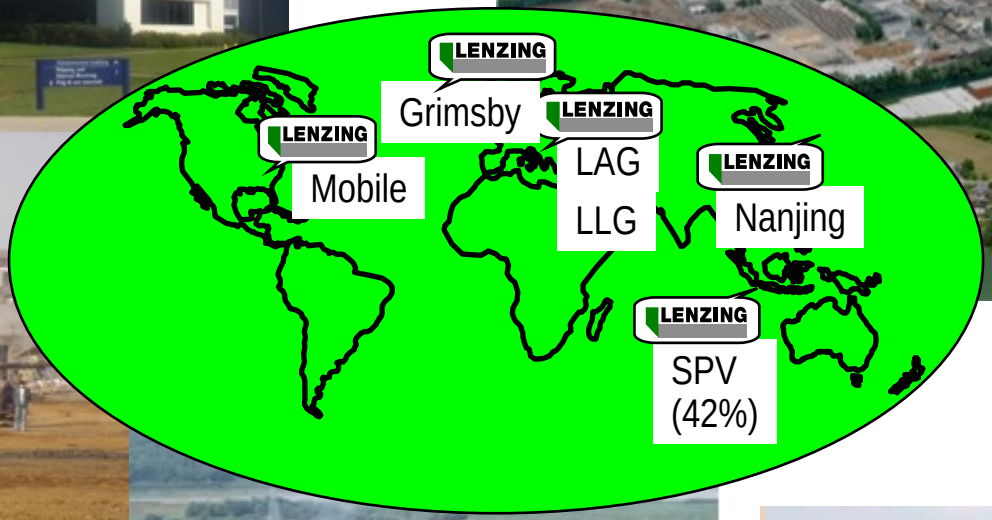
Separation of chemicals as co-products in pulp and fibre processing

Hedda K. Weber

Workshop Biorefinery

Vienna, October 4, 2007

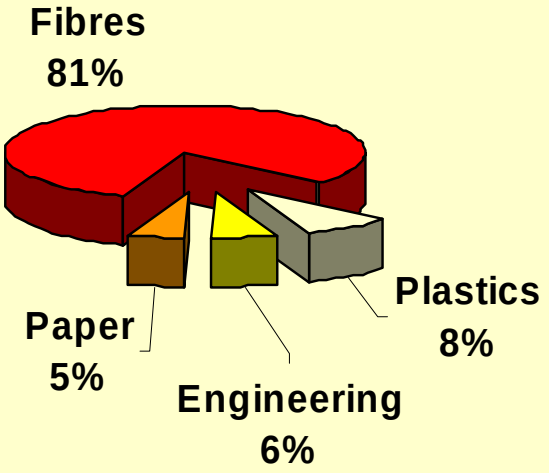
Diversification & Production Sites in all Economically Important Regions



Lenzing Group 2006 (*)

World leader in cellulose fibre technology

- Production of cellulose fibres: 478 100 t (+5%)
- World market share: 21%
- Turnover: 1100.5 M€
- EBITDA: 170.1 M€
- EBT: 98.6 M€
- Employees: about 5000
- R&D: 16.1 M€ (Frascati)
- Investments:105.3 M€



Turnover 2006: 1.1 Bio €

(*) ... IFRS;

The Lenzing Site, Austria

Largest integrated sulphite pulp and viscose fibre production in the world

- Business Units
  - Pulp production (incl. chemicals sales)
  - Fibres for textiles & nonwovens
  - Engineering, plastics, paper

- Pulp production: 240,000 t/p.a. air dry
- Fibre production: 225,000 t/p.a.
- Employees: 2,800

- **R & D -**
- the **source of Lenzing's success**
- among the 500 most research-intensive companies within the EU (one of only 10 Austrian companies)
- **headquarter** ⇨ critical mass of researchers
  - about 160 highly qualified co-workers
  - about 40 people from co-operations (Competence Centres, CD-labs, universities)
  - laboratories & pilot plants (~ 20 Mio €)
  - since1990: > 2500 patents

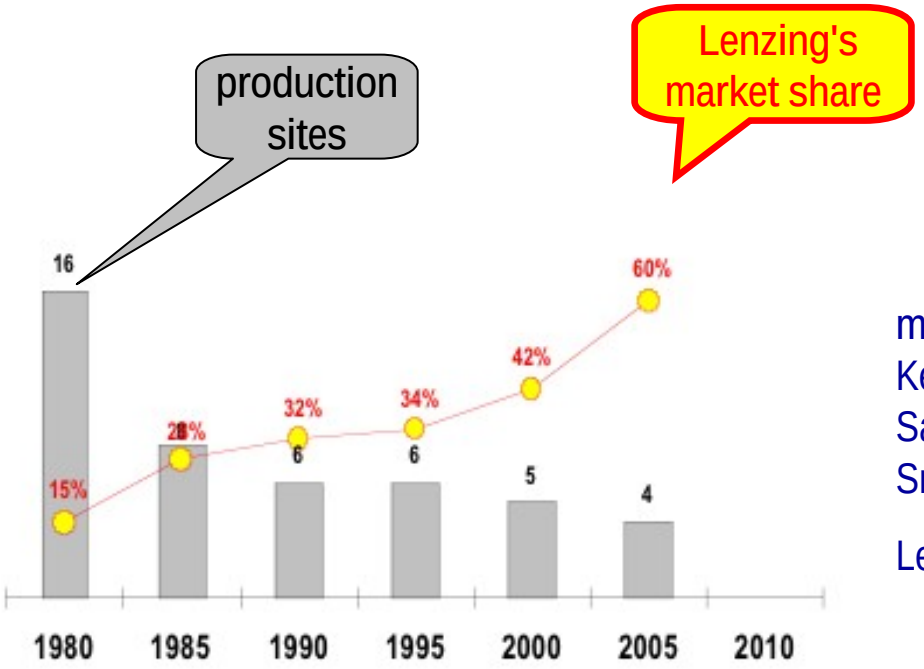
http://forschung.lenzing.com

... survival of the fittest

Lenzing succeeded despite the cut-throat competition because it is

- leading in quality: high-performance and specialty fibres, nonwovens
- market leader: sole supplier of the full product range & regional diversification
- cost leader: integrated production, energy efficiency, by-product utilisation

