INBIOM
INNOVATIONSNETVÆRKET FOR BIOMASSE

Green Biorefining Seminar
Aalborg University Denmark
Friday 29. June 2018

Green biorefinery and biotechnological work at Wood KPLUS

(Biorefinery linking agriculture/forestry and chemical industry)

BIRGIT KAMM

Wood Kplus, Area Wood Chemistry and Biotechnology, Linz, Österreich and BTU Cottbus-Senftenberg, Deutschland

WOOD KPLUS

Content

* RR- Renewable resources

1. Objectives

1.1 Use of biomass (RR=renewable resources)

- 13% or 2,7 million tons RR used in German chemical industry, mostly for the production of specialty chemicals.

- Until 2030, German chemical companies will use 50% more renewable resources for their processes.

- In Europe, a 10,4 billion EUR specialty chemicals market volume is expected (until 2030).

- Activities in the field of biomass use in Austria on various industrial areas like Upper Austria, Lower Austria, Steiermark, Kärnten

The Chemical Industry 2030
[https://www.vci.de/vci/downloads-vci/2012-12-10-vci-prognos-study-chemistry-2030-short-version.pdf]

1.2 Specialty chemicals

Specialty chemicals are the base for the production of relatively high priced derivatives, like

(1) Engineering Polymers (specialty plastics)
(2) Consumer chemicals (washing, cleaning and personal care products, fragrances etc.)
(3) Paints and coatings
(4) Plant production agents (insecticides, fungicides, nematicides, acaricides, etc.)
(5) Fuel additives

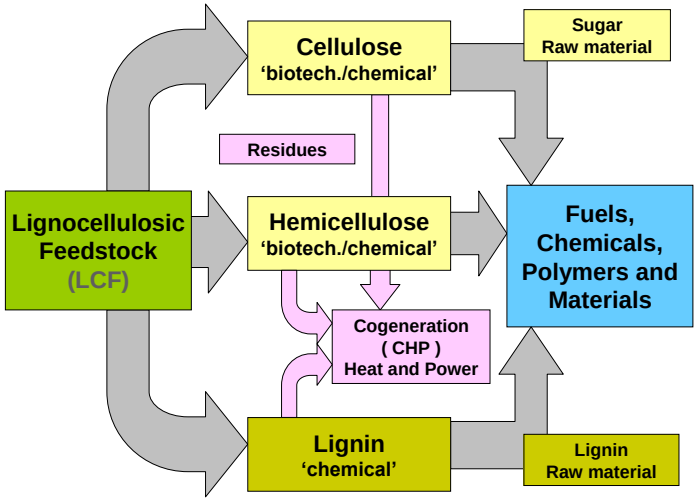
Example: German chemical industry, year 2011

- 43 % of the chemicals production
- Market volume 67 bn. Euro
- 12% of the world volume of 567 bn. Euro

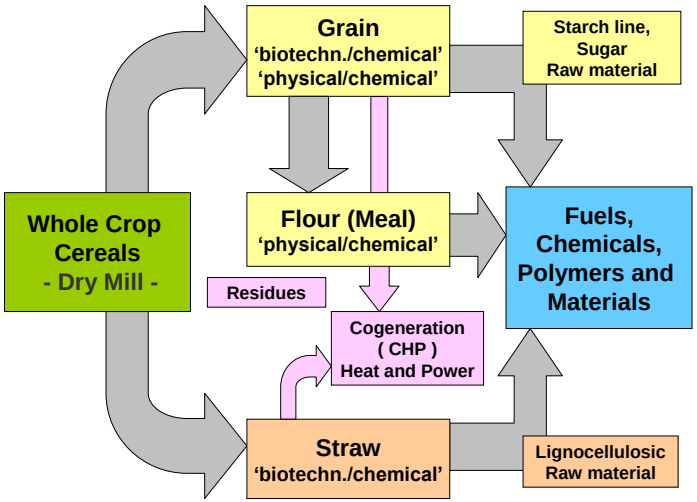
The Chemical Industry 2030
[https://www.vci.de/vci/downloads-vci/2012-12-10-vci-prognos-study-chemistry-2030-short-version.pdf]

1. 3. Biorefinery principles

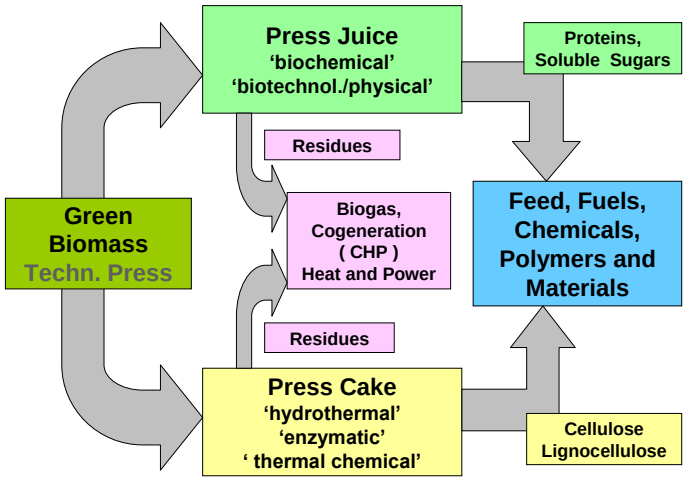
Kamm et al, Biorefineries-Industriel Processes and Products, Wiley-VCH, 2010



