Biorefinery Opportunities for the Pulp Industry

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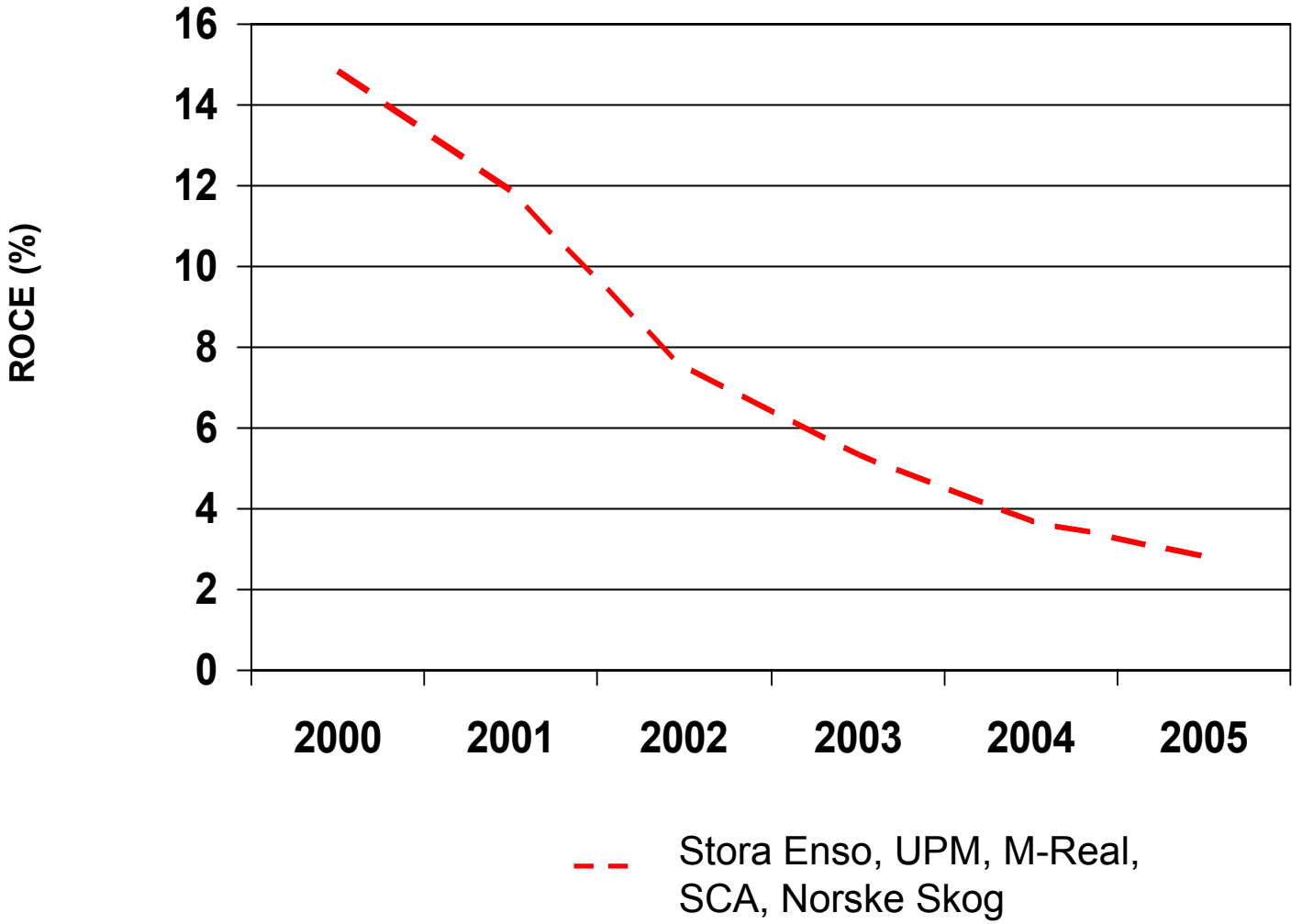
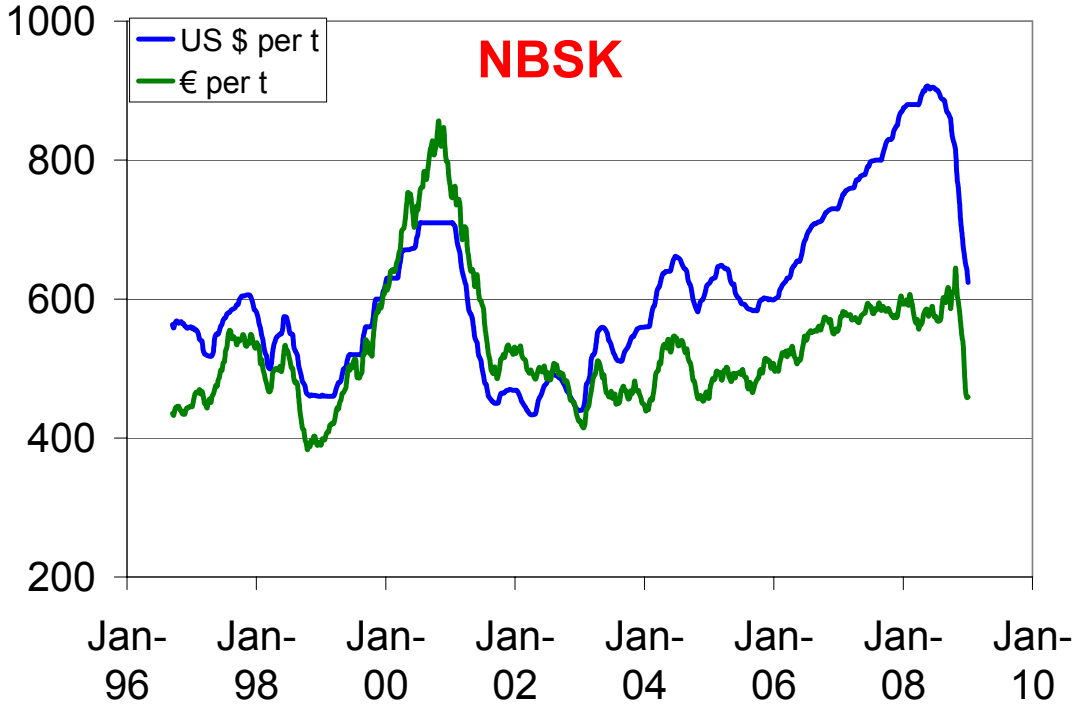
2nd Latin American Congress on Biorefineries,
May 4-6, 2009, Concepción, Chile