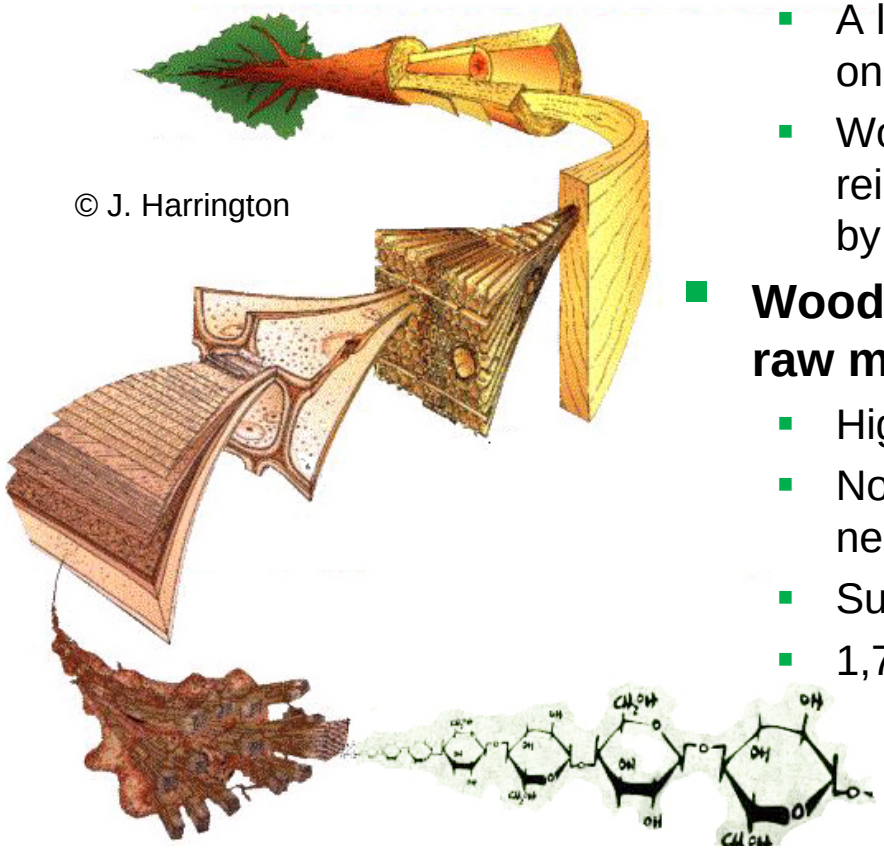
market shares 1980
Acordis 31%
Saeteri 27%
Lenzing 15%



market shares 2005
Kelheim 19%
Saeteri 16%
Sniace 6%
Lenzing 59%

*viscose and modal, Western Europe

Renewables-based materials, bulk and fine chemicals and the sustainable technologies for their production

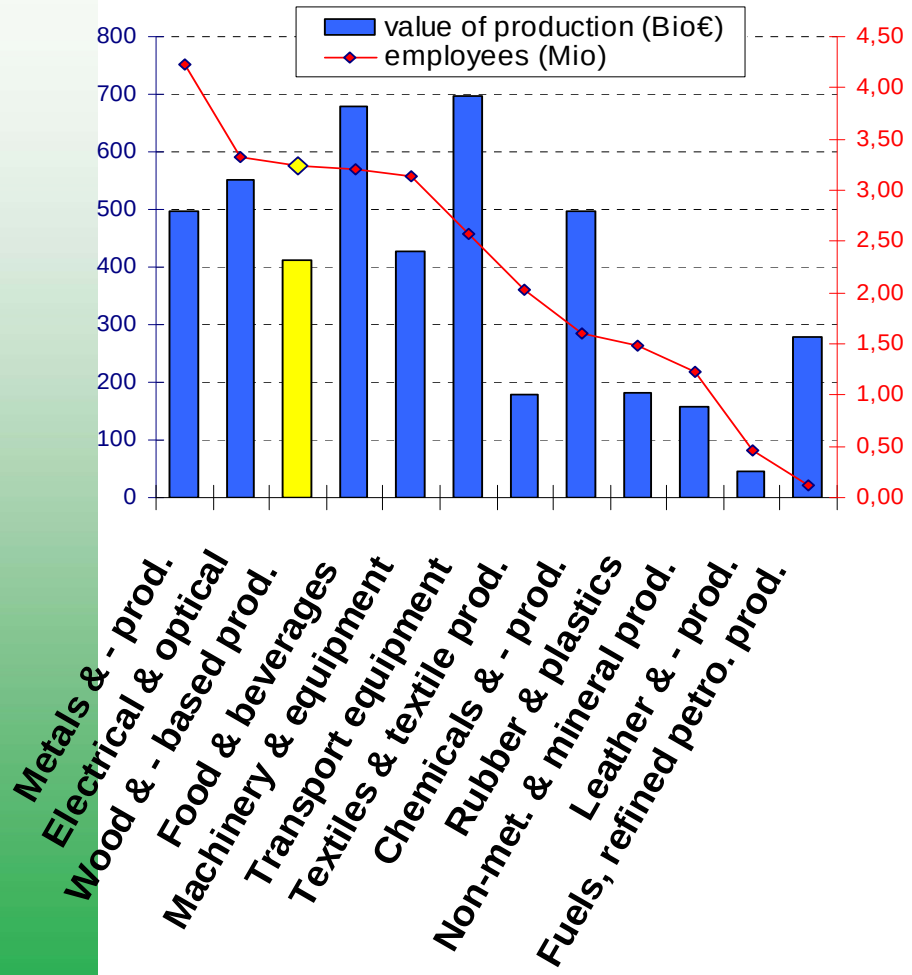


- **The constituents of wood provide structure to the world of plants**
  - A living tree is the most successful plant on earth
  - Wood, a natural high-tech material: a “fibre reinforced polymer composite”, optimised by evolution
- **Wood is the most abundant renewable raw material on earth**
  - High productivity on marginal land
  - No irrigation, fertilisers and pesticides needed
  - Sustainable, cost efficient resource
  - 1,7 billion tons p.a. harvested

Wood Economy

- **The forest-based sector is of highest importance for Austria/ Europe**

Industrial sectors EU(15) 2001

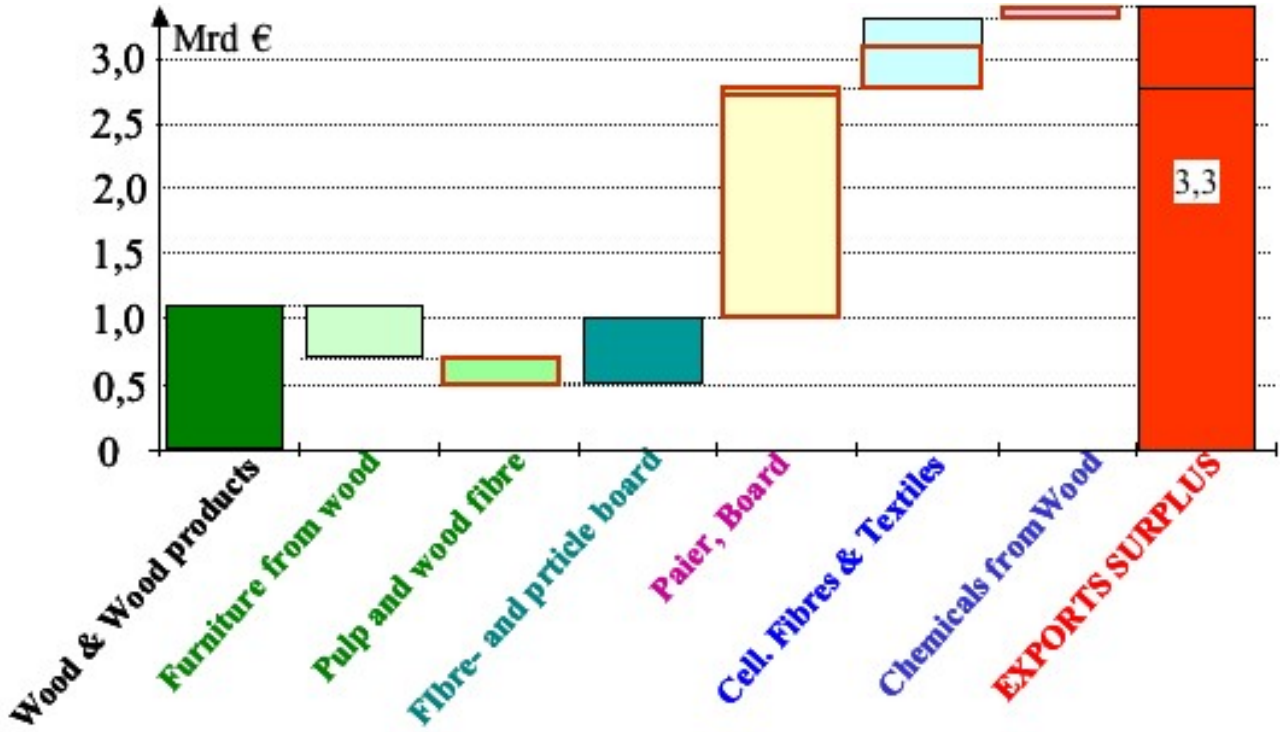


Europe:
24% of the territory
3rd in employment: 3.5 million persons
12 million forest owners
Production value: ~ € 400 billion
Share of EU-manufacturing: 8%
(comparable to automotive, textile, food, and chemical industries)