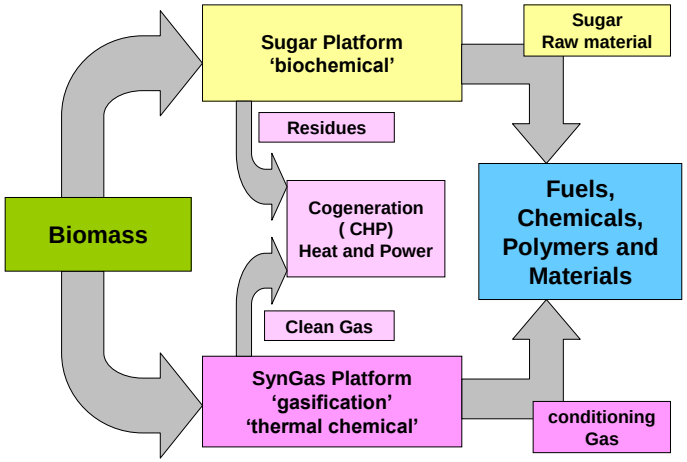
LCF-BIOREFINERY



WHOLE CROP-BIOREFINERY

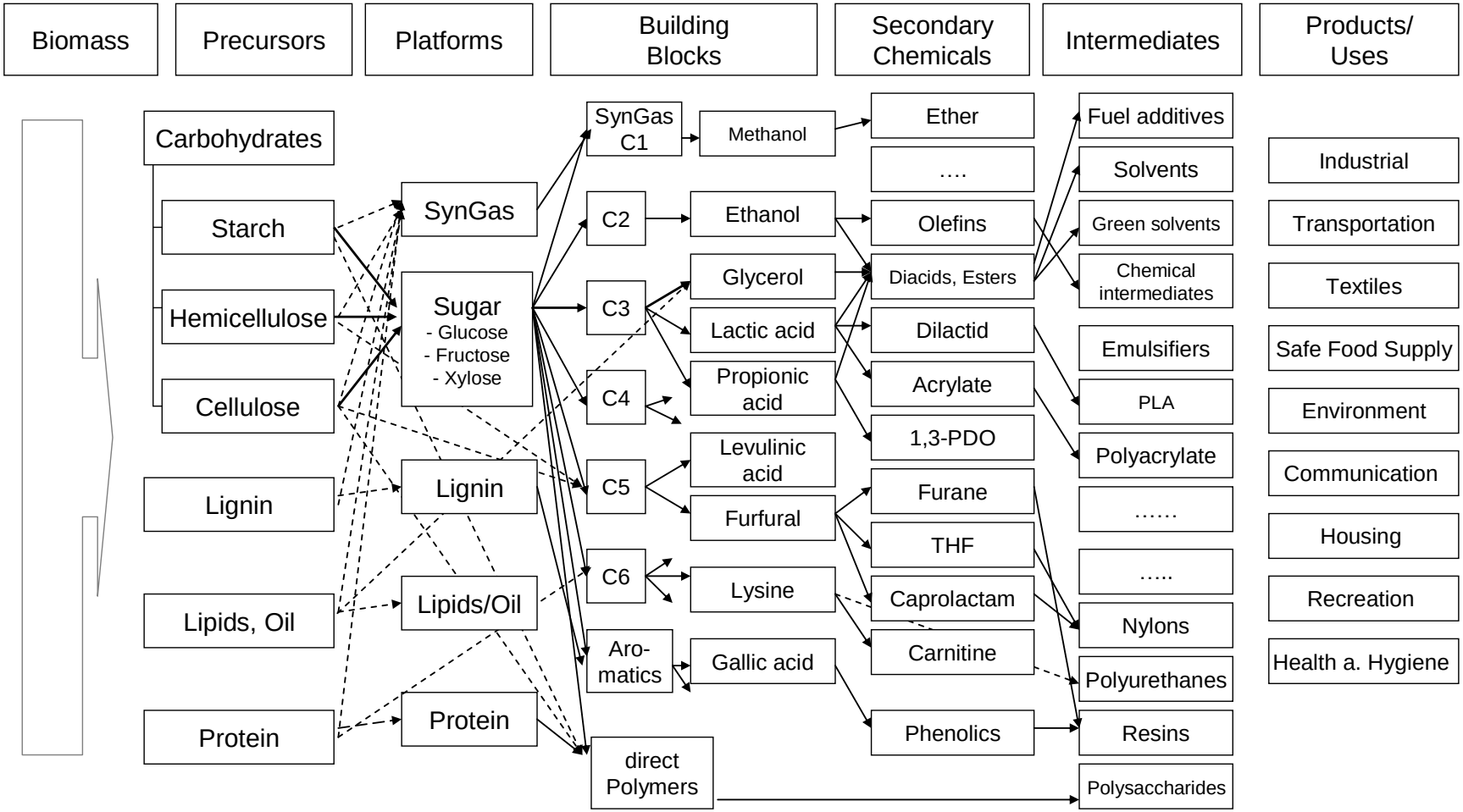


GREEN BIOREFINERY



TWO-PLATFORM-CONCEPT

1.4 Biobased platform chemicals and derived specialty chemicals



[Werpy, 2004, Kamm, B. et al; Wiley, 2006, 2010, 2015]

Biobased specialty chemicals 1.5 Market assessment (selection)

Nr.	DOE´s TOP 15	Source	Derivatives	Use and products	Marketable bio-based products		Note*
					Already available	In the next 10 years	
1	Succinic acid	Fermentation from glucose	1,4-Butanediol, tetrahydrofuran, γ-butyrolactone, maleic acid anhydride, pyrrolidone	Solvents, polyester, polyurethane, nylon, paints, food additives	Yes	Yes	A
2	Fumaric acid	Fermentation from glucose	Same as succinic acid	Same as succinic acid	Yes	Yes	A
3	Malic acid	Enzymatic hydroxylation of fumaric acid by fumarate hydratase	Same as succinic acid	Same as succinic acid	Yes	Yes	A
4	2,5-Furan dicarboxylic acid	Oxidation of 5-hydroxymethylfurfural	2,5-Bishydroxymethylfuran, 2,5-Bis(aminomethyl)-Tetrahydrofuran	Polyamide, Polyester z.B. Substitution der Terephthalsäure im PET	Demonstra-tion is planned	Yes	B

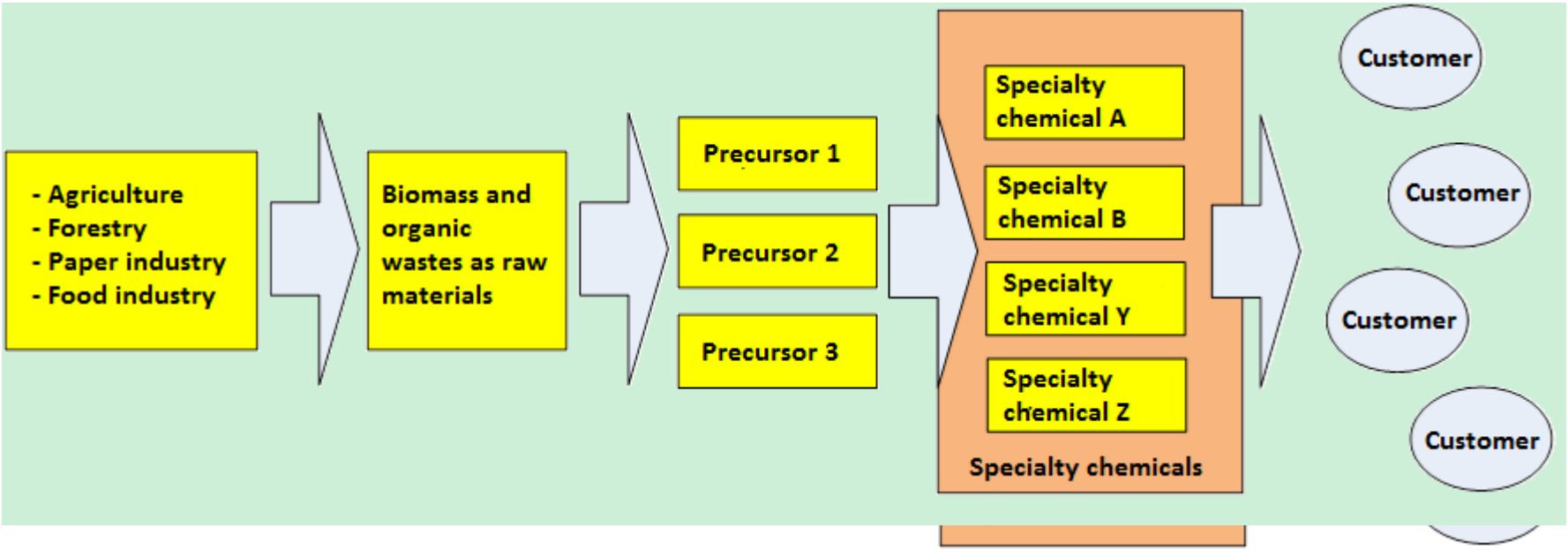
*A – Beginning of commercialization, B - significant activities [CEN. ACS. Org. 10, 2014]

