



THE
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COMPANY

The Pulp-and-Paper Based Biorefinery: Research Challenges ... and Market Opportunities

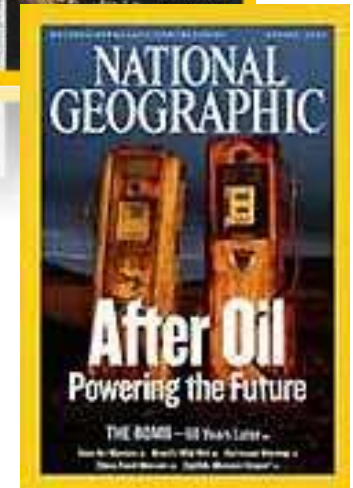
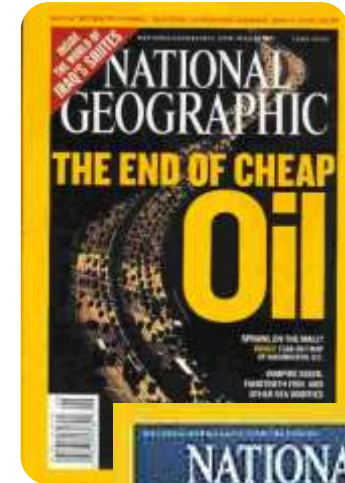
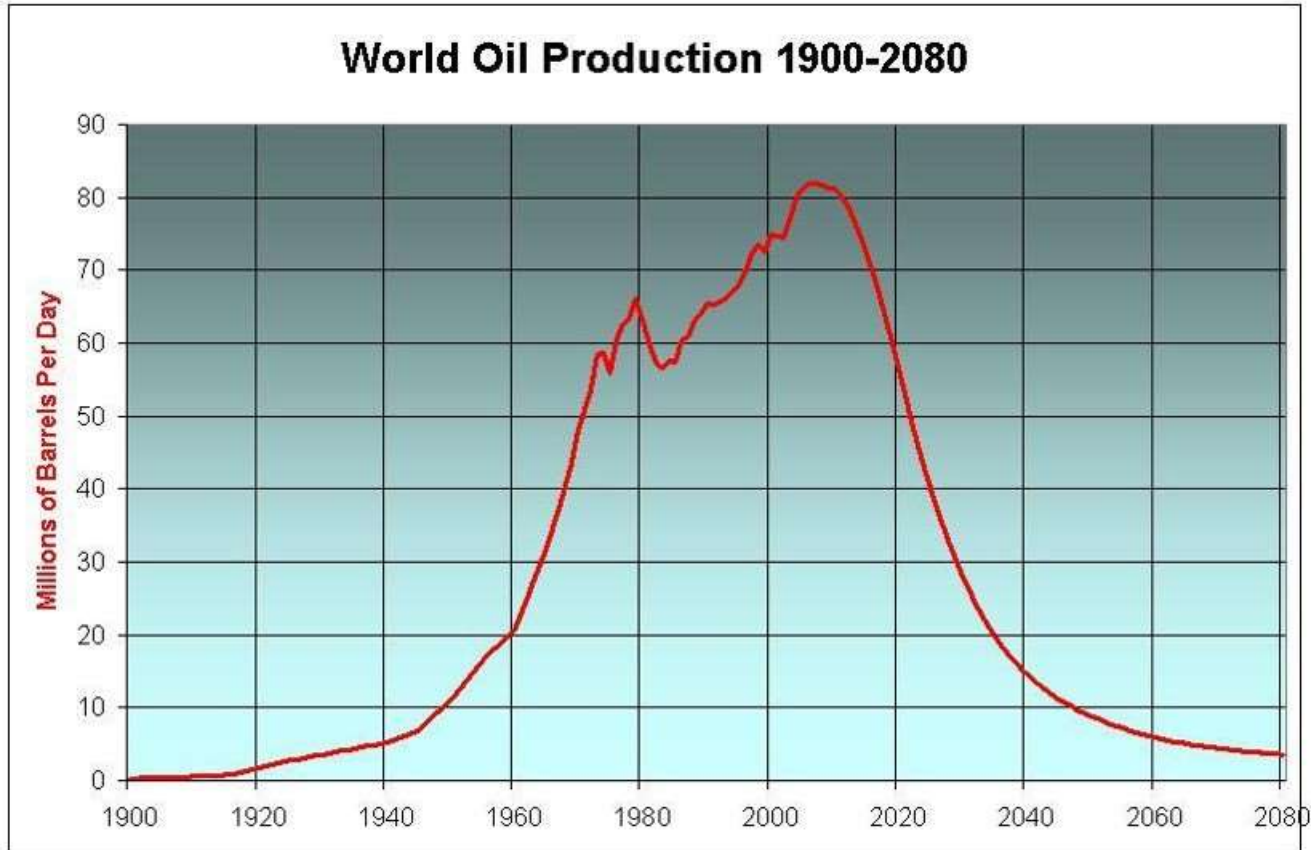
Carlos Pascoal Neto

RAIZ

- **The biorefinery vs oil refinery**
- **The pulp-and-paper biorefinery**
- **Research challenges and market opportunities**
 - **Cellulose**
 - **Nanocellulose**
 - **Hemicelluloses**
 - **Sugars**
 - **Lignin**
 - **Extractives**

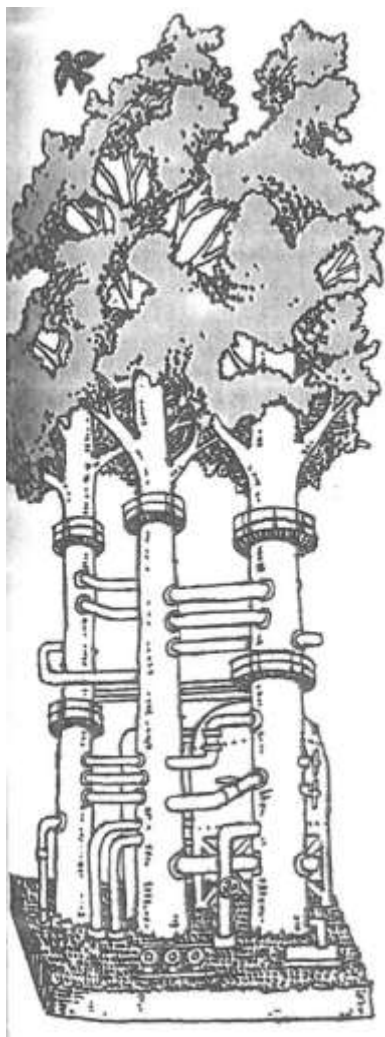
A couple of examples from RAIZ – The Navigator Company
Biorefinery R&D programme