Forest industry profitability (ROCE) 2000-2005



Pulp Price Development



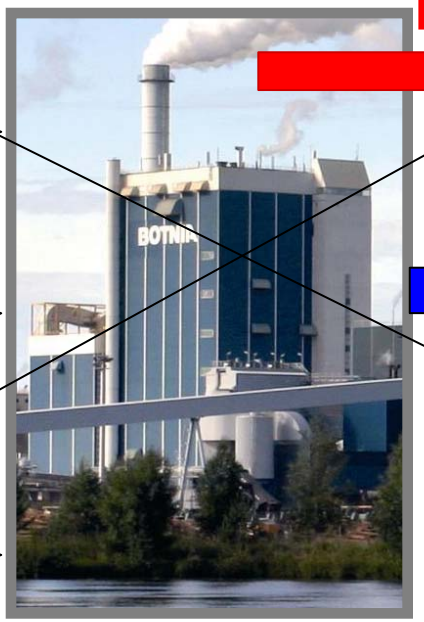
- Pulp&Cellulose ✹**High-Volume-Low-Price Industry**
- Long-term avergage pulp prices: 9/96 - 1/09
  - **500 €/ADT** for Bleached Hardwood Kraft (BHKP)
  - **540 €/ADT** for Bleached Softwood Kraft (NBSK)

How??

Wood Logs

Chemicals

Non-renewable energy



Emissions

PULP

Current business model based on commodity strategy is not working any more!

M&A cannot provide a major solution unless the merger supports an innovative strategy!