Biobased specialty chemicals – 1.5 Market assessment (selection)

5	3-Hydroxy propionic acid	Fermentation from glucose or glycerin	1,3-propanediol, acrylic acid, acrylamide, methyl acrylate	Polytrimethylene terephthalate, highly resistant carpet fibers, contact lenses	No	Yes	B
6	Glycerin	Chemical or enzymatic transesterification of vegetable oils	Propylene glycol, ethylene glycol, 1,3-propanediol, lactic acid, epichlorohydrin, acrolein	Polyester, soaps and cosmetics, antifreeze agents	Yes	Yes	A
7	Sorbitol	Hydrogenation of glucose	Isosorbide	Flame protection agents, pharmaceuticals, biobased softeners (Polysorb® ID 37), polymers	Yes	Yes	A

* A-[Fa. Solvay, Belgium, Fa. Zeppoil and Fa. Spolchemiegroup Czech Republic), B- significant activities, [CEN. ACS. Org. 10, 2014]

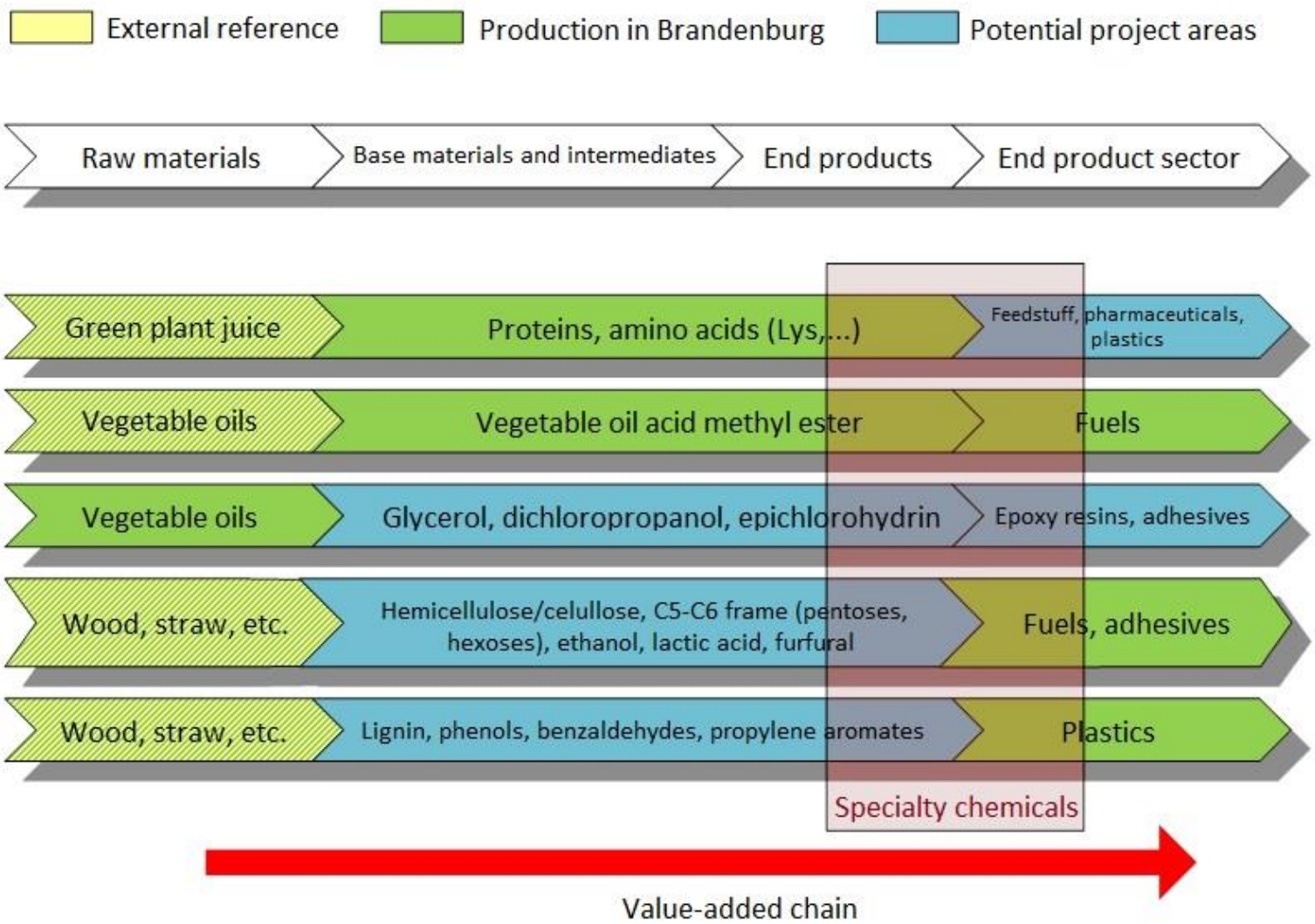
Starting position in different regions like Germany, Austria
Alignment of the value added chain



[Based on BASF-lecture in the frame Masterplan, cluster pastics, chemicals HF specialty chemicals]