The end of (cheap) oil



<http://www.paulchefurka.ca/Population.html>

The biorefinery vs oil refinery



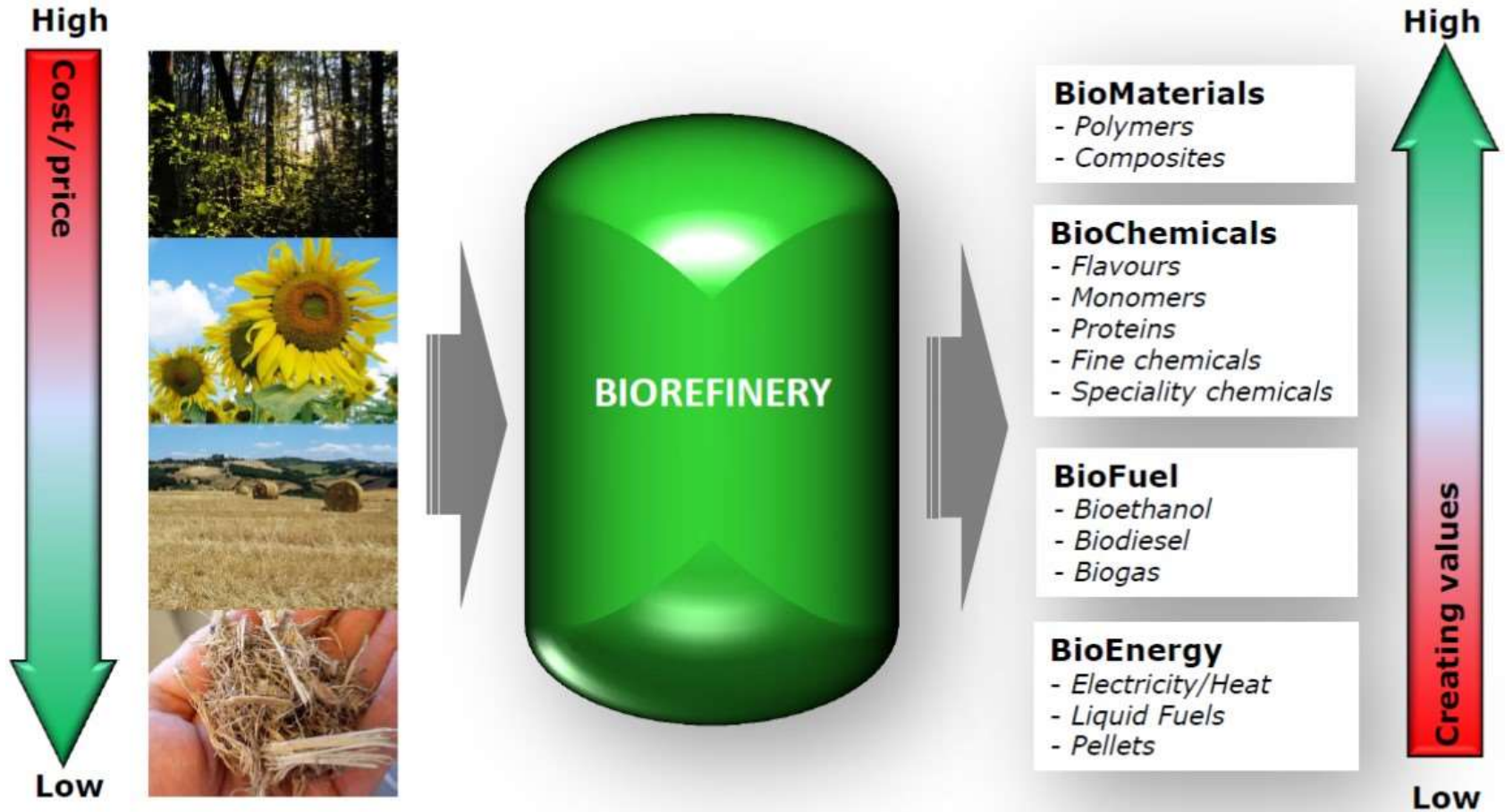
The forest refinery

R. C. Myerly, M. D. Nicholson,
R. Katzen, and J. M. Taylor

CHEMTECH MARCH 1981

An old concept for an old issue !

