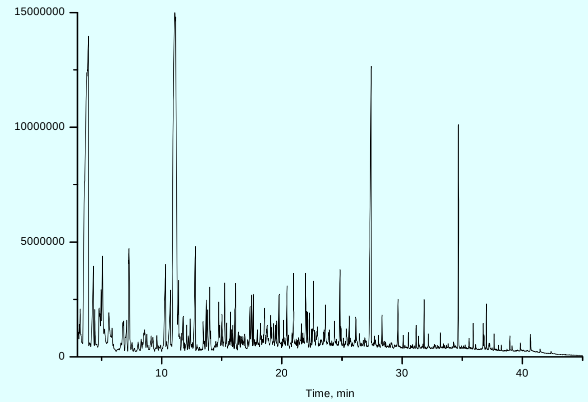
Hemicelluloses

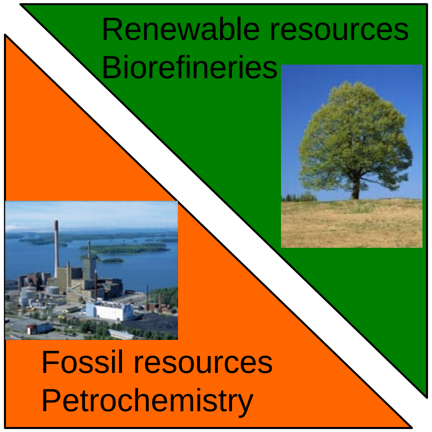
Biorefinery analytics

Carbohydrate (cellulose) analysis

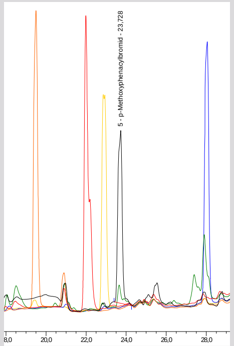


Lignin analysis





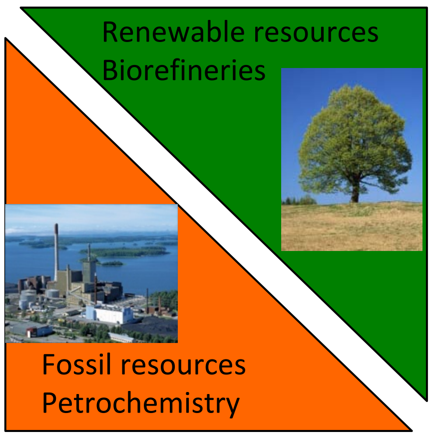
Analysis of products



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

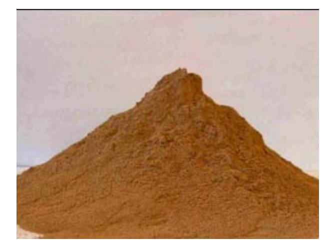
Development of new products and technologies based on renewables must go hand in hand with the development of robust and reliable accompanying analytics.

Biorefinery – looking into (far) future



~1000 kg

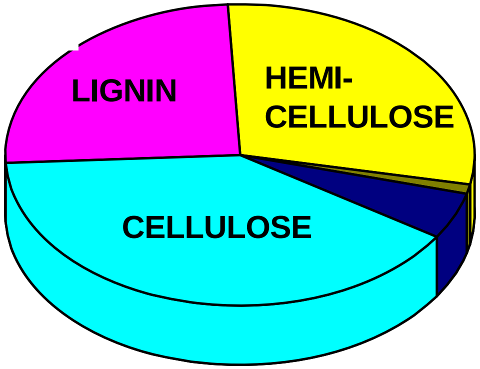
~400 kg



~400 kg

The amounts of cellulose and lignin produced are roughly the same. Utilization of the bulk lignin has been the bottleneck in all recent biorefinery approaches (irregular structure and „recalcitrance“ of lignin).

3^{rd} Generation biorefinery: ~100% use-up of biomass



novel separation technologies
(e.g. supercritical CO_2)

Cellulose, Hemicelluloses

Pulp, materials
Chemicals
Biofuels
Biogas

Lignin

NH_3 / O_2

Fertilizer / humic matter:
N-Lignin by ammonoxidation,
urea (CO_2-sequestration)

Solid / gaseous residues

→ modular setup

- small, cheap units for on-site use
- usage adjustable according to biomass (straw, wood, foliage, stalks)

→ complete use-up of biomass

- including lignin
- including residues from fermentation (biofuel / biogas)
- including CO_2 (up to 15%) and NH_3

→ return of organic matter to soil

- fertilizer / soil improver
- artificial humic matter

International scientific leadership of BOKU

Ammonoxidation of ligneous matter is the best option for bulk lignin utilization - artificial humic substances

Complex of dead organic matter

Topsoil
natural humification

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

Lignin containing raw / waste materials

Reactor
artificial humification

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

Natural humus

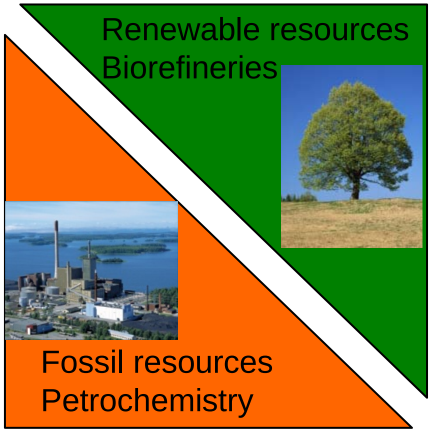
Artificial humus, „N-lignins“

Biorefeneries

BOKU network: Bioconversion of renewables

Developing biorefineries of the future

Starting materials of the future
Fractionation into main (pure) components
Analytics
Cascade utilization and sustainability
Biotechnology and further conversion into chemicals



Only BOKU covers the whole chain in (biorefinery) research from *primary production and fractionation of biomaterials* over *biotechnological and chemical conversions* to the final products, including *analytics, technology and socio-economic aspects*.

BOKU Network for Bioconversion of Renewables

- Bundle expertise at BOKU

- Initiate cooperations with industry, academic partners, agriculture and forestry, public partners…

Join our initiative !

www.boku.ac.at/bioconversion.html