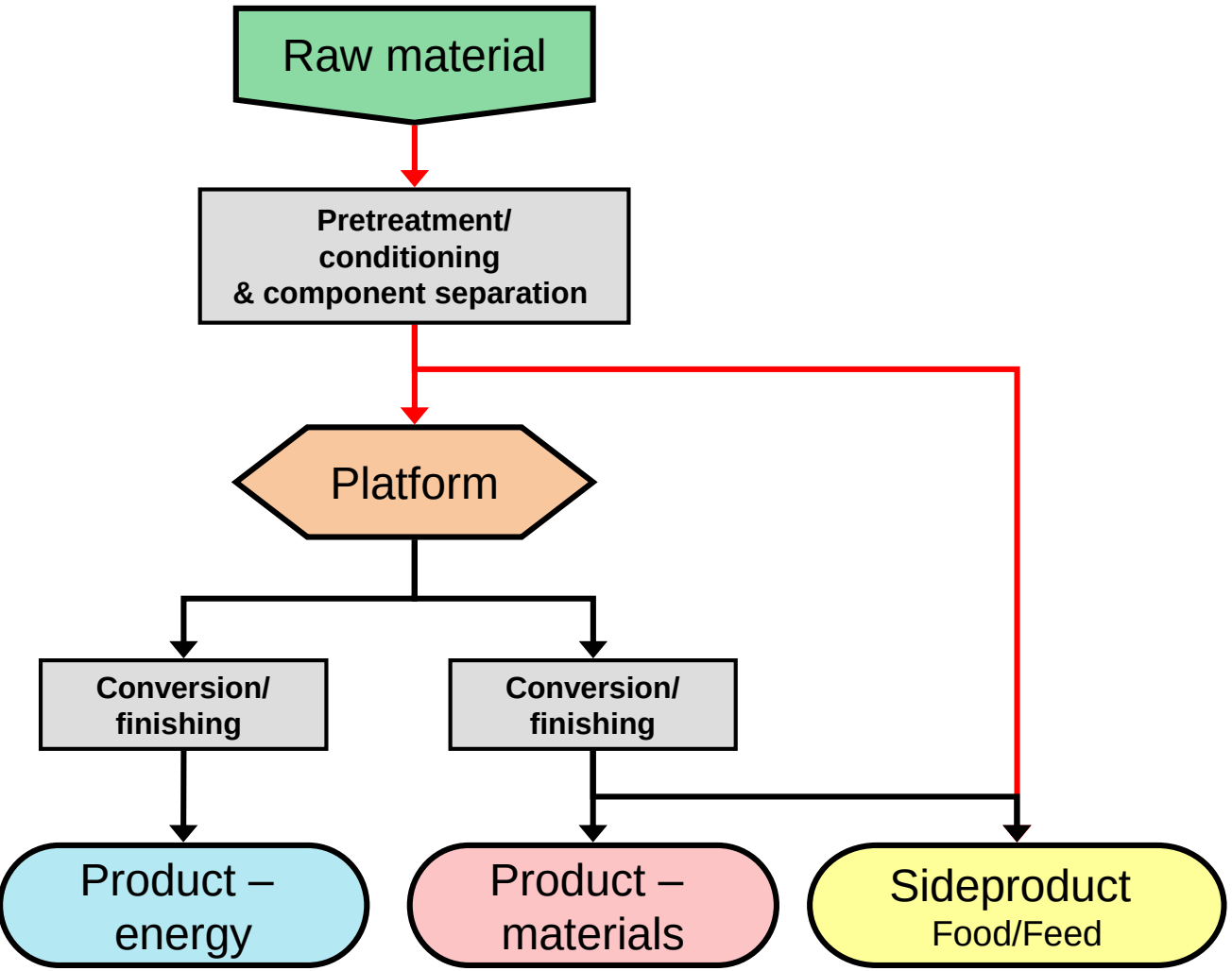
Biobased specialty chemicals

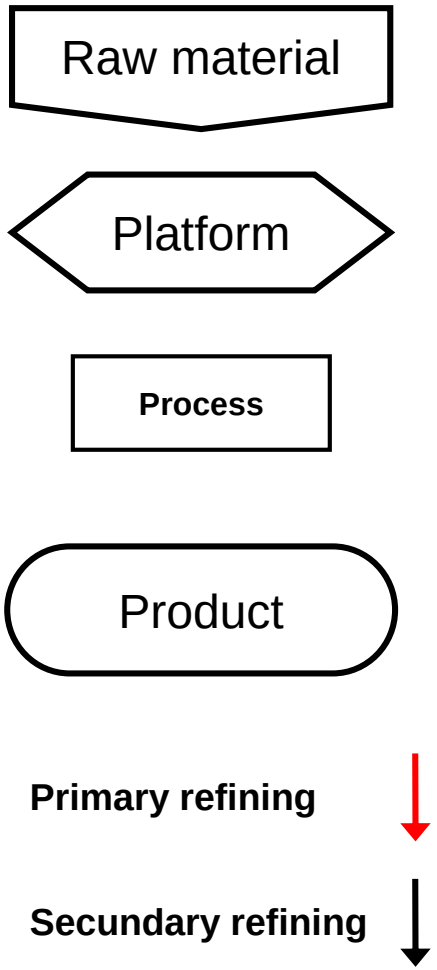
Current processing potential of bio-based raw materials



[Fig. from BASF-lecture in the frame Masterplan, cluster pastics, chemicals HF specialty chemicals]

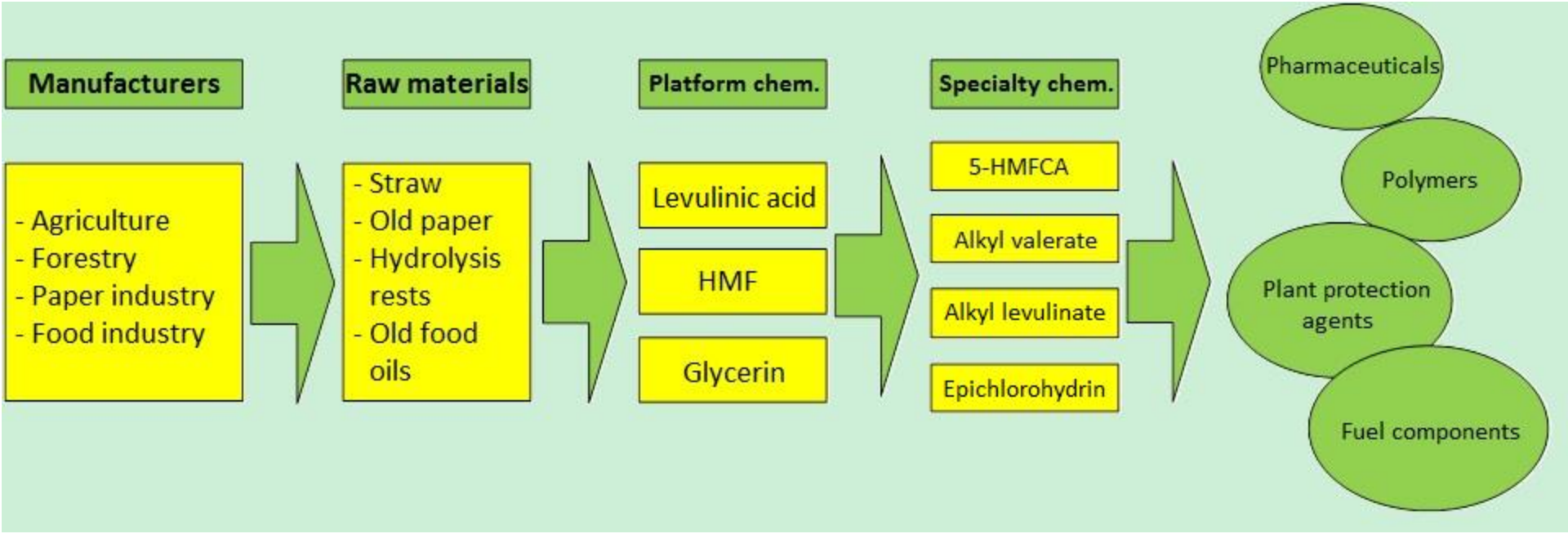
Biobased specialty chemicals by biorefining





[Roadmap Biorefineries, 2012, FNR e.V.]