Challenge

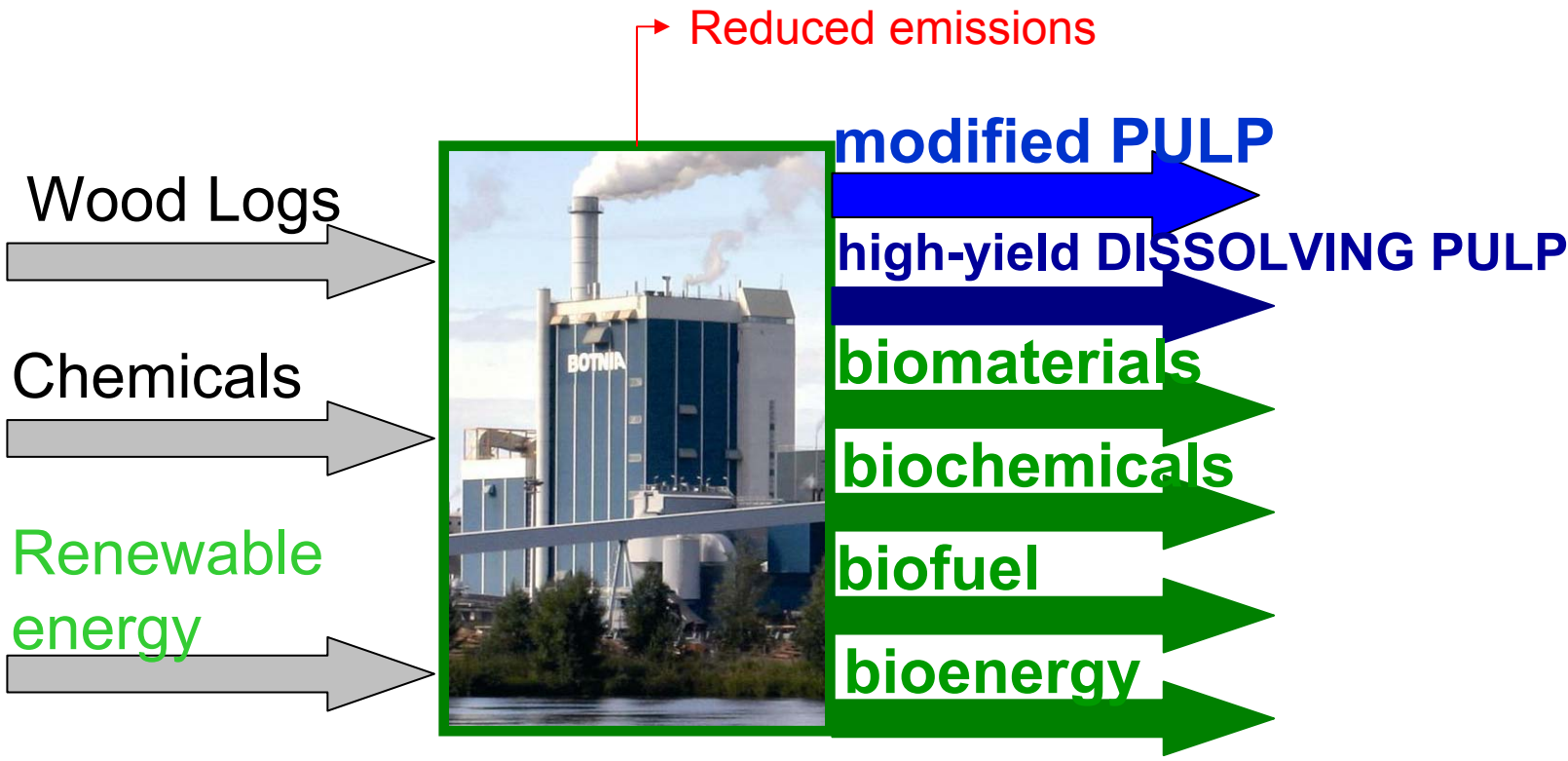
1. Conversion of the **non-cellulose&excess energy** part of the wood (~ *non-pulp-hemicelluloses*) into products of high added value.

2. Development of new **cellulose products** with high added value (*e.g.* replacement of oil-based polymers)

Opportunity for Pulp&Paper Industry

- Infrastructure and logistics available to handle massive amounts of biomass
- Assets and locations available on which future production of **bio-energy&bio-materials** can be build
- Chemical Pulping is the key process for biomass fractionation to create added value!

New Business Strategy!



Leveraging the infrastructure of the pulp industry can ensure the production of biomaterial at low cost.

Kraft Pulping Opportunities

1. Tomlinson Boiler 1930
2. Chlorine Dioxide Bleaching 1950
3. Modified Cooking Technologies 1980
4. BIOREFINERY >2010

Old Business Strategy

stemwood
chipping
chips
pulping
PULP
• Cellulos
Product
• Paper
round wood
debarking
black liquor
harvesting
bark
com-bustion
heat
power
pulping chemicals
ash