Austria:
47% of the territory
Employment: 250,000
Production value: € 10 billion
Contribution to GNP: 4.3%
Export rate: 70%
Export surplus: € 3.31 billion

WOOD … Important for the Balance of Austrian Payments

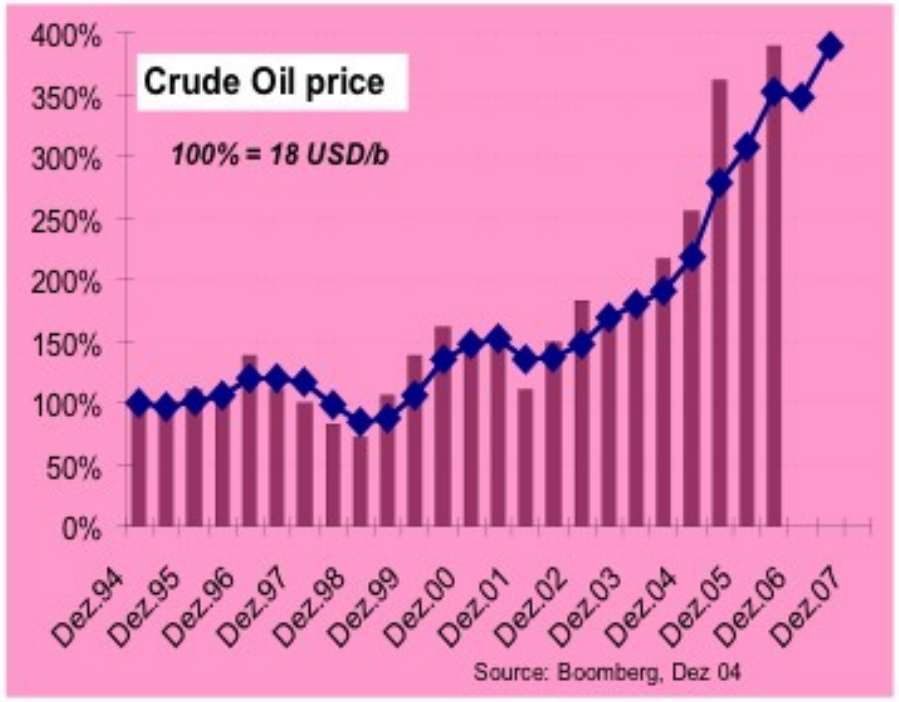
- Next to tourism* the utilisation of wood is the most important contributor to the export surplus
  - ... mainly from chemical processing
  - ... about 15% by LAG and the Austrian companies subsequently processing the LAG materials



(*) **Tourism: 3.7 Mrd €;** 2004 (Statisitk Austria, FPP, supplemented by estimates)

… New Conditions for Competition

- An essential change in the behaviour of the consumers is expected because of the continuously increasing oil prices:
  - materials from wood and cellulose
  - chemicals based on wood
  - energy & fuels based on wood



WOOD: First Process it - then Burn it

- Wood and its ingredients are too valuable to be wasted as primary energy source
  - utilising cellulose as a material offers added value!
  - beforehand fractionation of the wood is sensible!

The final poducts are
technology-intensive!

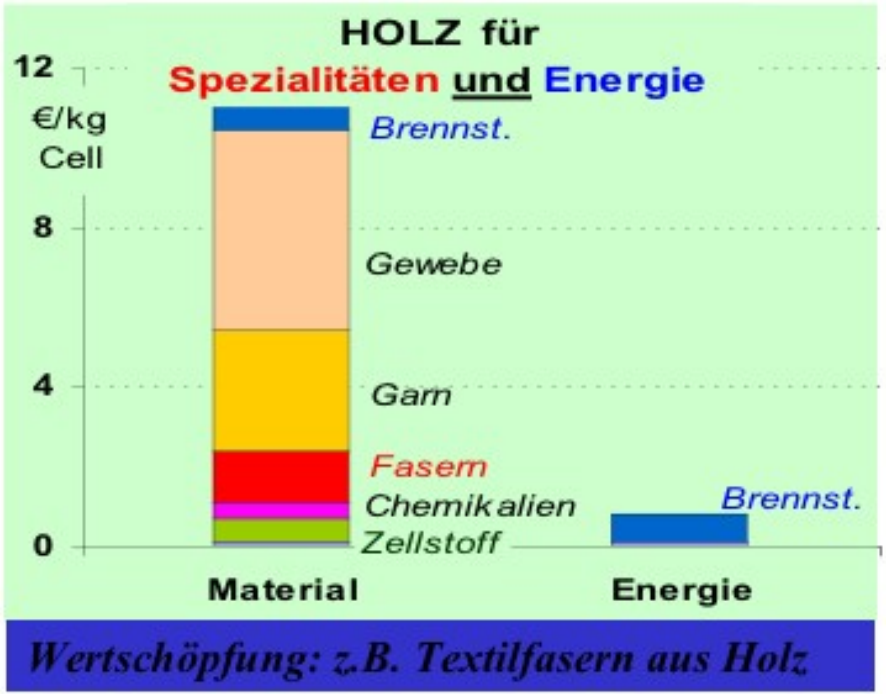
capital-intensive !

labour-intensive!

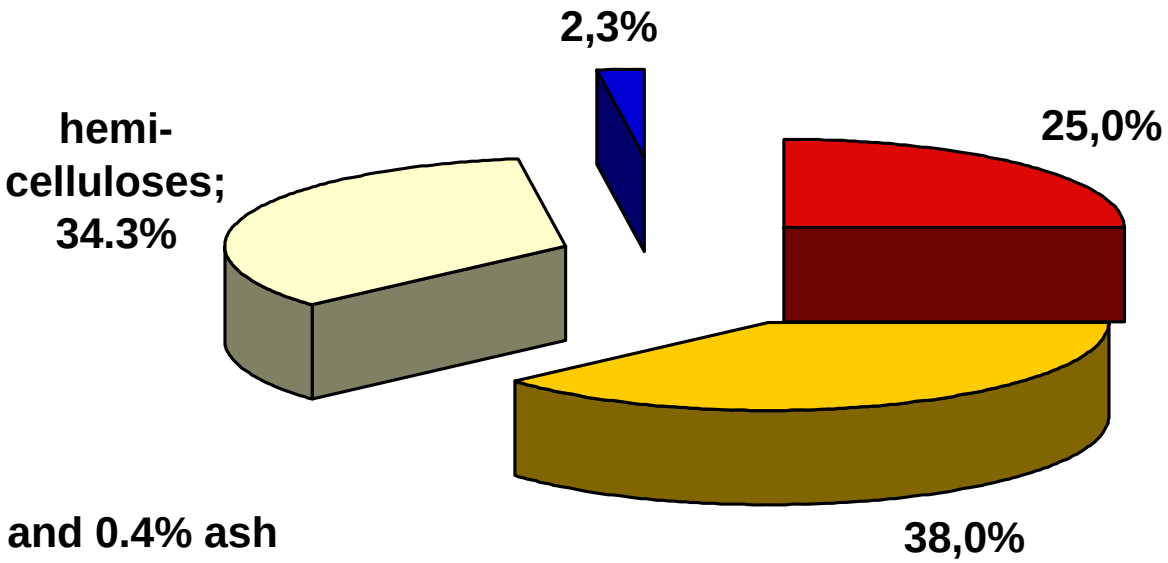
export-intensive!