New biobased specialty chemicals by biorefining

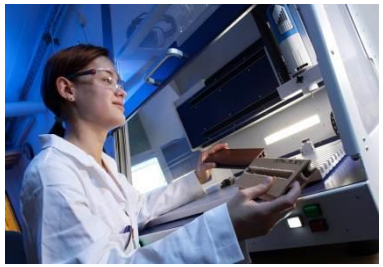


Example: Potential Analysis State of Brandenburg (Germany), 2015

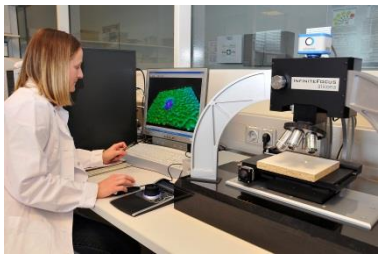
WOOD

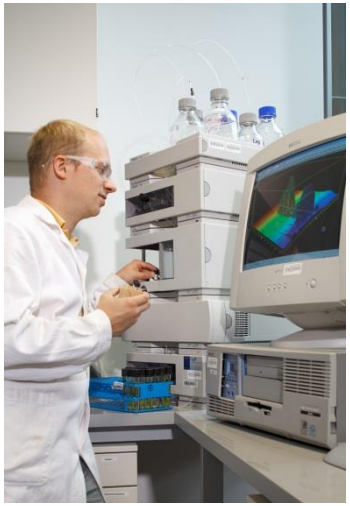
KPLUS

2. From Fundamentals to Implementations



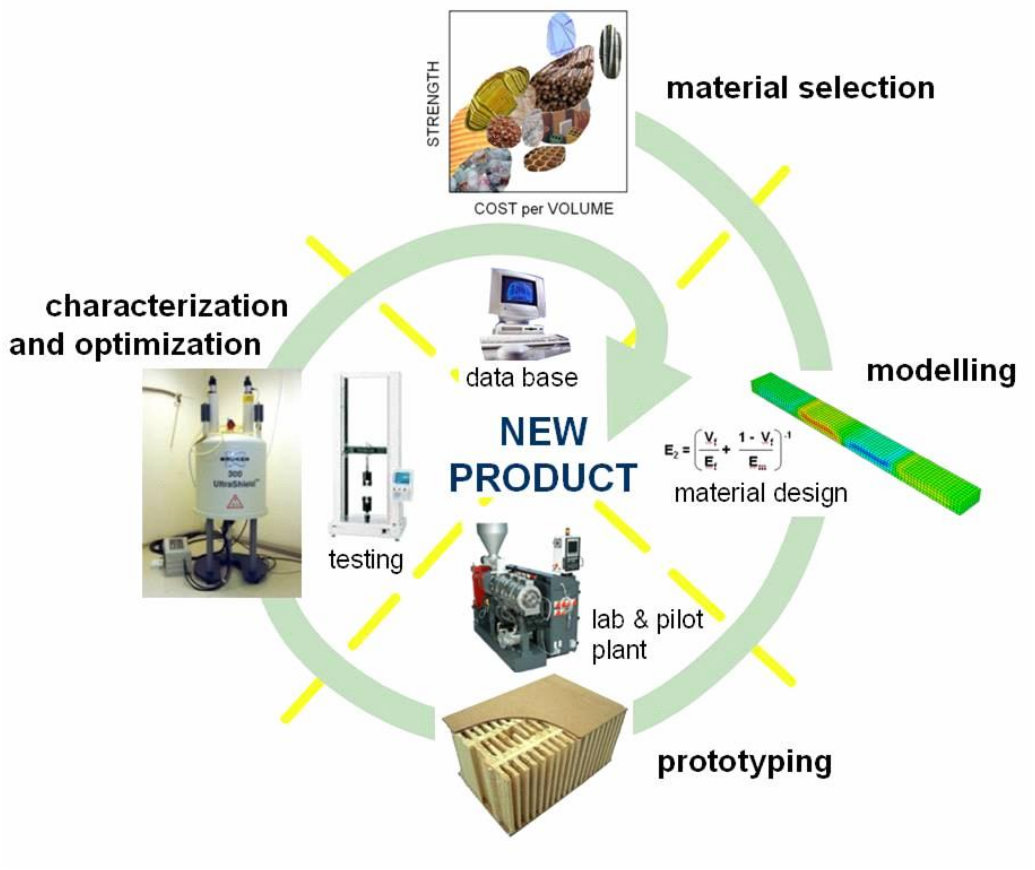


Lab Space: 2.500 m² / Office Space : 1400m² / 115 Employees / > 200 Projects

Research Areas



Wood Chemistry & Biotechnology

Wood - Polymer-Composites

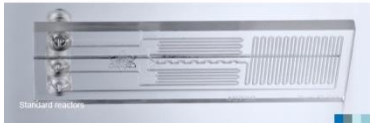
Wood & Paper Surface Technologies

Wood Materials Technologies

Kompetenzzentrum Holz

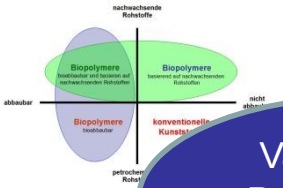
Market Analysis & Innovation Research

Wood Chemistry & Biotechnology



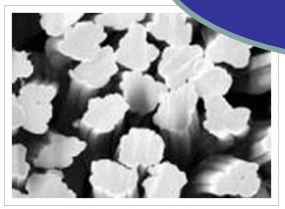
Alternative feedstocks & decomposition processes

Chemical Process technology for biomass utilisation



Value added Products from Biomass

Bioprocess Technology



Process Development - Wood KPlus

Pretreatment → Conditioning → Fermentation → Down Stream → Application

- Wood Kplus can contribute along the whole process chain (some examples)
  - Steam Explosion, Refiner, Thermal etc.
  - Inhibitor Screening and Detoxification
  - Biomass decomposition (Hydrolysis)
  - Strain selection, fermentation and optimisation
  - Polymer formulation……..

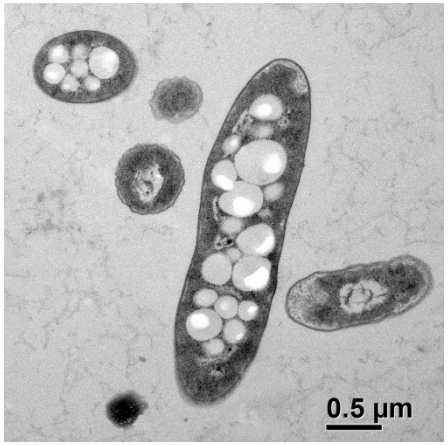
2.1.Extremophiles as New Process Building Block

- Industrially relevant properties
- Combinations possible (e.g alkalihalophile)

Type	Range
Thermophile	T = 60-80°C (max. 113 °C)
Psychrophile	T < 15°C (min. -18°C)
Acidophile	pH< 5 (min. pH=0)
Alkaliphile	pH>9 (max. pH=11)
Halophile	Salt >3,5% (max. 35%)

Product fermentation with extremophiles Example – PHA fermentation

- PHA an intracellular biopolymer



- Benefits using Halophiles:
  - Non sterile process
  - Easy cell lysis (osmotic pressure)
  - Conversion of C5 and C6
  - Conversion of polysaccharides possible

Lactic acid and its industrial applications

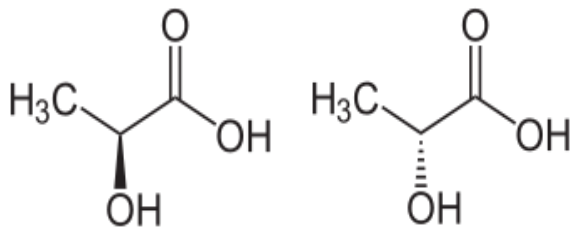
Food

- Preservative
- Flavour
- Acidulant
- Acid mineral fortification

Chemistry

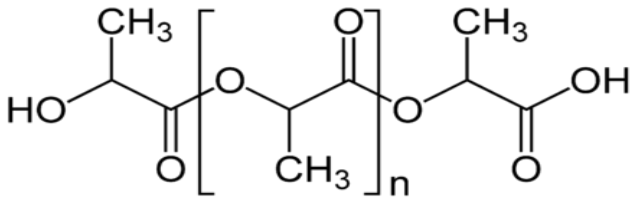
- Agro-chemicals
- Green solvents
- Cleaning agents
- **Bioplastic**