New Business Strategy: Biorefinery

harvesting

round wood

debarking

stemwood

chipping

chips

pulping

PULP

- Cellulos Products
- Paper

knots

extraction

polyphenols

extraction

Sugar chemicals

black liquor

separation

Lignin

Poly-sacch

HCA

bark

extraction

Fine chemicals

residues

pulping chemicals

com-bustion **pyrolysis gasifi cation**

heat | power

pyrolysis prod

synthesis gas

synthesis

biofuel

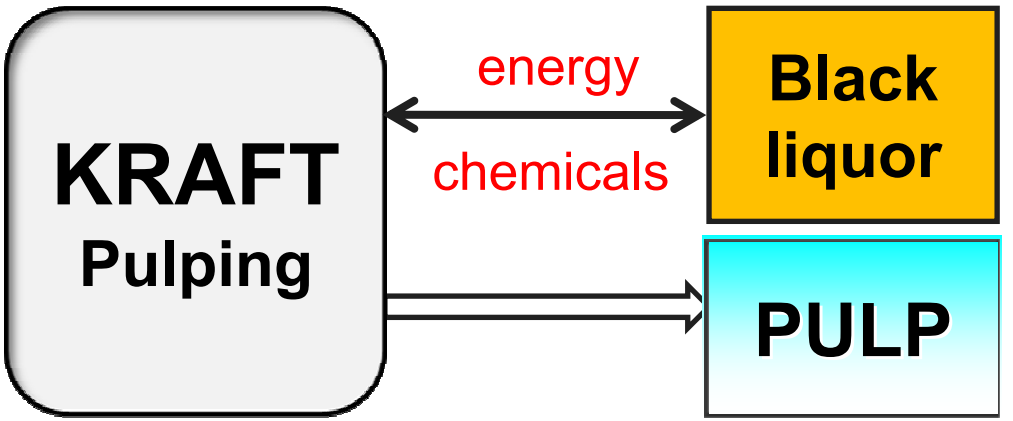
Chemi-cals

ash

recycling

adapted from Mikko Hupa, Åbo University, Biorefinery Conference (2007