Lignin:
calorific value 25 – 26 MJ/kg (aromates)

Cellulose, hemicelluloses:
calorific value 16 – 18 MJ/kg (hydrocarbons)

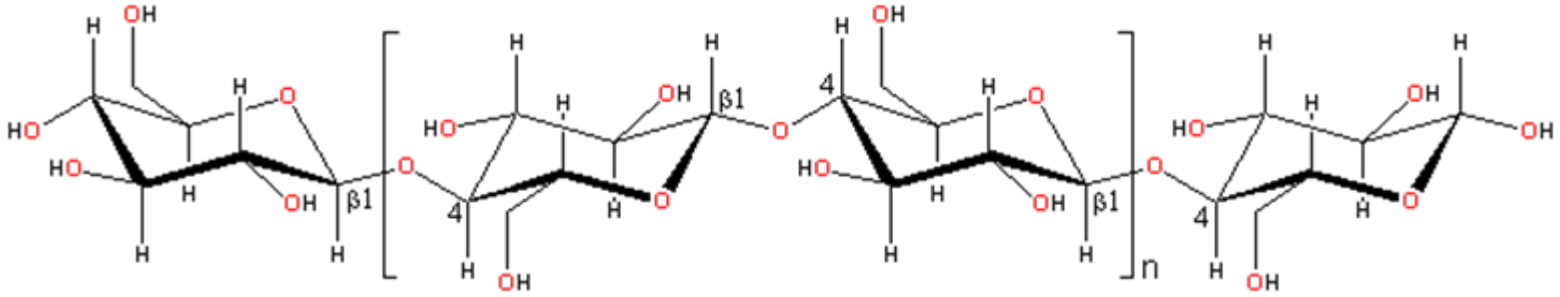


Composition of Beech Wood



H. Sixta (1986) *Lenzinger Berichte* **61**, 5-11.

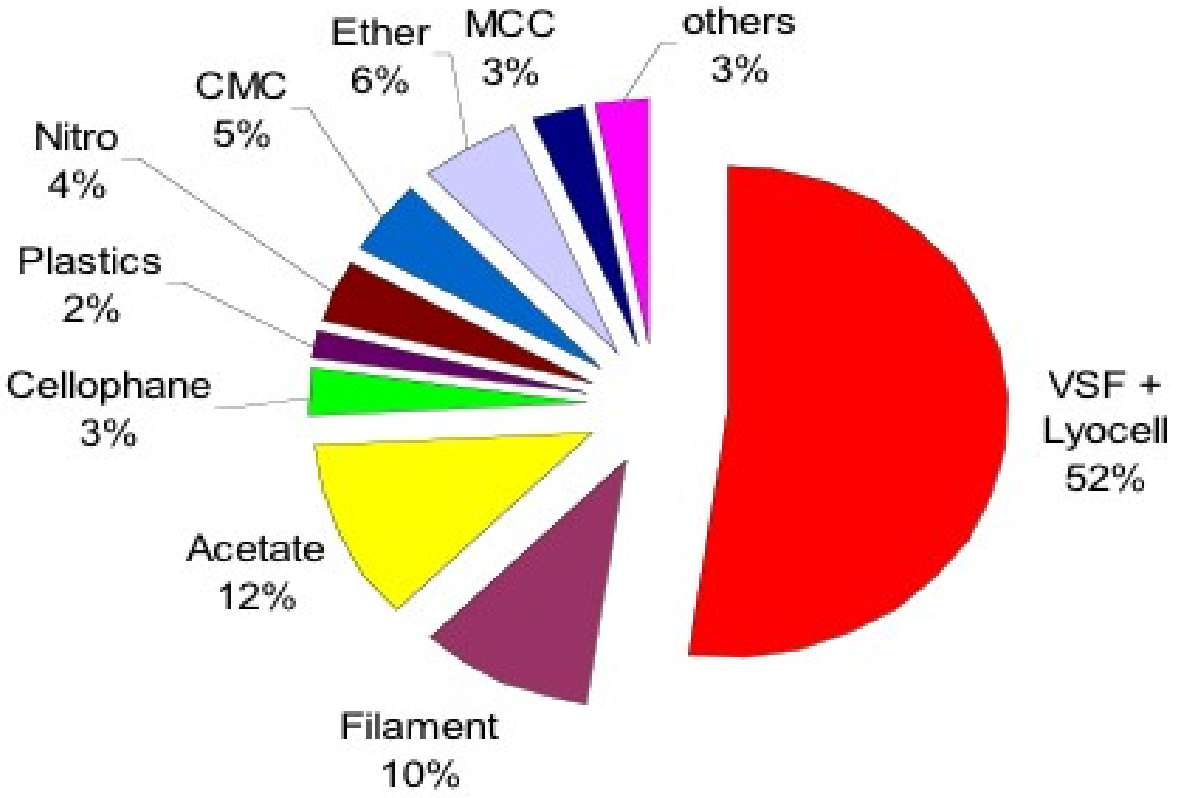
Cellulose: Simple Structure - Sophisticated Function



- The fibre forming compound in the high performance composite wood
- Multifunctional molecule, polymorph
- Its versatility concerning structure and properties: unattainable by synthetic polymers

Cellulose-Based Specialties

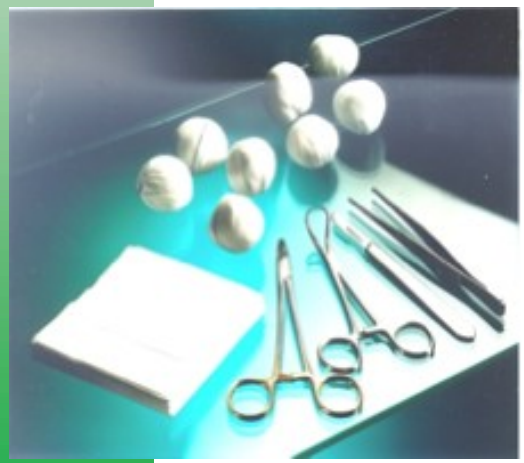
- Consumption of dissolving pulp: about 4 Mio t (worldwide)
  - materials & chemicals