2-hydroxypropionic acid



L(+) D(-)

Polymerisation



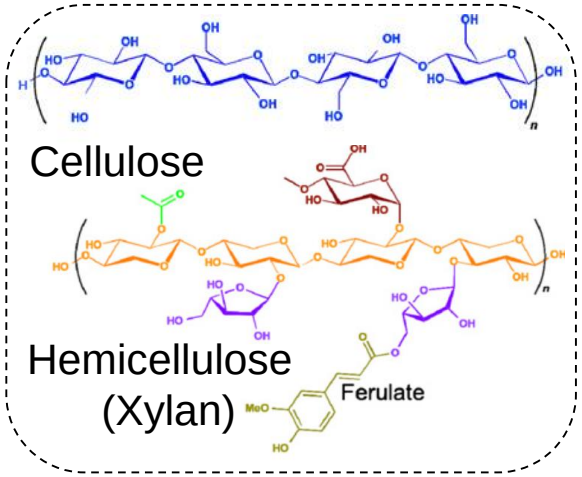
Polylactic acid

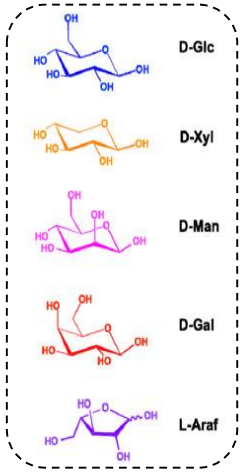
Pharmacy

- Chiral intermediates
- Pharmaceuticals
- Dialysis solutions
- Parenteral solutions