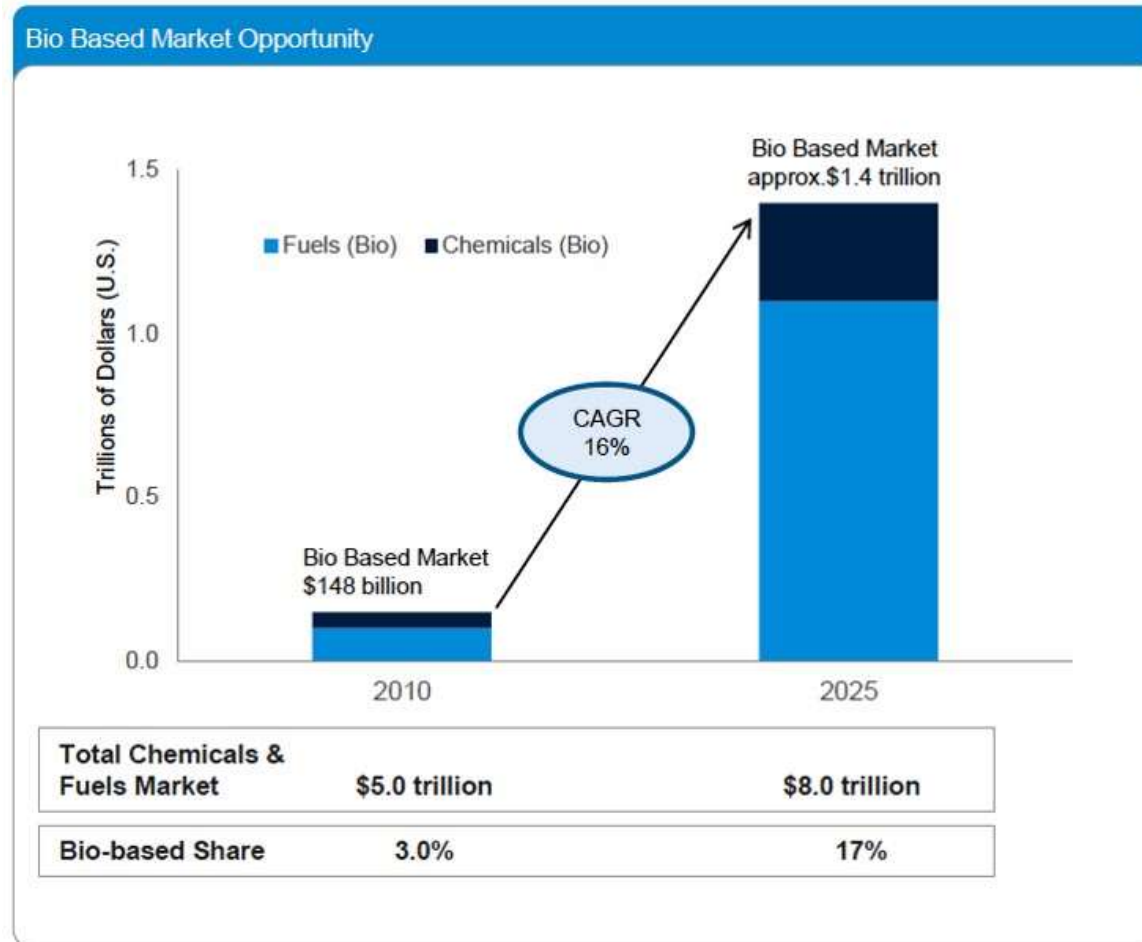
The biorefinery vs oil refinery



Source: Borregaard

The emerging bioeconomy

Bio chemical / fuels market trend



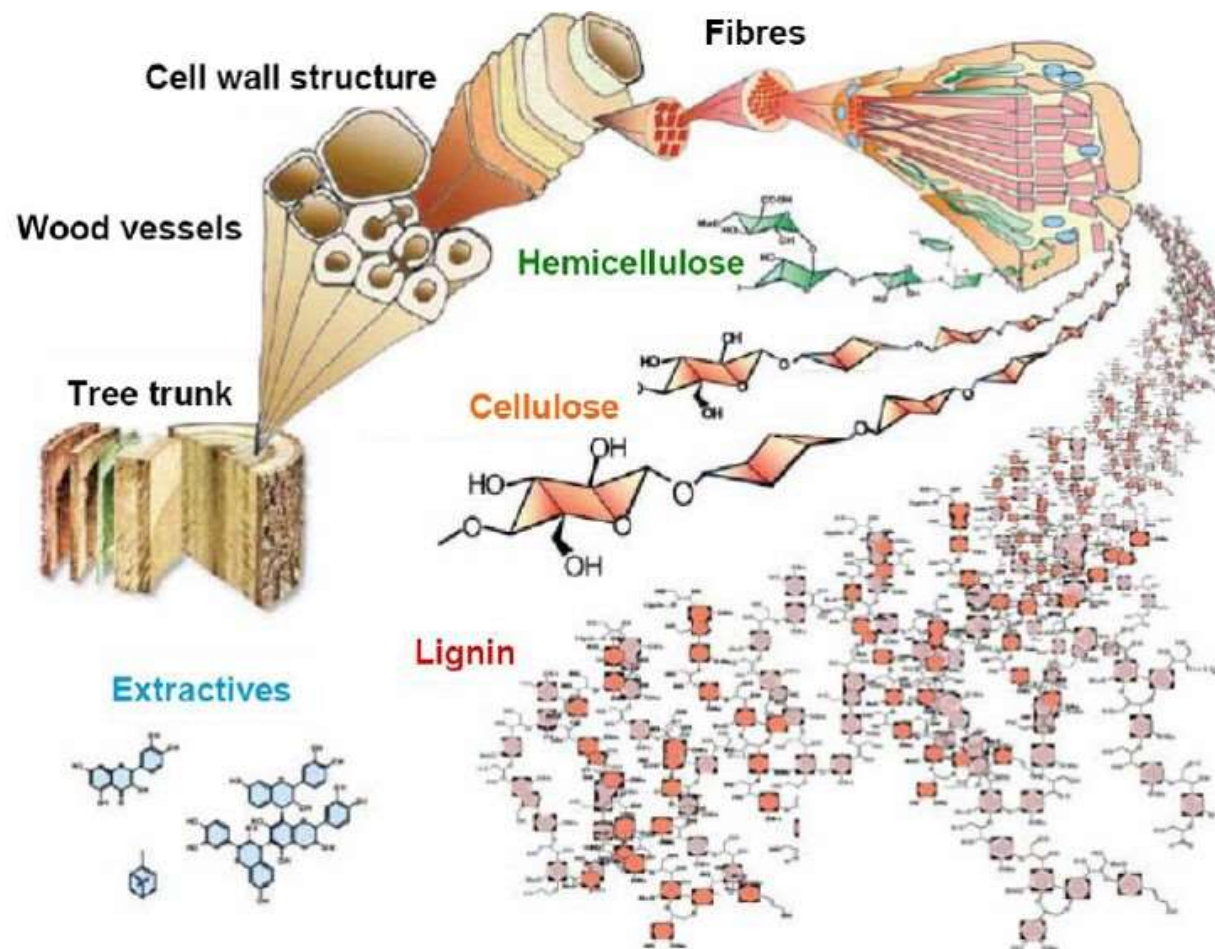
Silicon valley bank

The emerging bioeconomy



Lignocellulosics composition

Forest

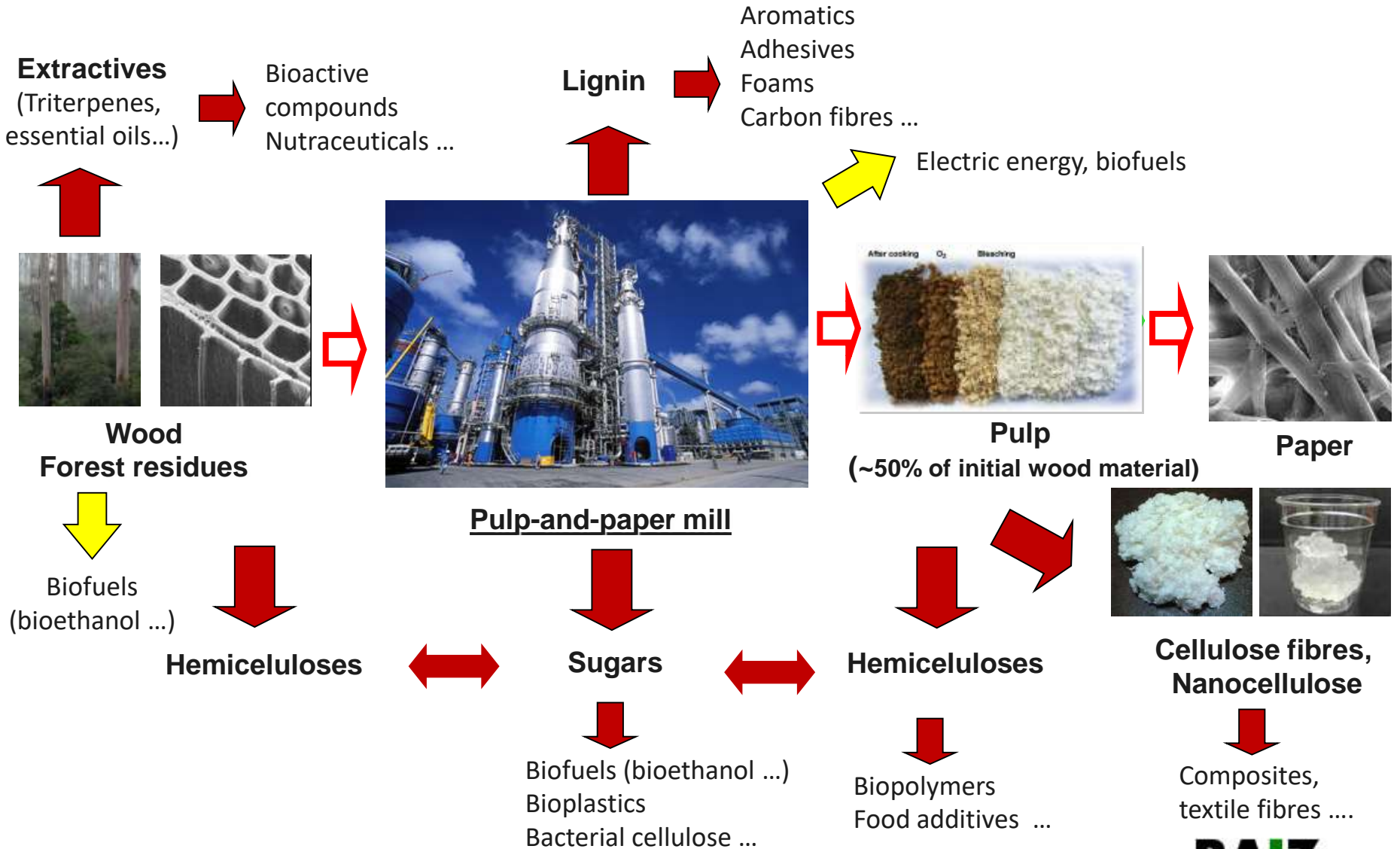


Agricultural



Per Hoffmann, Oskar Faix and Ralph Lehen

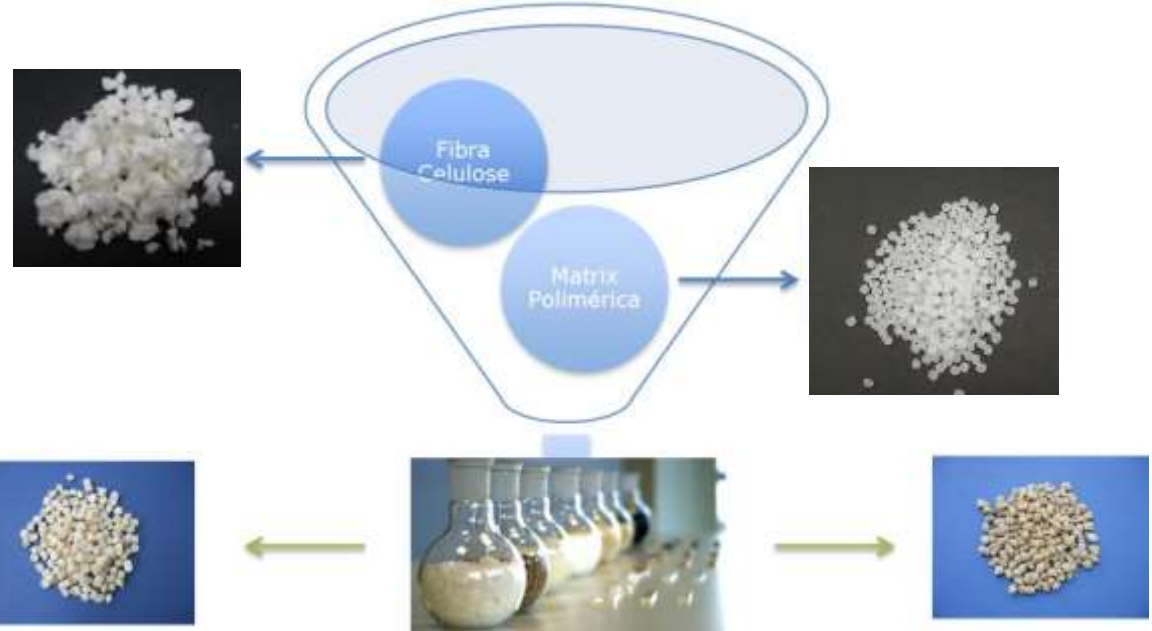
The pulp-and-paper biorefinery