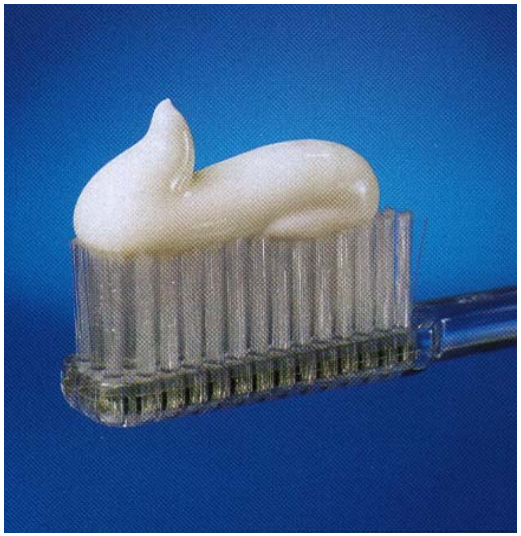
… Materials: e.g. Cellulose fibres

- Sanitary, textile and technical applications
- Unmatched properties:

physiologically compatible,
hydrophilic, water absorbing
slow growth of microorganisms
chemically stable
chemically reactive (dyeing, refining, derivatising)
special visual appearance and feel: soft, smooth, brilliant colours
mechanically and thermally stable, do not melt, …



… Chemicals: Celluloseether



Thickening
cosmetics,
food

Structural viscosity
oil production

Gelatinising
food

Glueing
paper production

Quelle: Nachtkamp, WolffWalsrode Symposium 14.4. 2000

… Chemicals: Celluloseester

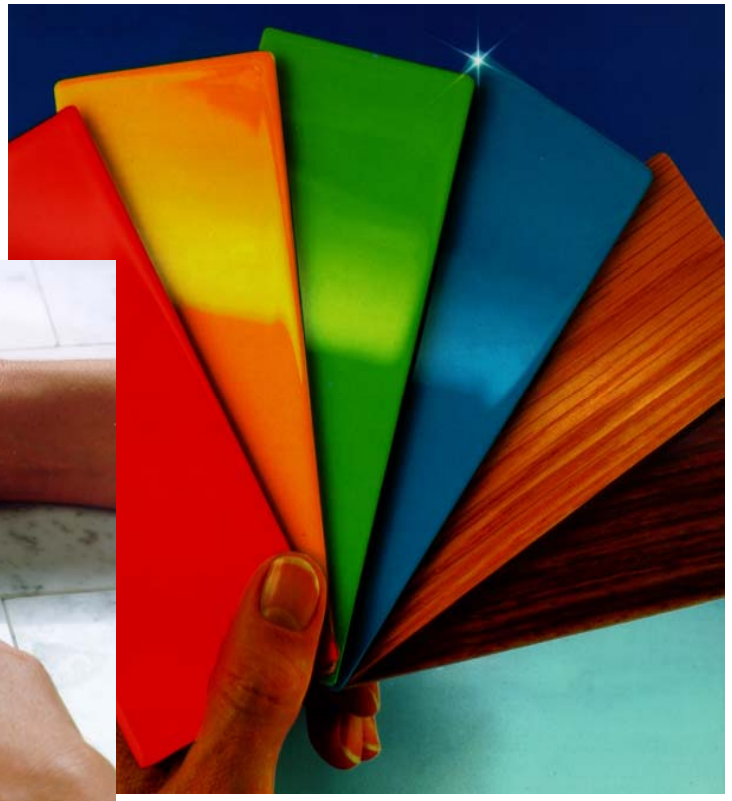
- Organic Esters:
  CELLULOSE ACETATE
  - rayon, photographic films, glasses frames, cigarette filters
- Inorganic Esters:
  NITROCELLULOSE
  - brilliant print colours and high-grade varnishes for wood, metals or paper, nail polish

surface activity

impact strength,

brilliant colours,

transparency

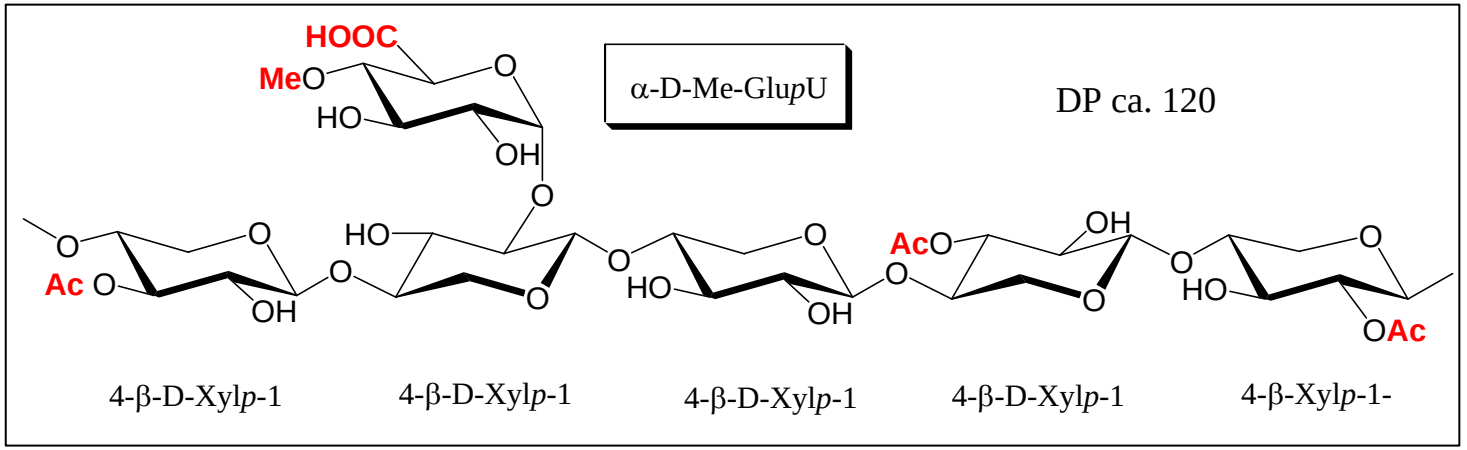


… Hemicelluloses

- Hemicellulose sources:
  - wood (pulp & paper production)
  - oat spelts & other agricultural waste
  - brewery waste
  - ...
- To date use of hemicelluloses limited
- **Hemicelluloses and rare sugars** (20 to 30% of the wood) are dissolved in the process liquors of the pulp production

Hemicellulose from TMP Spent Liquor (STFI)

… Xylan - Xylitol



- Structure of xylan from beech wood (*Fagus sylvatica*)⇧
- During pulping xylan is degraded to xylose (and other compounds).
- Xylose is reduced to xylitol and used as an artificial sweetener, for preventing caries, as a humectant (nasal wash) ⇩