Biochemical conversion of lignocellulose to D-Lactic acid

Lignocellulosic raw material





Waste products from paper industry

Pretreatment

- Biological
- Physico-chemical
  - Steamexplosion
- Chemical
  - LX-Process

Enzyme production

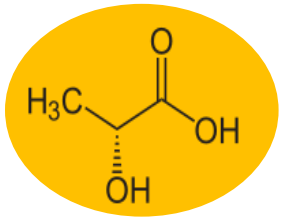
Saccharification

- Cellulase mixture
  - Celluclast
  - Cellic CTec2

Microbe enrichment

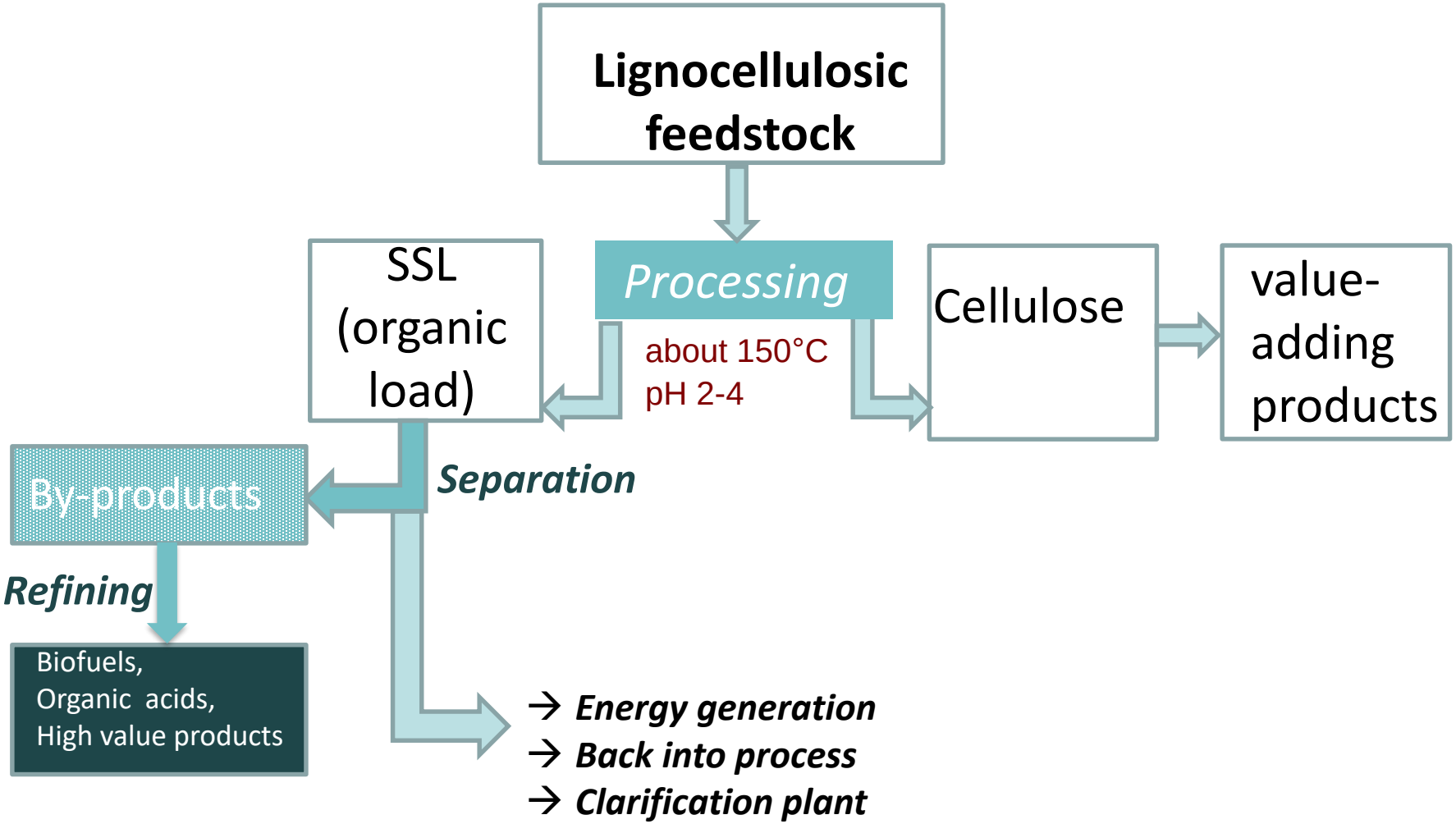
Fermentation

- GMO E.coli
- GMO Yeasts
- LAB
  - Natural
  - GMO



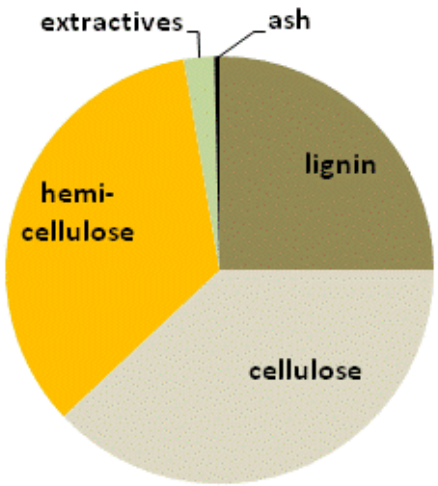
D-Lactic acid

2.2 The Pulp Mill Biorefinery

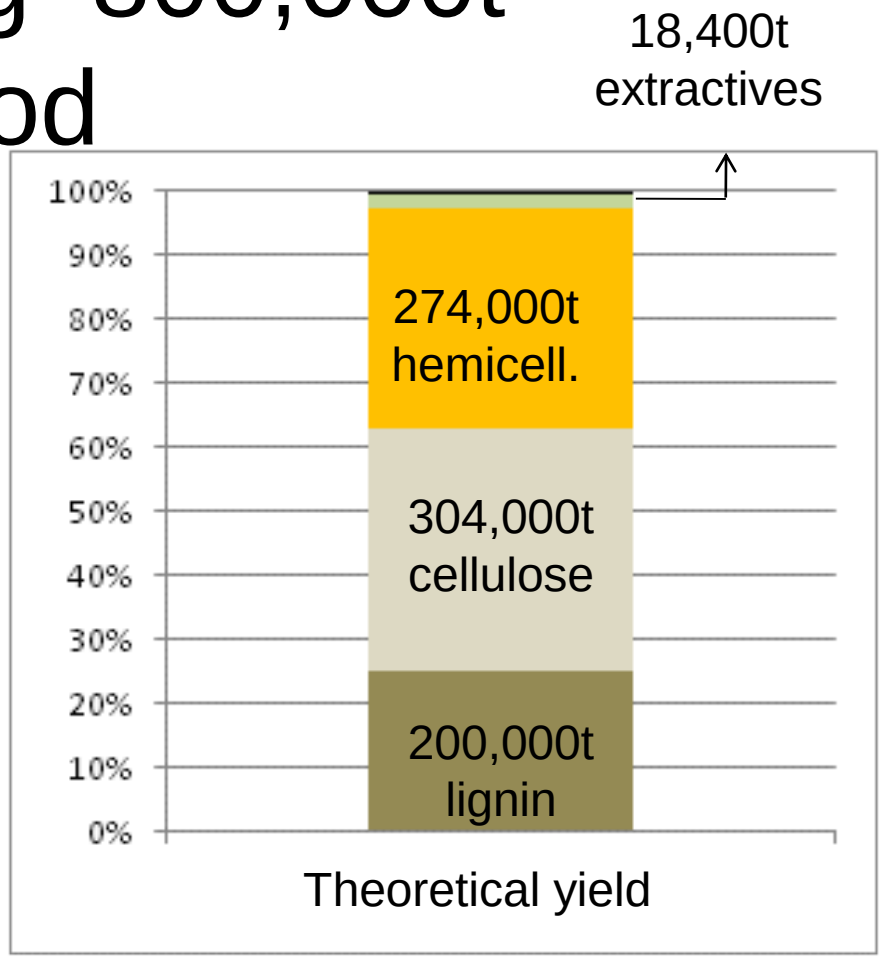


SSL= spent sulphite liquor

Example: A Medium-Sized Pulp Mill Converting 800,000t Beech Wood



Composition of beech wood
H. Sixta (1986) Lenzinger Berichte 61, 5-11)



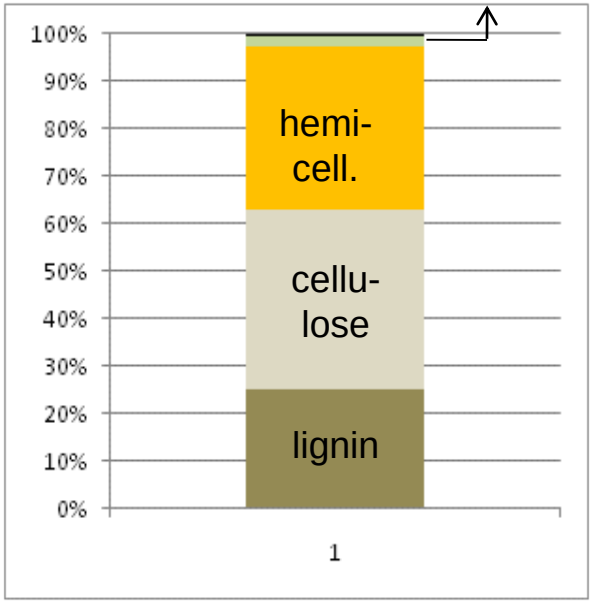
Biorefinery Potential

→ **cellulose** sells as pulp, paper, fibres or derivatives

→ **lignin** sufficient to provide energy for pulping process

→ **hemicellulose** needs to sell at a higher price than 0.104€/kg

(based on today's oil price - not including CAPEX/OPEX)



Target Product	Selling Price Estimate €/kg	dated from
EtOH	**0.50**	**2015**
BuOH	1.89	2015
PHB	6.50	2015

Ex. EtOH:

Fermtable hemis in SSL: 120,000 tons

yield factor estd. 0.32g/g

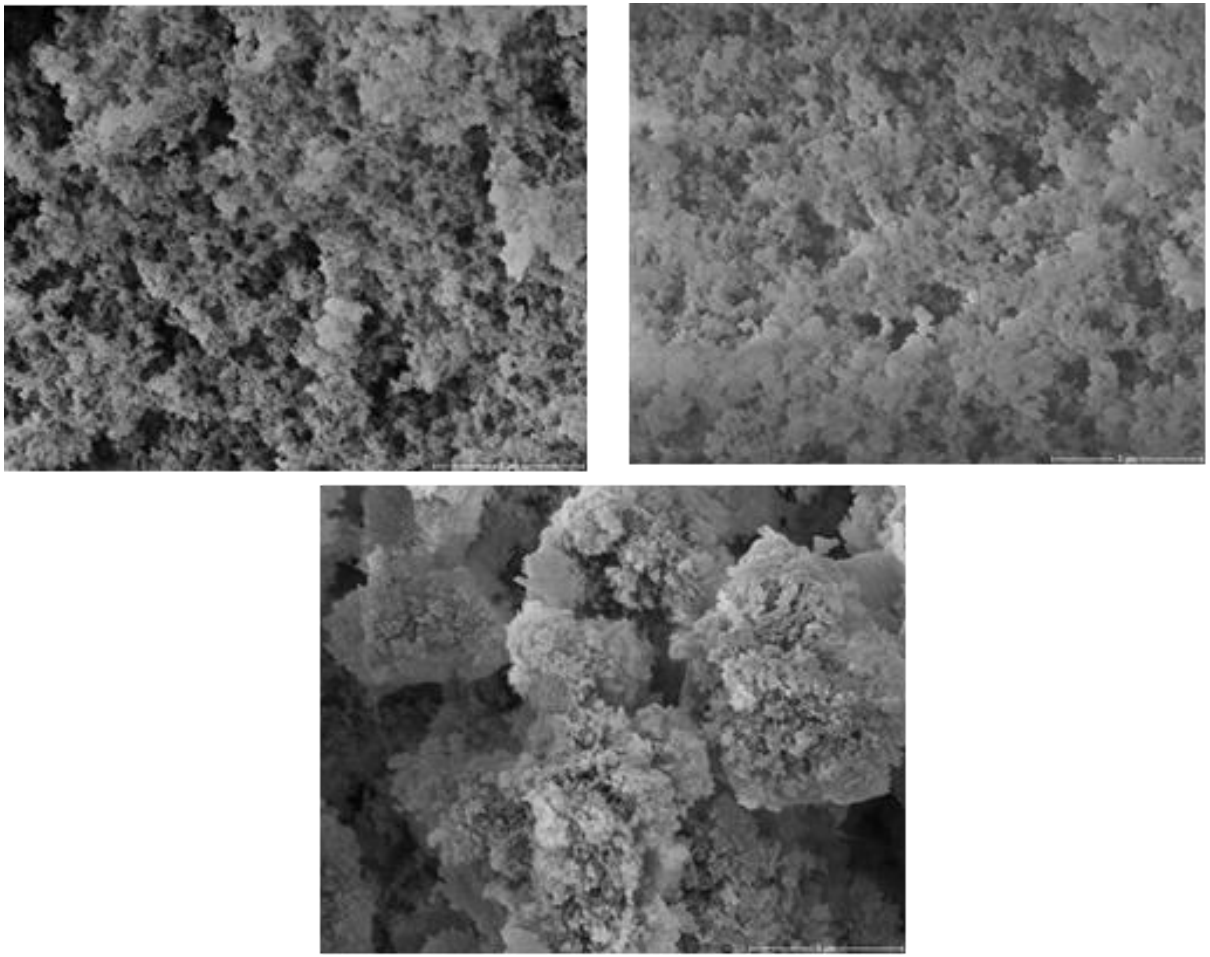
→ earnings minus heating value: **6.5 Mio €**