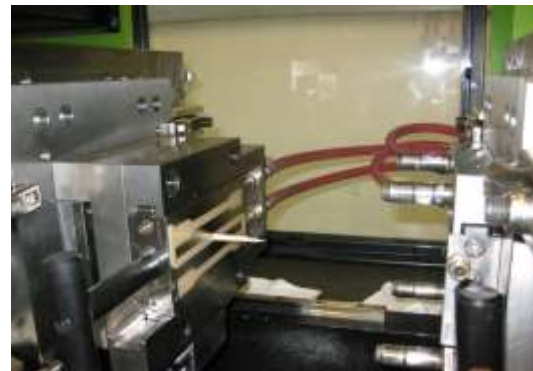
Cellulose



Cellulose-based composites for automotive industry



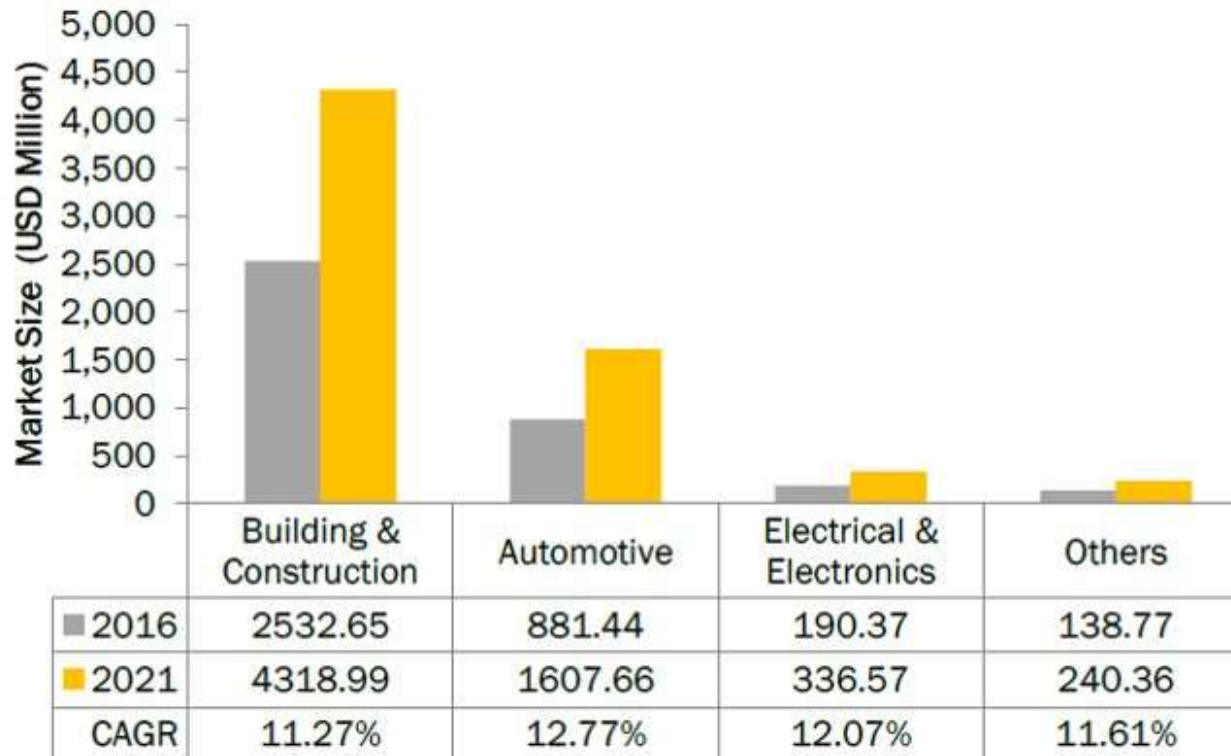
Injection



Moulding



Wood Fibre Composites Market



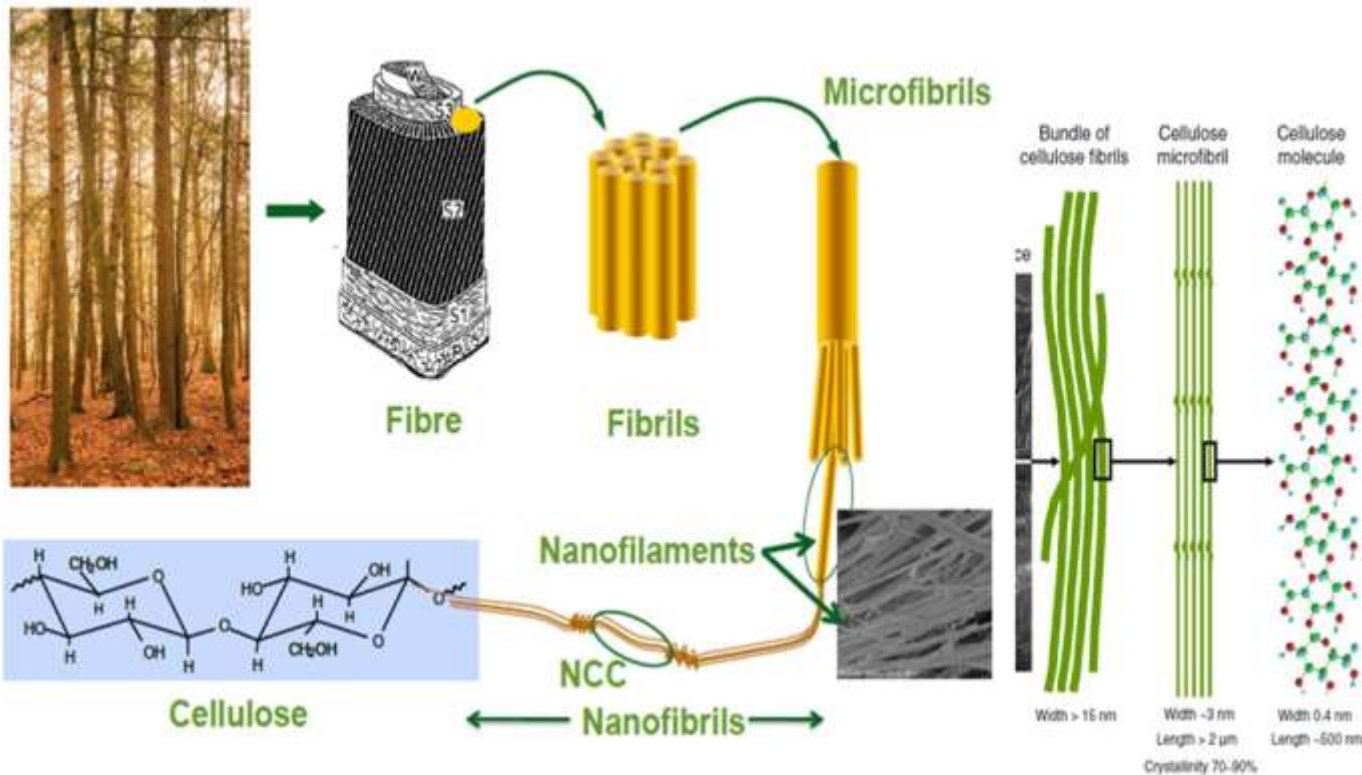
NATURAL FIBER COMPOSITES MARKET

GLOBAL FORECASTS TO 2021



Nanocellulose

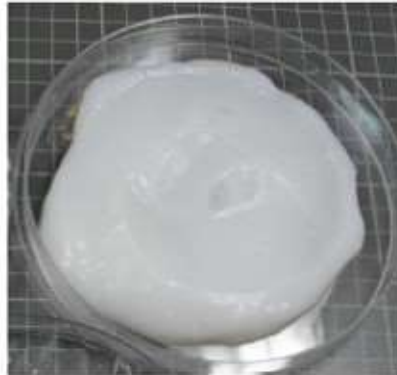
Nanocellulose: Exploiting the nano scale of cellulose fibres