Base Case

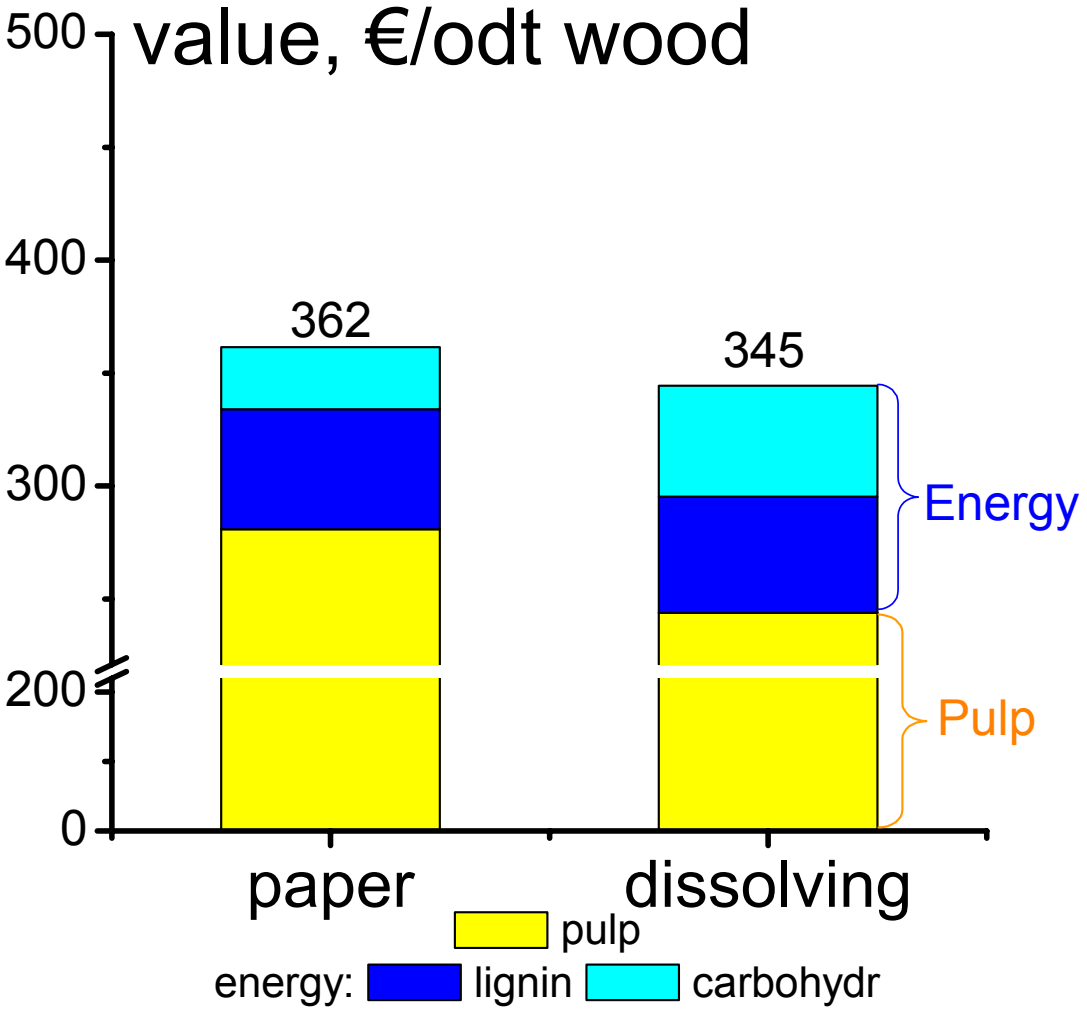


Carbohydrates account for > 20 % of wood yield loss.

May this fraction be recovered prior to kraft cooking?

Base Case, Added Value to Wood

E. globulus used as raw material



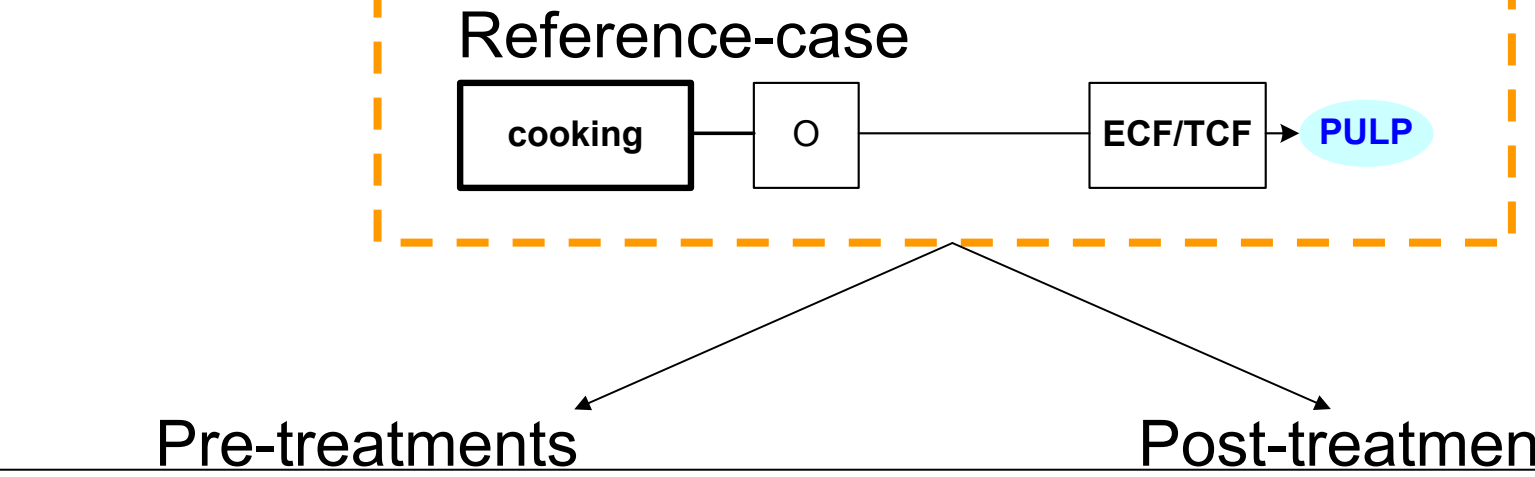
Added Value Factor

- **3 – 4** in Europe

New Generation Kraft Process

- Pre- and post-treatments to selectively remove hemicelluloses.

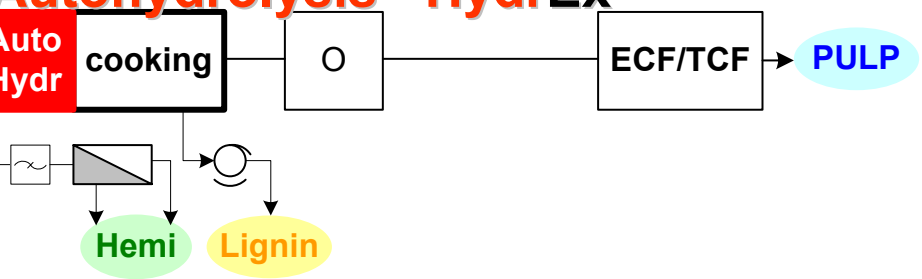
- Joint basis for the manufacture of different pulp grades.