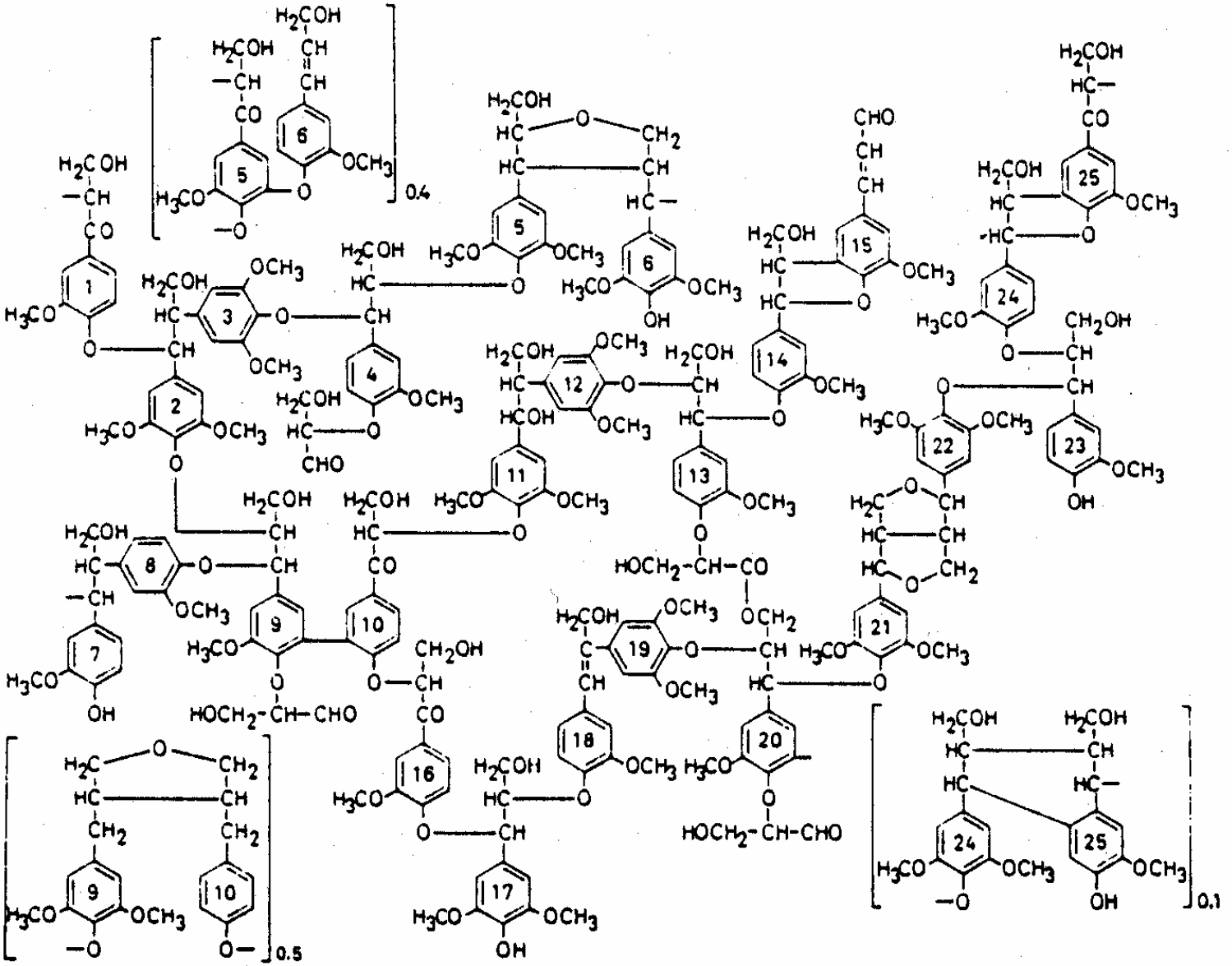
Other Uses for Xylan

- Bread baking
  - dietary fibre
  - thickener

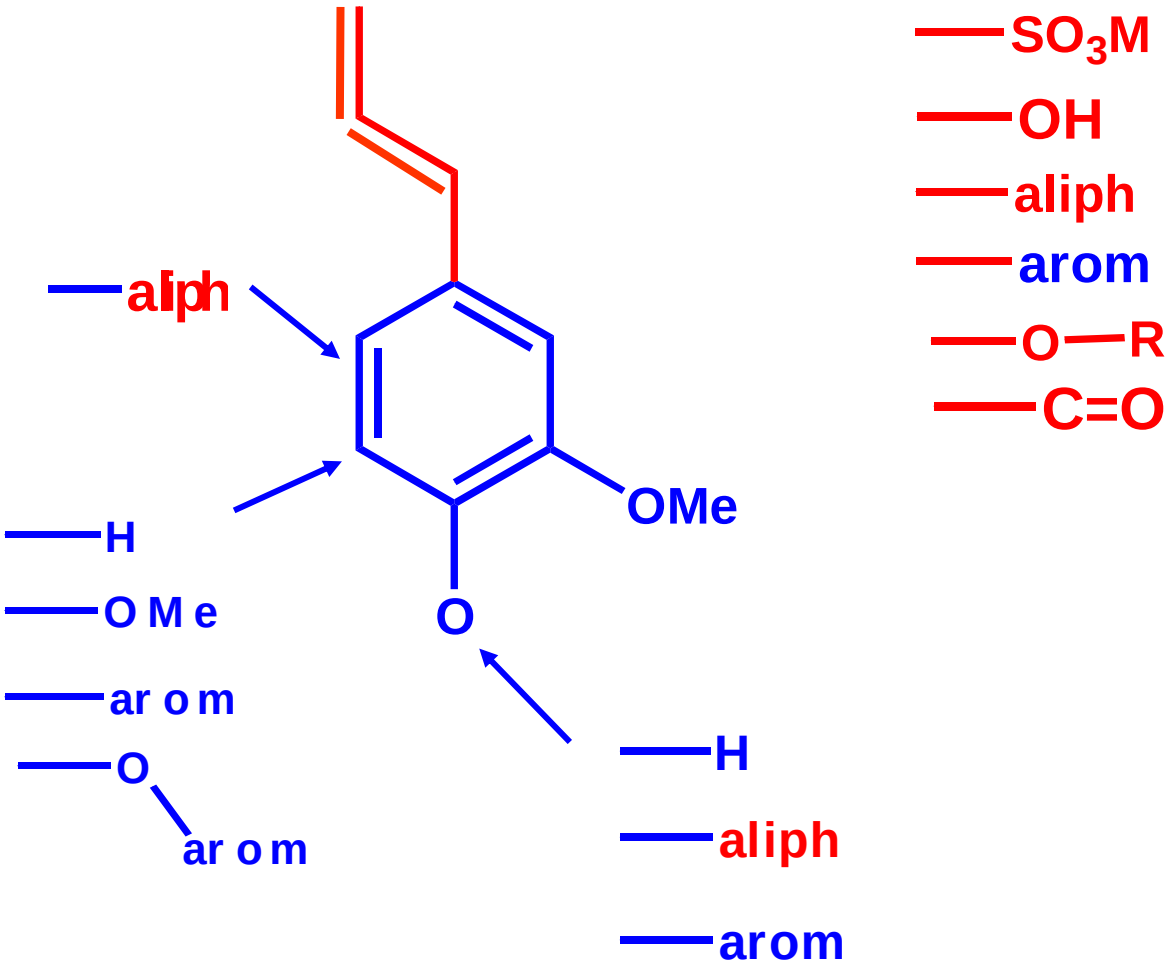
- Medicine (mostly xylan sulphate)
  - inhibits blood coagulation
  - inhibition of tumour cell attack (->anti- HIV)
  - stimulates immune system
- Pharmaceutics
  - excipients
- Cosmetics

- hydrogels
- „bioplastics“/films
- xylo-oligosaccharides
- paper additive
- additive in construction
- chemicals
  - butanol
  - acetone
  - fatty acids
  - furfural
  - xylose
  - xylitol