GEA Niro Soavi Panther NS3006L
50 l/h – 1500 bar



Different micro/nanofibrillated celluloses



Grinding



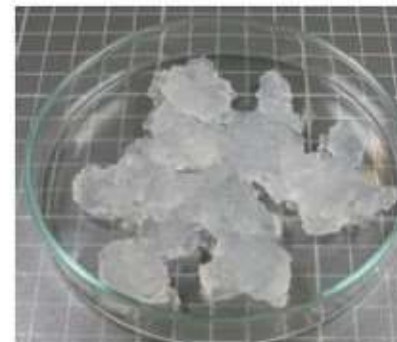
Homogenisation



Carboxymethylation



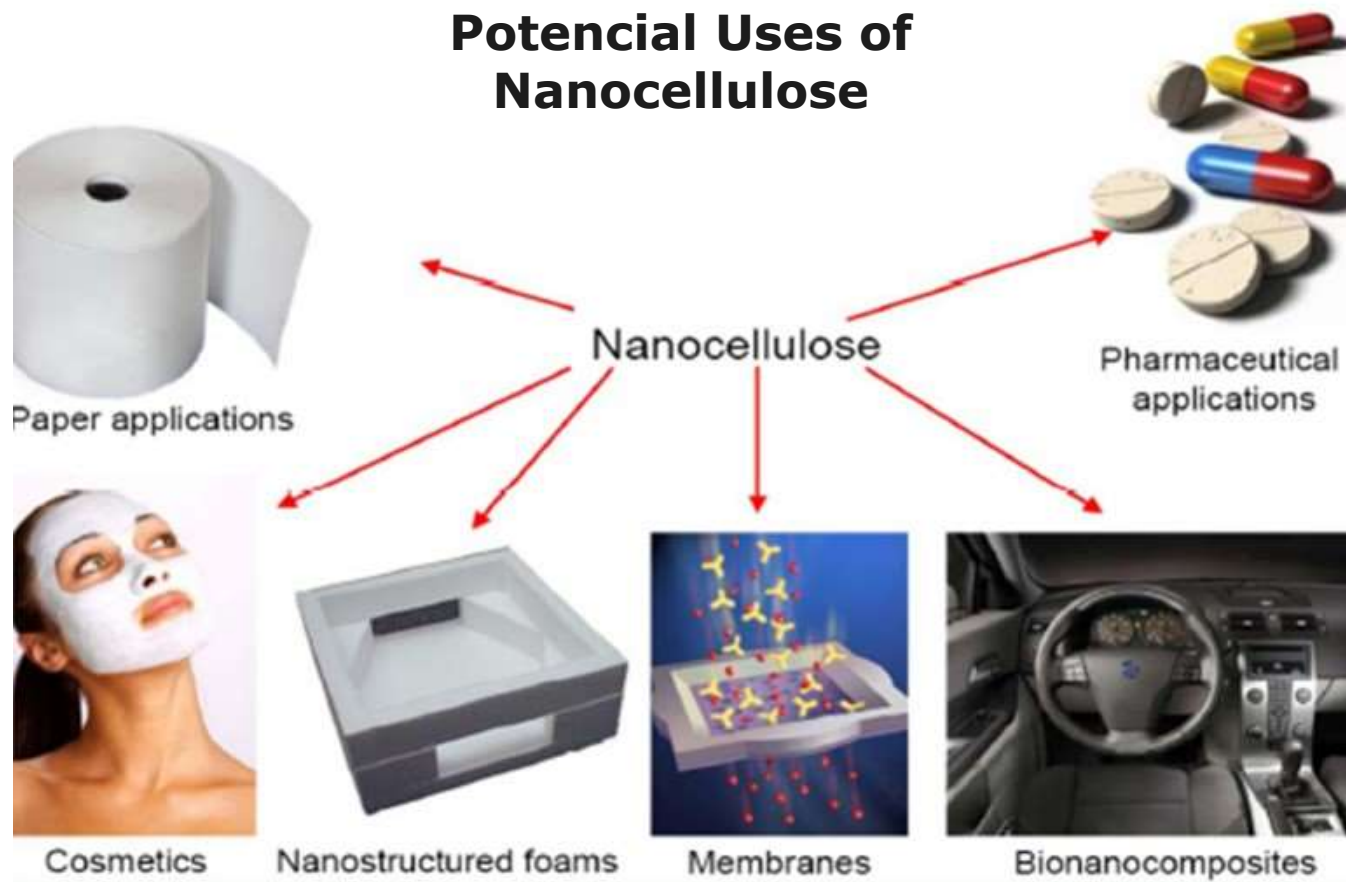
TEMPO -oxidation



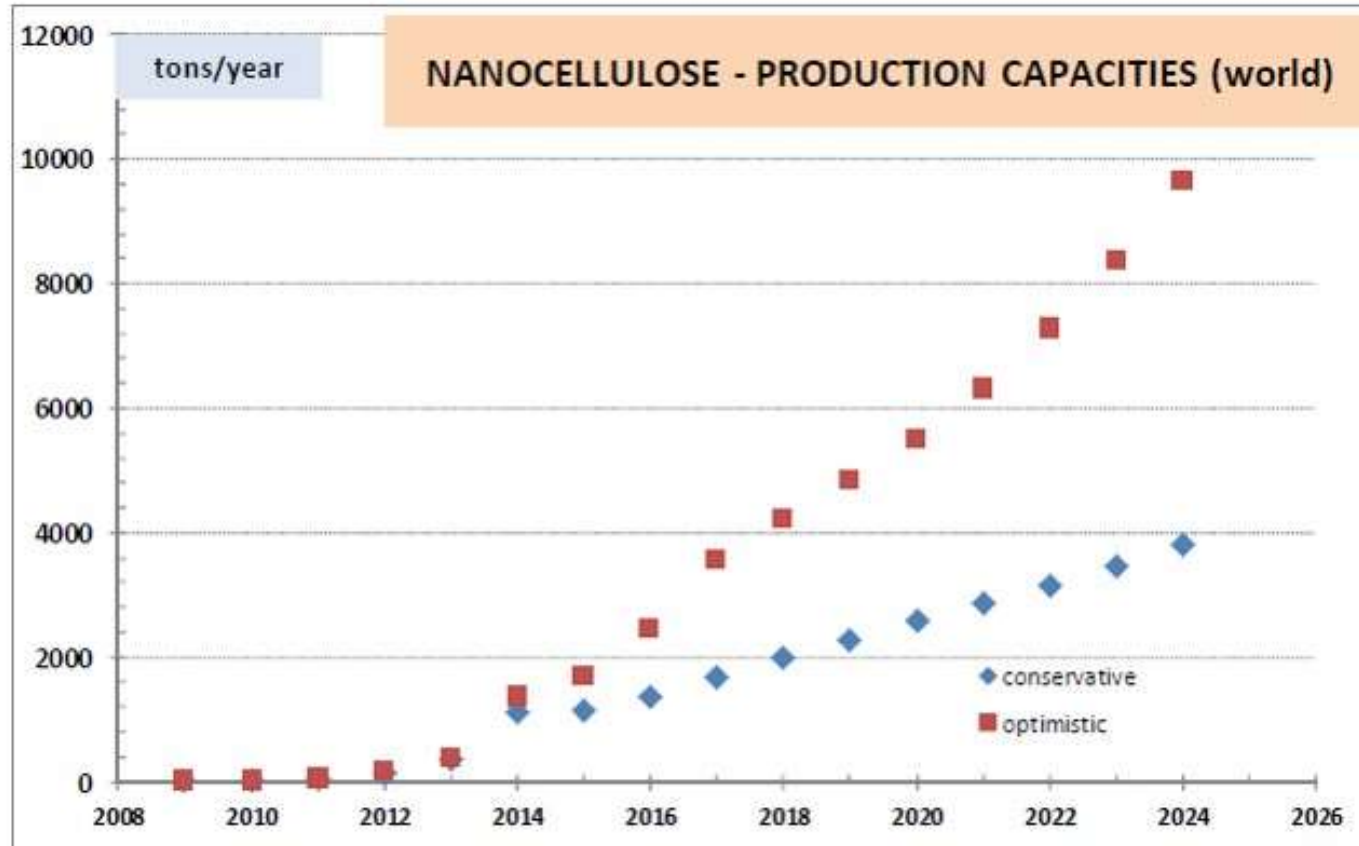
Cationisation

Tiina Pöhler et al, 2010 TAPPI International Conference on Nanotechnology for the Forest Product Industry

Potential Uses of Nanocellulose



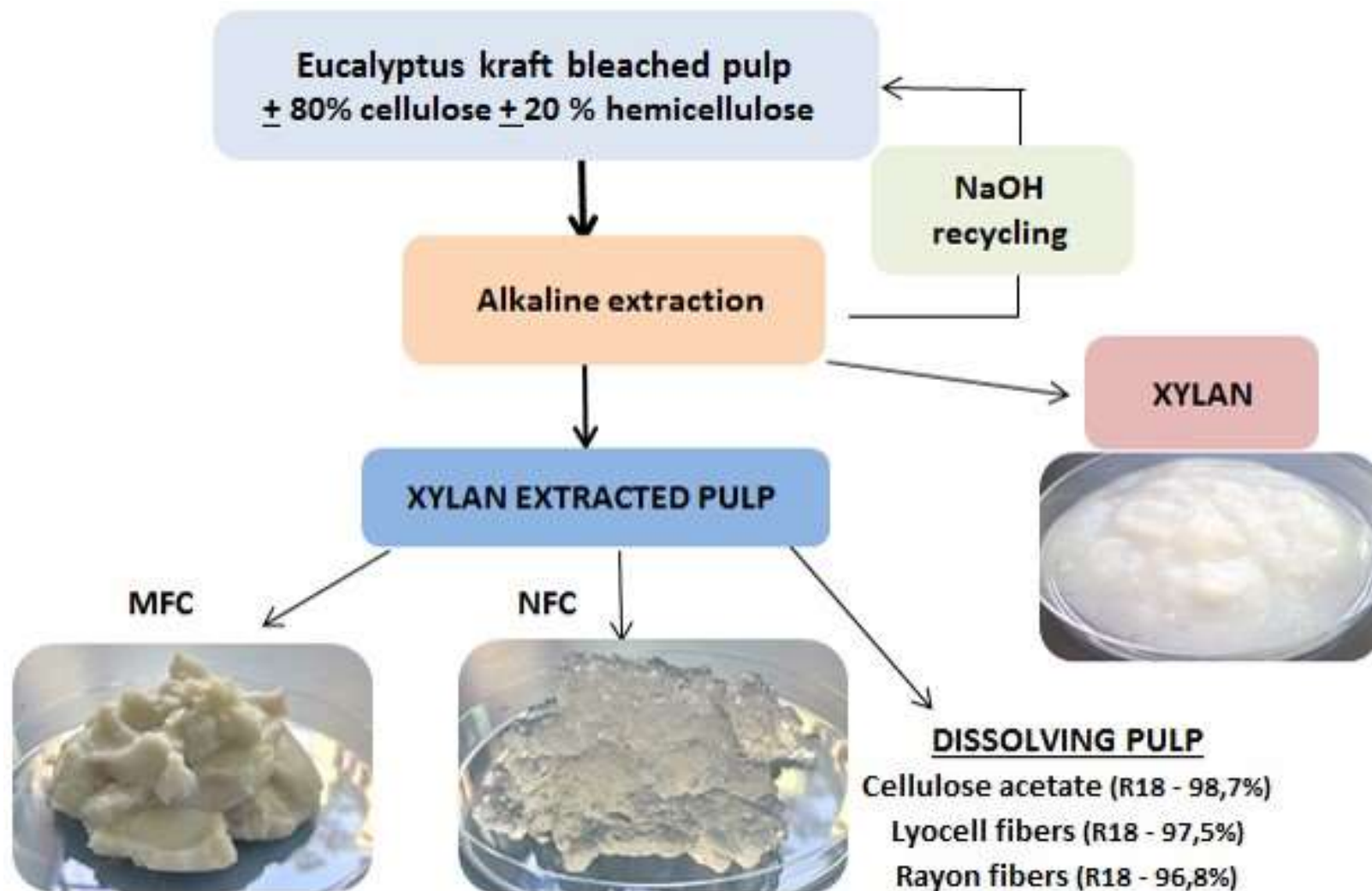
Nanocellulose



2014 March, Future Markets Inc, The Global Market for NANOCELLULOSE to 2024

Global Nanocellulose production capacities estimates for 2020
Conservative – **2500 tons /year**. Optimistic – **5500 tons /year**.