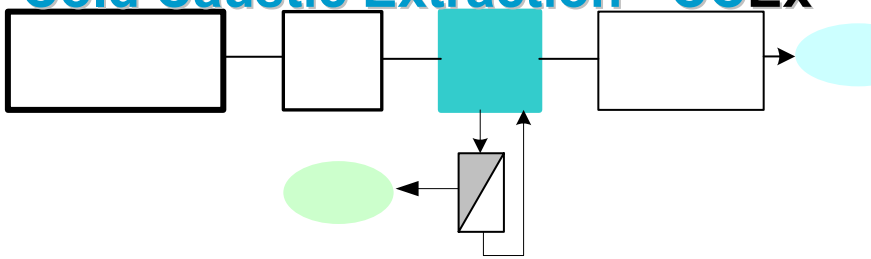
Pre-treatments

Post-treatments

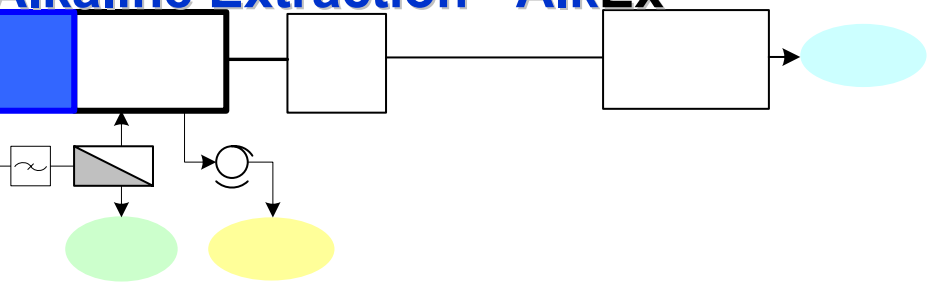
Autohydrolysis - HydrEx



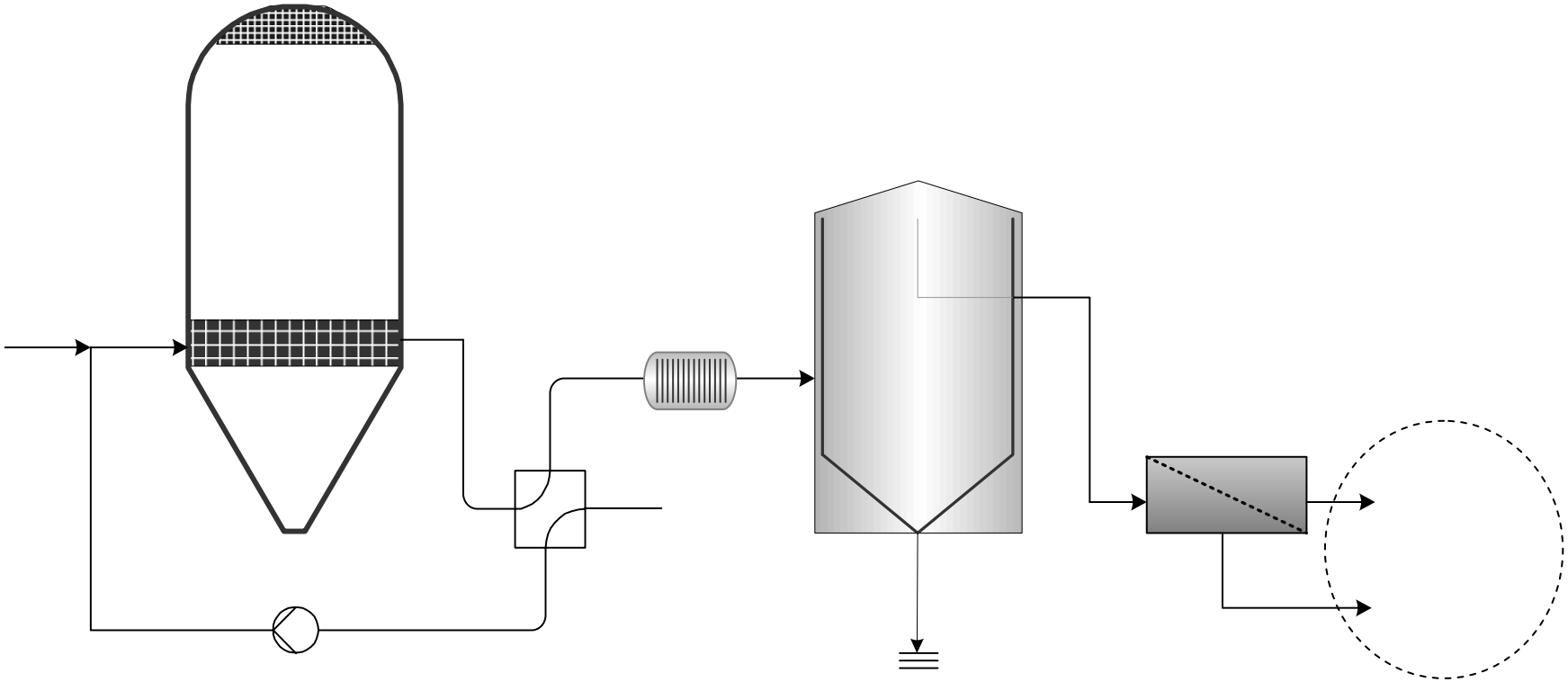
Cold Caustic Extraction - CCEx