[Prices: From the Sugar Platform to biofuels and biochemicals Final report for the European Commission Directorate-General Energy, N° ENER/C2/423-2012/SI2.673791, April 2015]

Selection of possible value chains to be realized at wood KPLUS

- Development of Wood-PLA compounds (or other biobased popymers) with improved thermo-mechanical properties) and of related high performance products (e.g. 3D-printing)
- **Production of high value lignins → product development (e.g. lignin based carbon fibers, respective composites, aerogels, carbogels)**
- Development of fully biobased fiber composite materials
- Development of system solutions (e.g. compostable dishes or insecticide releasing carriers for forestry and agriculture)

2.3 Novel Materials from Byproducts: e.g. Lignin Aerogels



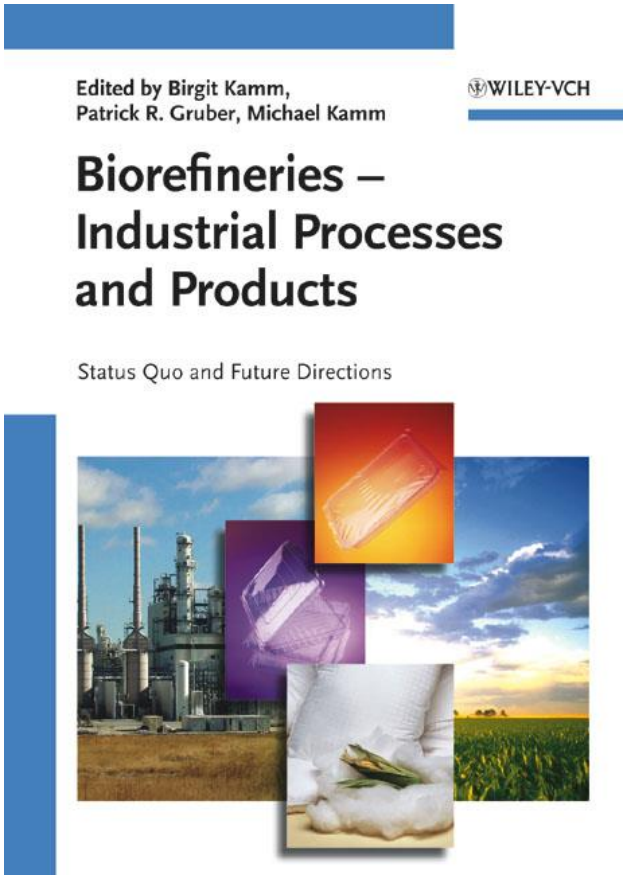
SEM-Pictures of the pore structure of different aerogels.
(A) 8 %, (B) 13,4 % and (C) 20,7% Lignin-Formaldehyd [wt% in H_2O].
(Zoom 10.000-times)…..(B) BET specific surface: 200 qm/g

Reputation, Biorefinery activities

- **Editor of the „biorefinery" book series**
  Biorefineries – Industrial Processes and Products
  (Wiley-VCH)
  Vol. 1 + 2 (published January 2006, 2010)

- **Author in Ullmann's Encyclopaedia Industrial Chemistry (Wiley-VCH)**
  Technical Chemistry and Biotechnology (2007,2011, 2016)

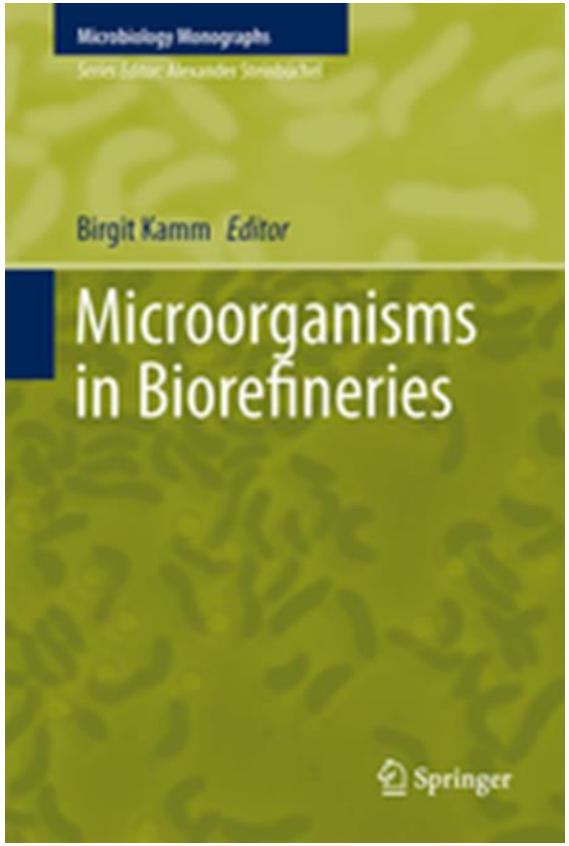
- **Member of the Advisory Board**
  CLEAN-Soil, Air, Water (Wiley-VCH)
  CHEMSUSCHEM (WILEY-VCH)
  Biofuels, Bioproducts and Biorefining
  (Wiley & Sons, Society of Chemical Industry)



Reputation, Biorefinery-Activities

B. Kamm (Ed.) Microorganisms in Biorefineries, In: Microbiology Monographs, Series Editor A. Steinbüchel, 2015

http://www.springer.com/life+sciences/microbiology/book/978-3-662-45208-0



Topics covered include: new metabolic pathways of microbes living on green plants and in silage; using lignocellulosic hydrolysates for the production of polyhydroxyalkanoates; fungi such as Penicillium as host for the production of heterologous proteins and enzymes; bioconversion of sugar hydrolysates into lipids; production of succinic acid, lactones, lactic acid and organic lactates using different bacteria species; cellulose hydrolyzing bacteria in the production of biogas from plant biomass; and isoprenoid compounds in engineered microbes.

Invitation

Student Camp Biorefineries and Biobased Industrial Products
25. - 28. February 2019

Venue: Linz and Lenzing (Austria)

THANK YOU FOR INVITATION.

WOOD

KPLUS

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