Hemicelluloses



Hemicelluloses

HEMICELLULOSES - XYLANS - POTENTIAL APPLICATIONS



- furfural**
- xylitol**
- rheology modifiers**
- emulsifiers**
- gelling agents (prevent ice formation)**
- absorbents (increase water content bread)**
- food additives**
- adhesives**
- paper additives**
- medicine / pharmaceuticals**
 - pentosan polysulfates PPS (Elmiron)**
 - XOS - xiloologosaccharides**



GLOBAL MARKETS – XYLAN END PRODUCTS

Xylitol	2013	162 ktons - 670 M USD	± 4 USD / kg
(corn cobs)	2020	242 ktons - 1 000 M USD	

Furfural	2013	300 ktons	± 1,8 USD / kg
(corn cobs)	2020	655 ktons - 1 200 M USD	

Rheology modifiers

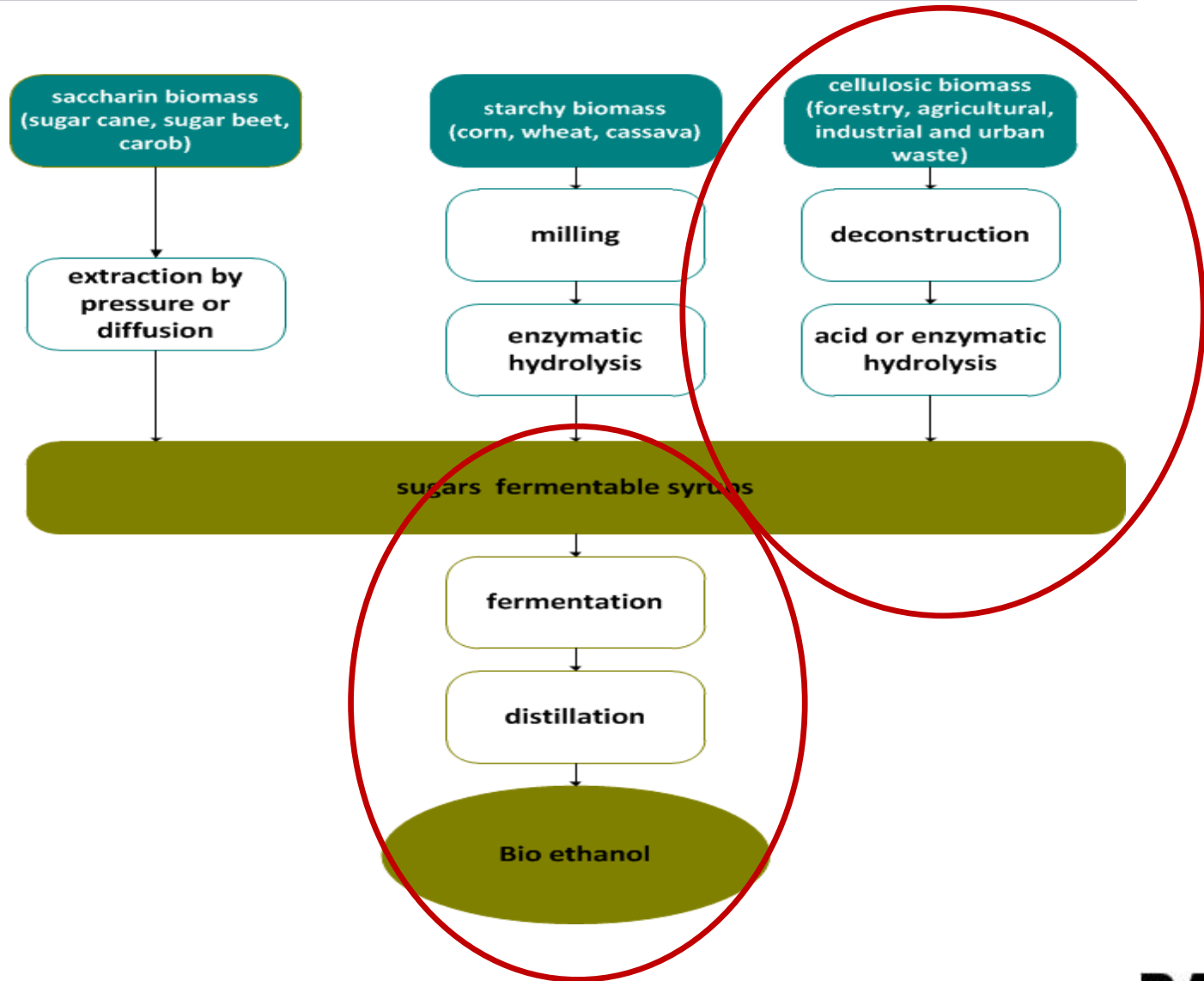
(organic & inorganic)	2020	5 600 M USD
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XOS - xilooligosaccharides

(corn cobs)	10 – 25 USD / kg
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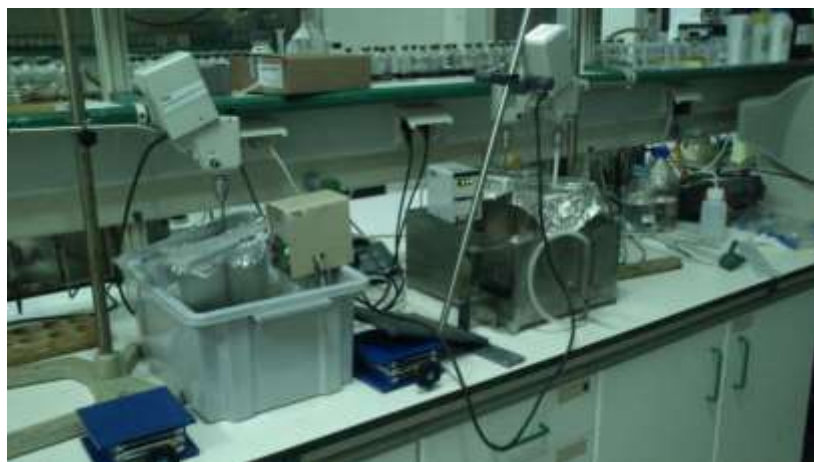


