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 ?!

WOOD

Bagasse

Straw

Cost of the raw material

Value created

Polymers
Composites
Fibers

Chemicals

Biofuels
Ethanol

Energy
Biorefinery – looking into (far) future
Where do the resources come from?

Renewable resources
Biorefineries

Fossil resources
Petrochemistry
(Energy and chemicals)

Time

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
Distribution of wood constituents in beech 
(*Fagus sylvatica*)

- Cellulose: 40%
- Lignin: 29%
- Hemicellulose: 25%
- Extractives: 5%
- Residue: 1%
From other natural starting materials:
- Extractives (fats, oils, isoprenoids)
- Proteins
- Carbohydrates in general
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.
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).
3rd Generation biorefinery: ~100% use-up of biomass

- **Cellulose, Hemicelluloses**
- **Lignin**
- **Pulp, materials**
  - Chemicals
  - Biofuels
  - Biogas

→ **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 CO₂ (up to 15%) and NH₃

→ **Return of organic matter to soil**
- fertilizer / soil improver
- artificial humic matter

**Fertilizer / humic matter:**
N-Lignin by ammonoxidation, urea (CO₂-sequestration)

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

- Demethoxylation
- Demethylation
- Formation of quinones

Required chemicals
\[ \text{O}_2, \text{NH}_3, \text{H}_2\text{O} (T, p) \]

Lignin containing raw / waste materials

- Oxidation of aliphatic side chains
- Cleavage of aromatic ring systems
- Nitrogen enrichment

Topsoil
natural humification

Reactor
artificial humification

Natural humus

Artificial humus, „N-lignins“
Biorefineries

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