Lignin Structure of Beech Wood Proposed by Nimz

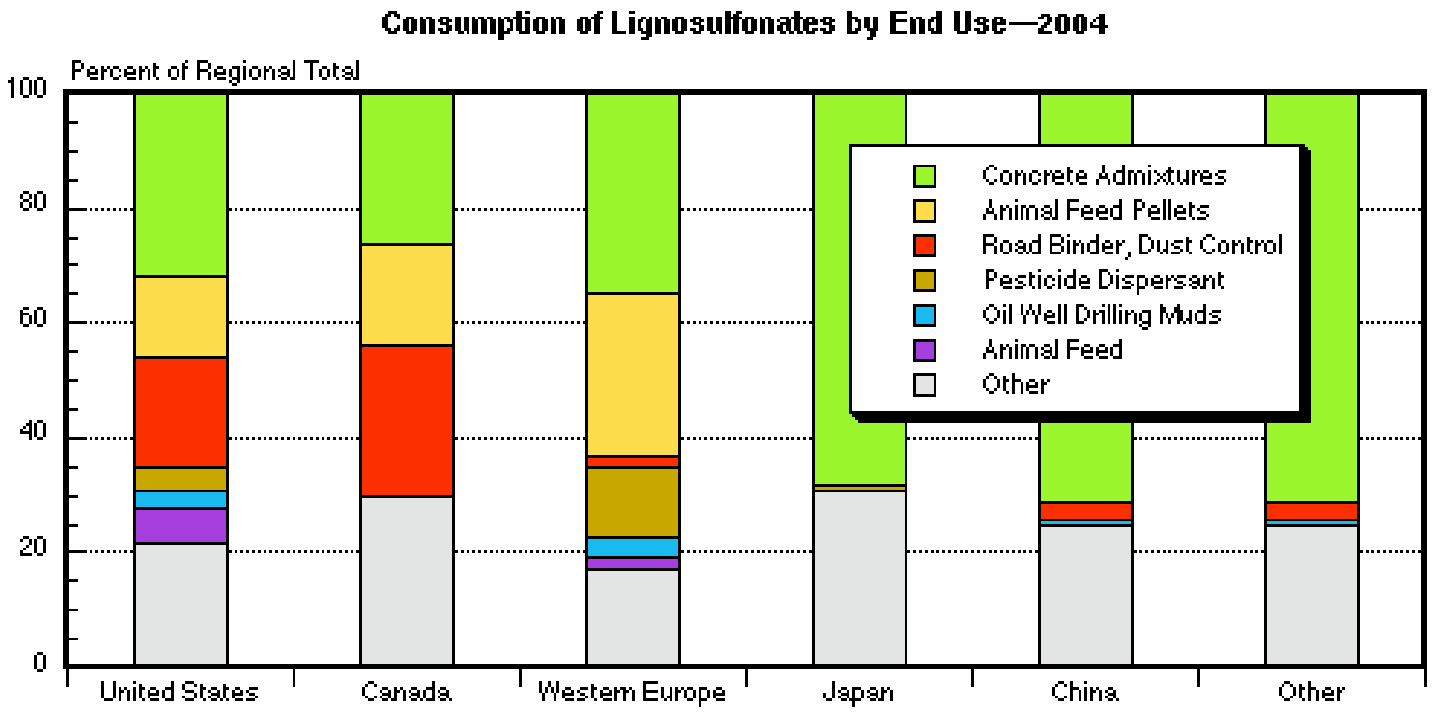


Lignosulphonates (LS)



Utilisation of Lignosulphonates

- Mixture of sulphonated lignins, sugars, sugar acids & inorganics
- Mixture is complex & variable, water soluble, anionic, suface active
- Dispersing, wetting, binding and sequestering properties
- Canada, W-Europe, China net exporter, US & Japan net importers
- World production value (2004) about 500 Mio US$
- No high-price applications



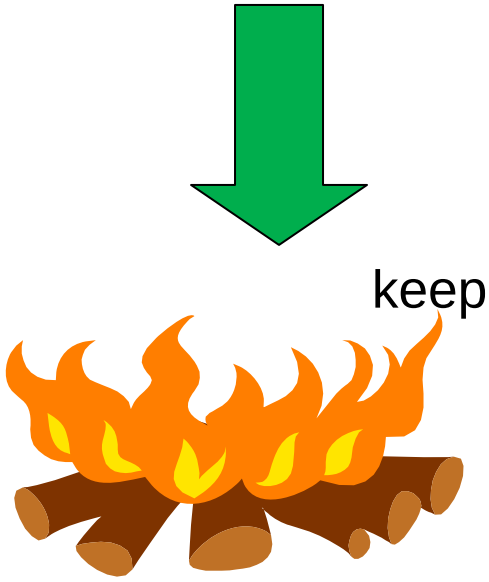
SRI Consulting CEH Report, http://www.sriconsulting.com/CEH/Public/Reports/671.5000/

Lignins ...

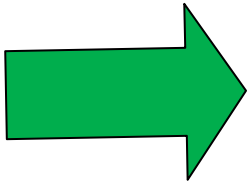
...are the most difficult materials to study

...generally are a nuisance to humans at present

(C&EN / April 2, 2001)