Sugars



Enzymatic hydrolysis – scale up

Sugar syrups



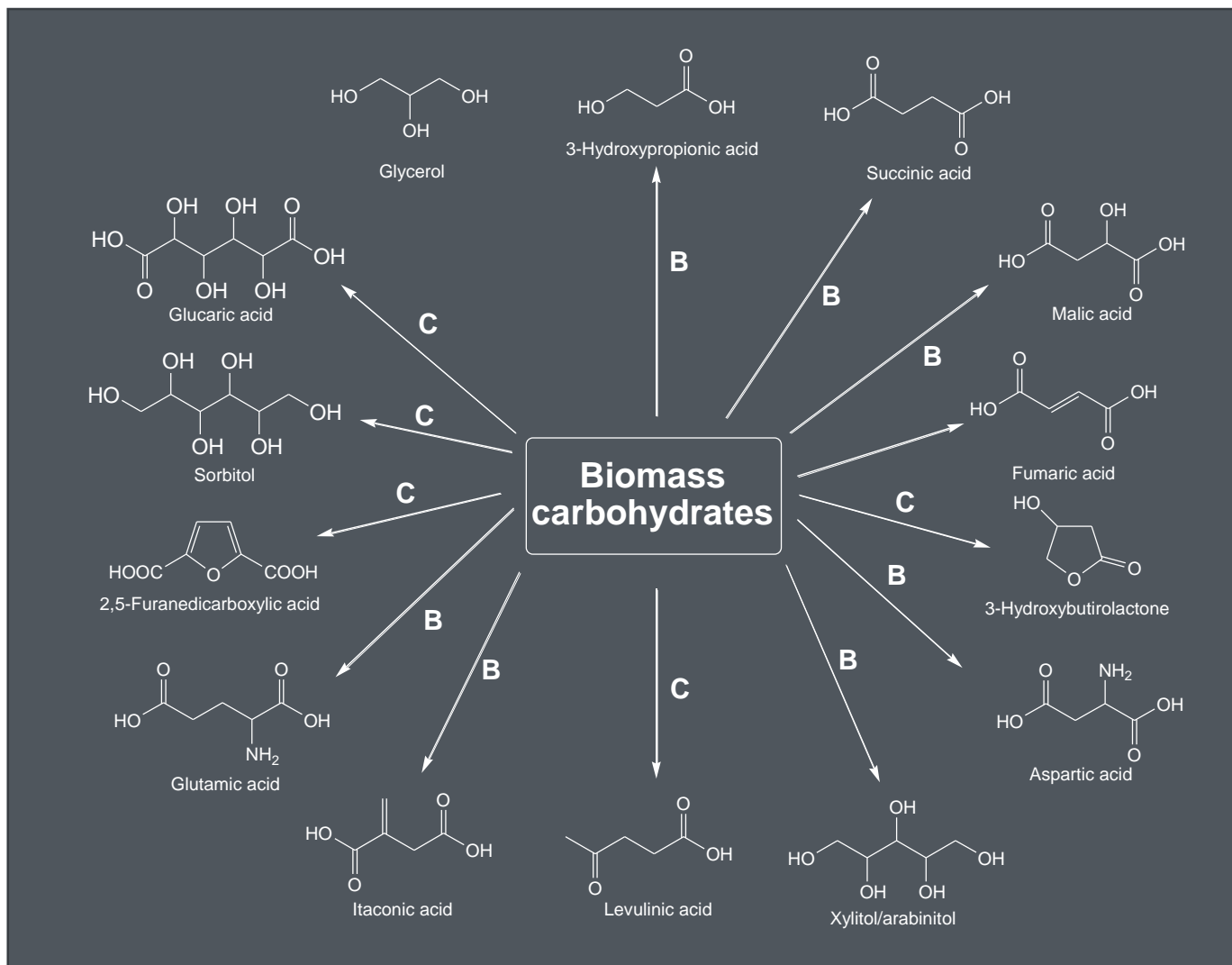
5 L beakers - RAIZ



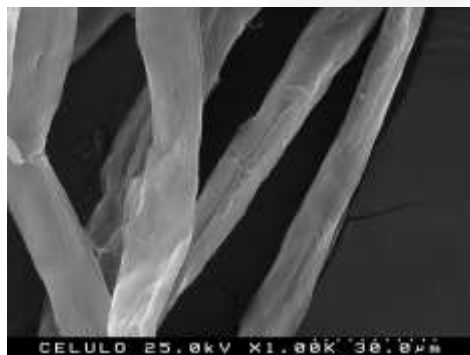
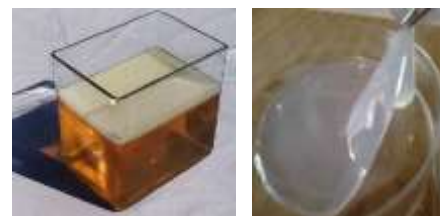
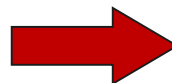
50 L reactor - LNEG



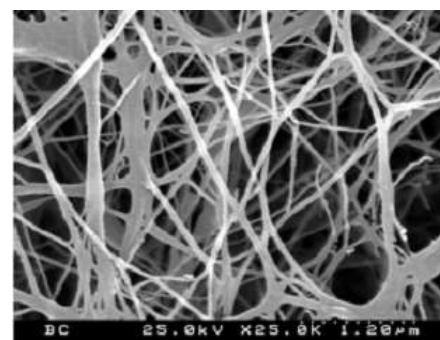
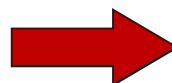
Platform chemicals from sugars



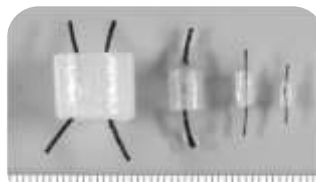
Bacterial cellulose from wood/cellulose sugars



Wood fibers
~20-40 mm width, ~1-3(>) mm length

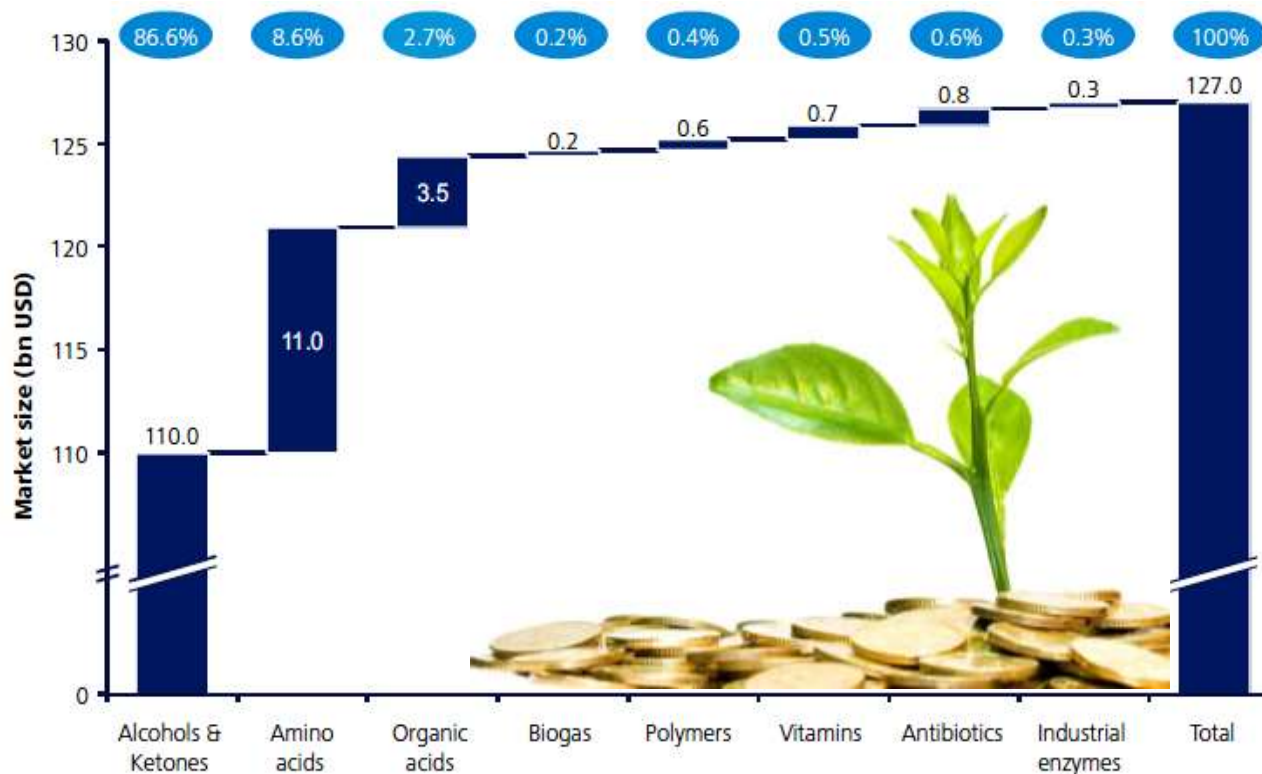


Bacterial cellulose (*Gluconacetobacter*)
Nanofibrils 10-100 nm width, 3D network



Sugar based bio-products market

Global fermentation market value in 2013 (bn USD)

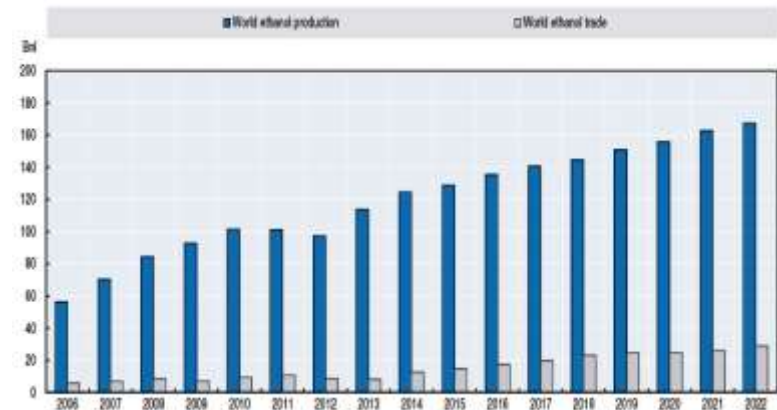
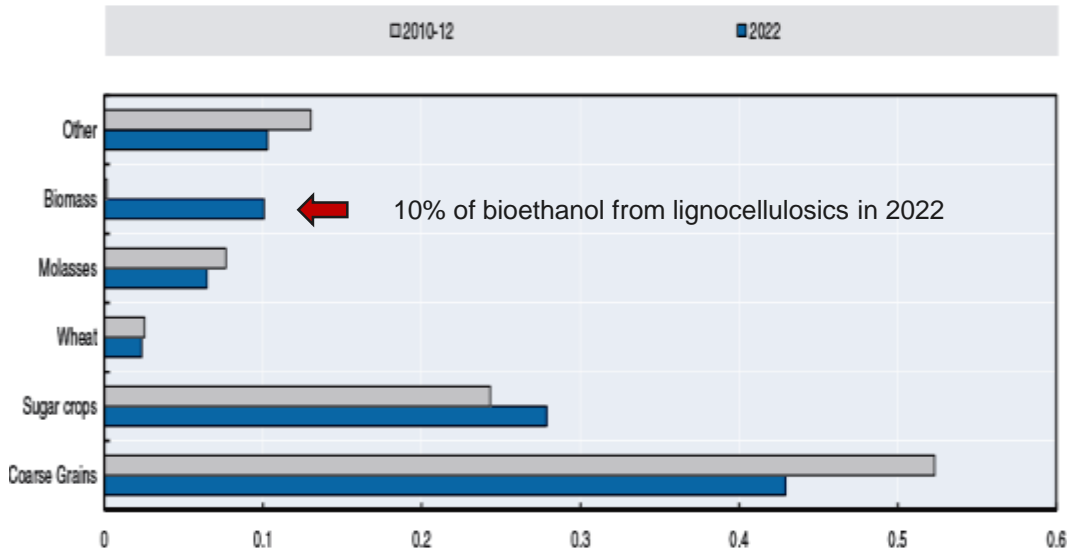


Note: prices are average prices price ranges for the different products based on publicly available data
Source: BCC Research, FO Licht, NOVA Institut, OECD-FAO Agricultural Outlook 2013, Deloitte Analysis

% = percentage of global fermentation market

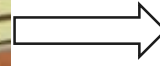
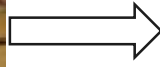
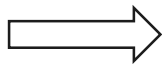
Bioethanol – a worldwide growing market

Cellulosic bioethanol is emerging ≈ 17 billion L in 2022, 10% share

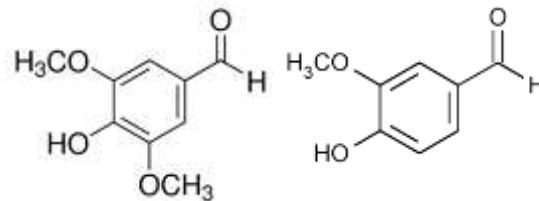


Lignin

Lignin recovery from kraft black liquors



Vanillin and Syringaldehyde

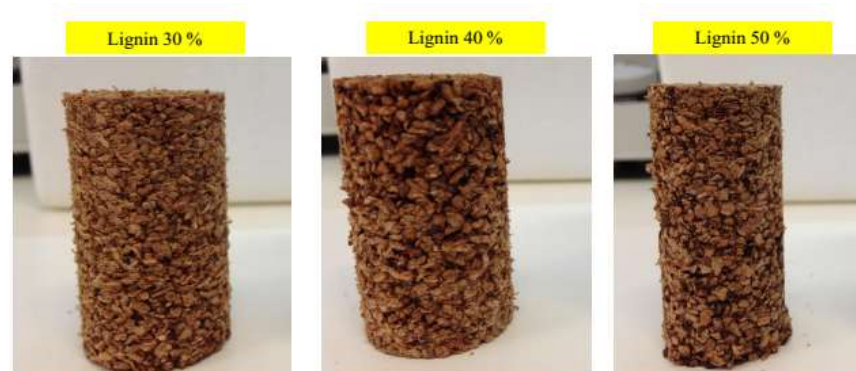


Vanillin and syringaldehyde obtained (2,5%) by eucalyptus globulus lignin oxidation

Glues for cork composites and stoppers



Lignin isolated and purified was used on the production of glues, mixed with polymeric methylene diphenyl diisocyanate (pMDI).



Lignin polyols

- Lignin dried and submitted to oxypropylation reaction, using propylene oxide and KOH as catalyst.
- Lignin-based polyols led to the production of foams with lower densities and thermal conductivity, compared to the ones produced with the commercial material.

Flexible polyurethane foams

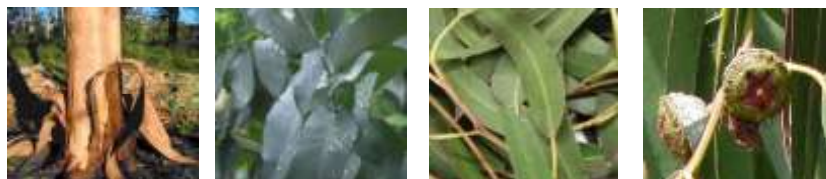
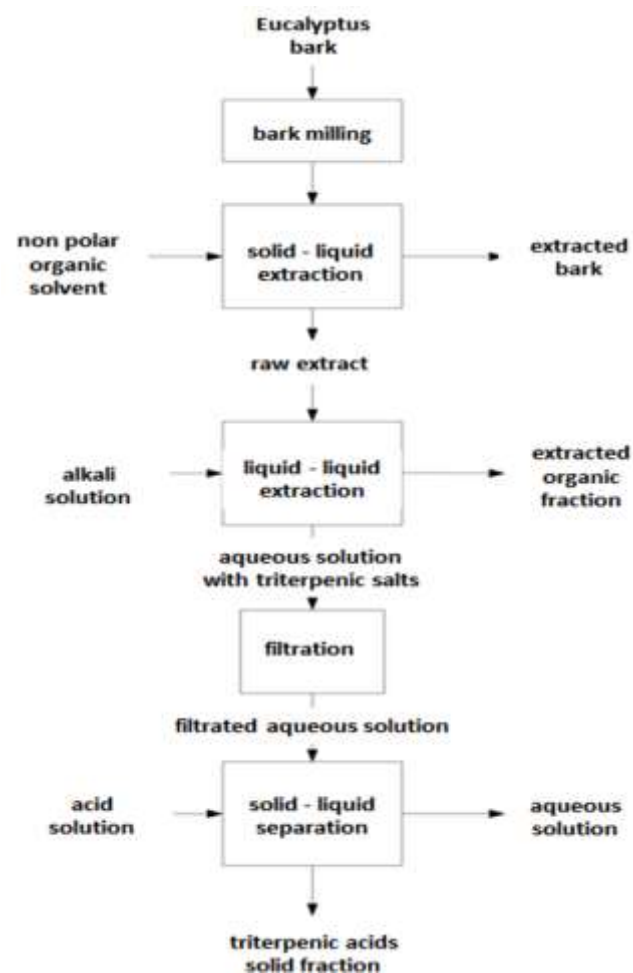
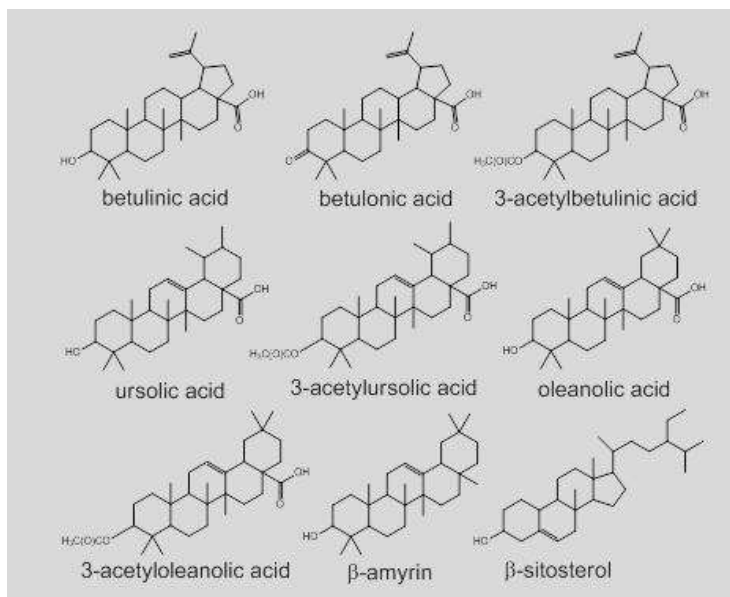


Rigid polyurethane foams



Triterpenic acids from *Eucalyptus* bark / biomass

Purity (% ac. ursólico)	Market value	End user
25 %	70 \$/kg	nutraceutical
50 – 60 %	200-500 \$/kg	cosmetic / pharmaceutical
> 98 %	2700 \$/kg	pharmaceutical

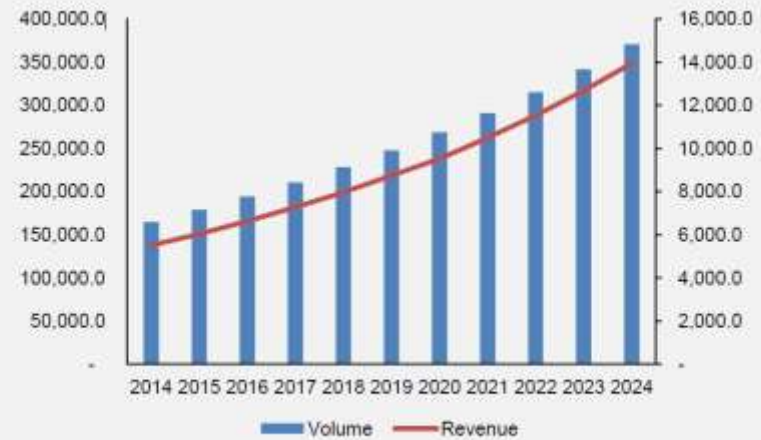


Extractives

Eucalyptus essential oils



Global essential oils market estimates and forecast, 2014 – 2024, (Tons) (USD Million)



Source: FFDC India, ITC, SADC Trade, CBI, EOAI, AEOTA, JETRO, DAFF and Grand View Research

For fragrances, cosmetics and pharmaceutical products, a 1,5 billion € market

An option?



Acknowledgements

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University of Lisbon

University of Porto

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Bragança Polytechnic Institute

Biotrend

LNEG

PIEP