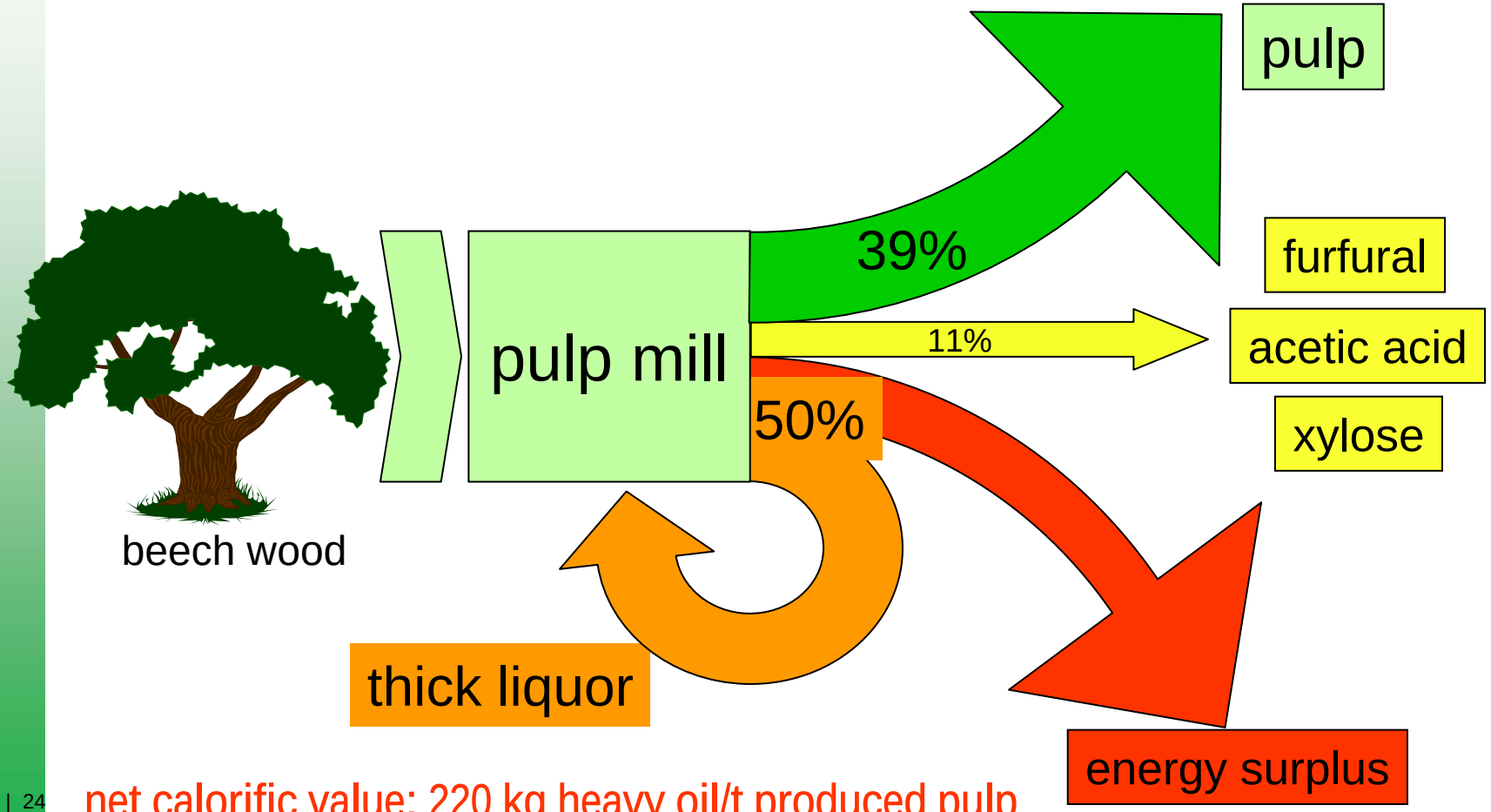


burn it
&
keep Lenzing going



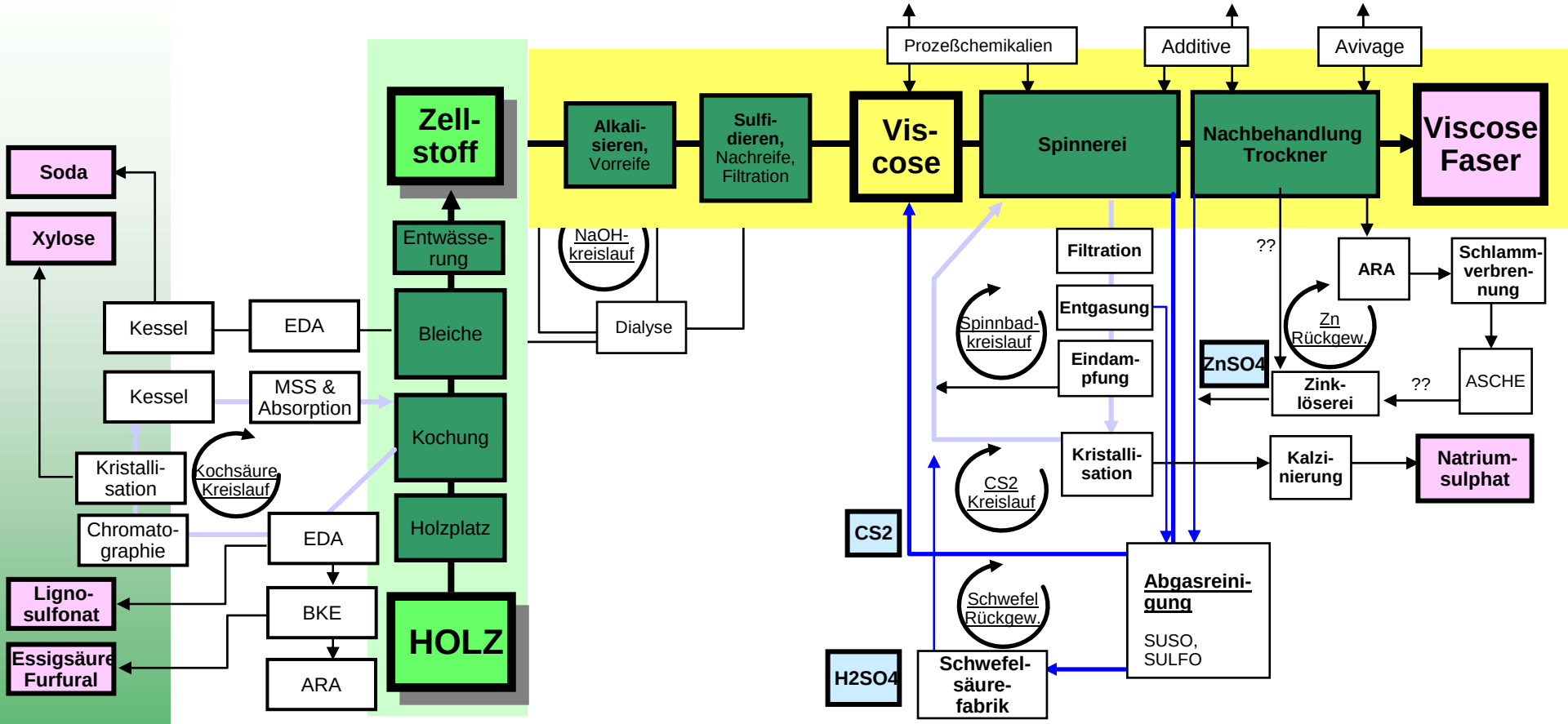
Wood Refinery in Lenzing

- Major product from acidic Mg-sulphite cooking: dissolving pulp (cellulose for man-made cellulose fibres)
- 25% higher wood yield - fine chemicals based on hemicelluloses
- Export of energy surplus from the LS-combustion



net calorific value: 220 kg heavy oil/t produced pulp

Fibre Production in Lenzing



Challenges & Questions

- No substitution of process possible
- Closed loop operations allow only limited changes
- The process lyes are very crude mixtures with unpleasant pH-values
  - separation very tricky
  - microorganisms/enzymes very unhappy
- Wood supply
  - competition of wood as fuel
  - federal/provincial funding of wood (chips) as fuel
- Better use of inorganics?

Top 12 Potential Biobased Chemicals

- 1,4-Dicarboxylic acids (succinic-, fumaric- & other)
- 2,5-Furandicarboxylic acids
- 3-Hydroxypropionic acid
- Aspartic acids
- Aldonic acids
- Glutamic acids
- Itaconic acid
- Levulinic acid
- 3-Hydroxybutyrolactone
- Glycerine
- Polyols (sorbitol, xylitol, arabitol)

Study published by the US Dept. of Energy, about 300 chemicals investigated, seven criteria

Outlook

- Lenzing will widen its wood refinery concept
- This will be done in co-operation with the Competence Centre WOOD (currently Kplus - from 2008 a K1-centre)
- Focus will be on hemicellulose utilisation
- The question about inorganics will be addressed
- There will always be a careful evaluation of materials use versus energetic use

Acknowledgements

- FFG, Austrian & Upper Austrian Government that they will support our wood refinery concepts.
- Haio Harms for introducing me to the wood refinery concept, his generous gifts of transparencies - if needed and his general support.

Topliste potentieller biobasierter Basischemikalien

Biomasse ⇨Plattform ⇨Building Blocks ⇨sekundäre Chemikalien ⇨Zwischenprodukte ⇨ Produkte/Anwendungen

- ca. 300 Chemikalien
- Kriterien:
  - Rückführung zu welcher Plattform & Einschätzung d. Effizienz
  - chemische Funktionalität (einfach/mehrfach)
  - Zahl und Zugang möglicher chemischer Folgeprodukte
  - wenn vorhanden: gegenwärtige Nutzung und Potential
  - Stand der Forschung und Erfolgsaussichten
  - Beziehung zur Chemie fossiler Brennstoffe
  - Abschätzung des allgem Marktpotentials & Potential als Supercommodity (Basischemikalie mit potentieller Mehrmillionen-Tonnage)