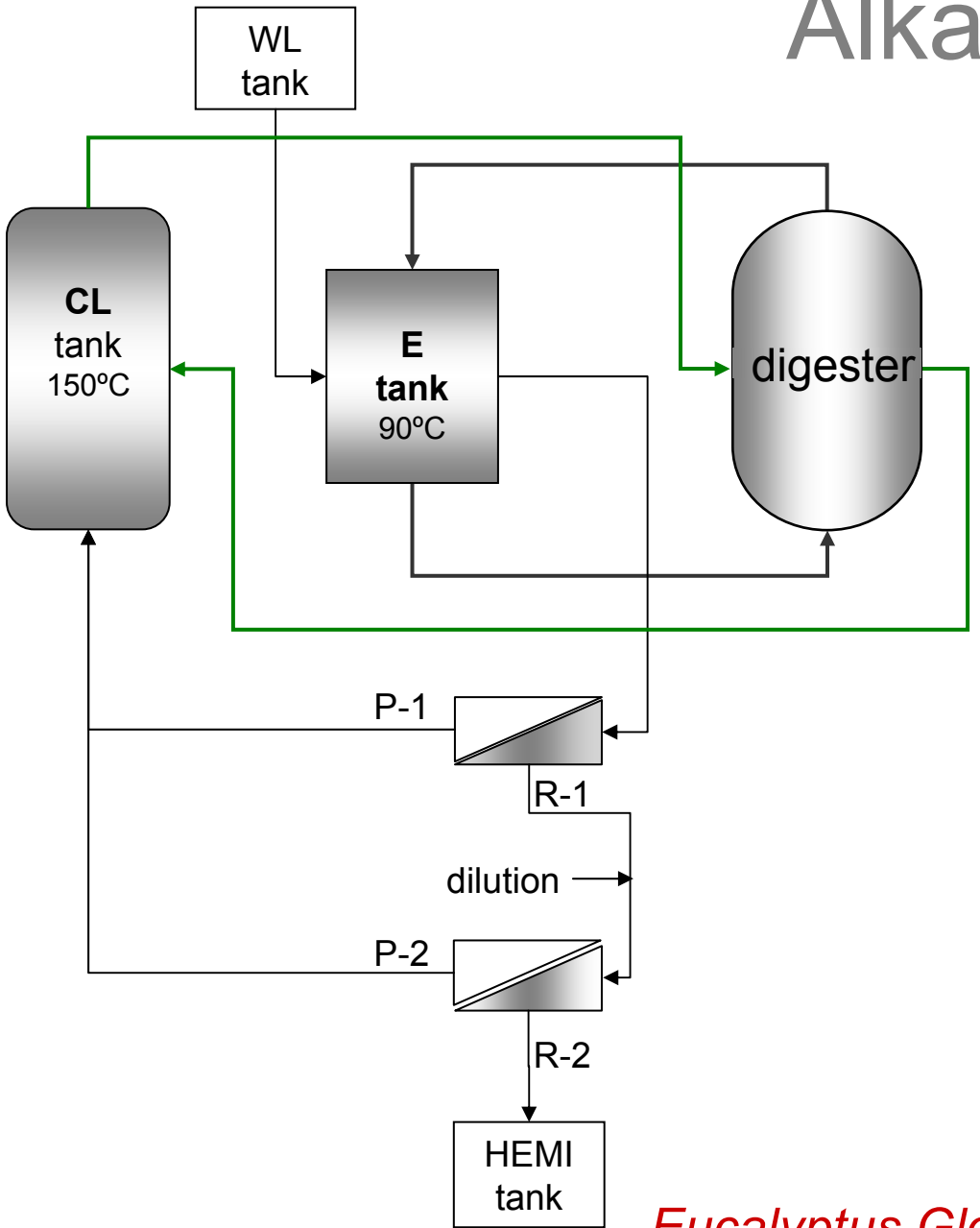
Alkaline Extraction - AlkEx



Water Autohydrolysis



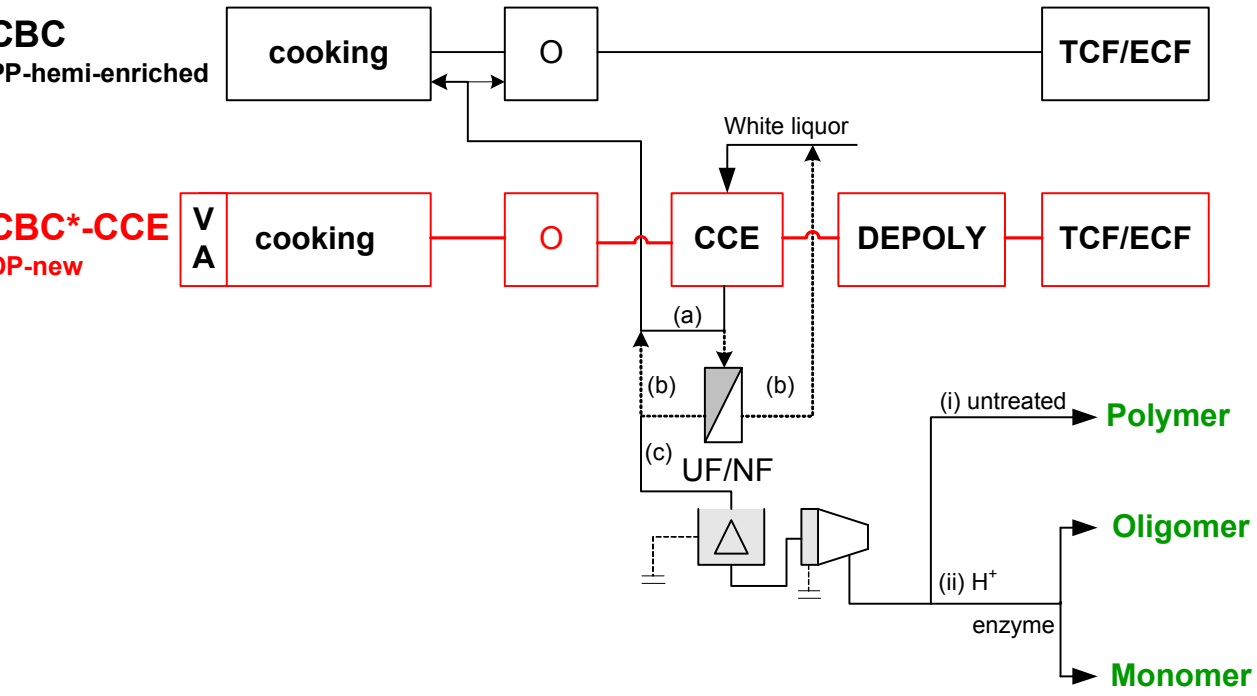
Alkali Pre-Extraction

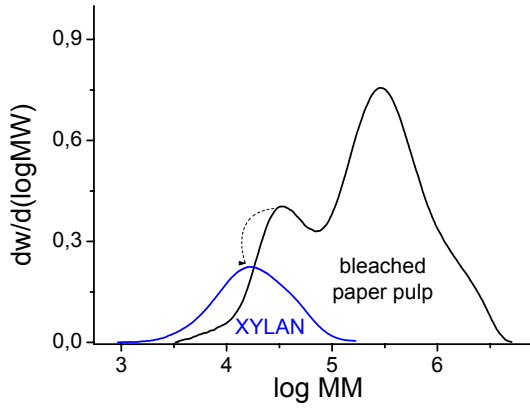


1. Feed of WL from caustizising plant to E-tank.
2. Recycle of WL through digester from bottom-to-top.
3. Change to cooking liquor (permeates of UF and DF) charge until desired H-factor is reached.

Eucalyptus Globulus (Uruguay)

Alkali Post-Extraction

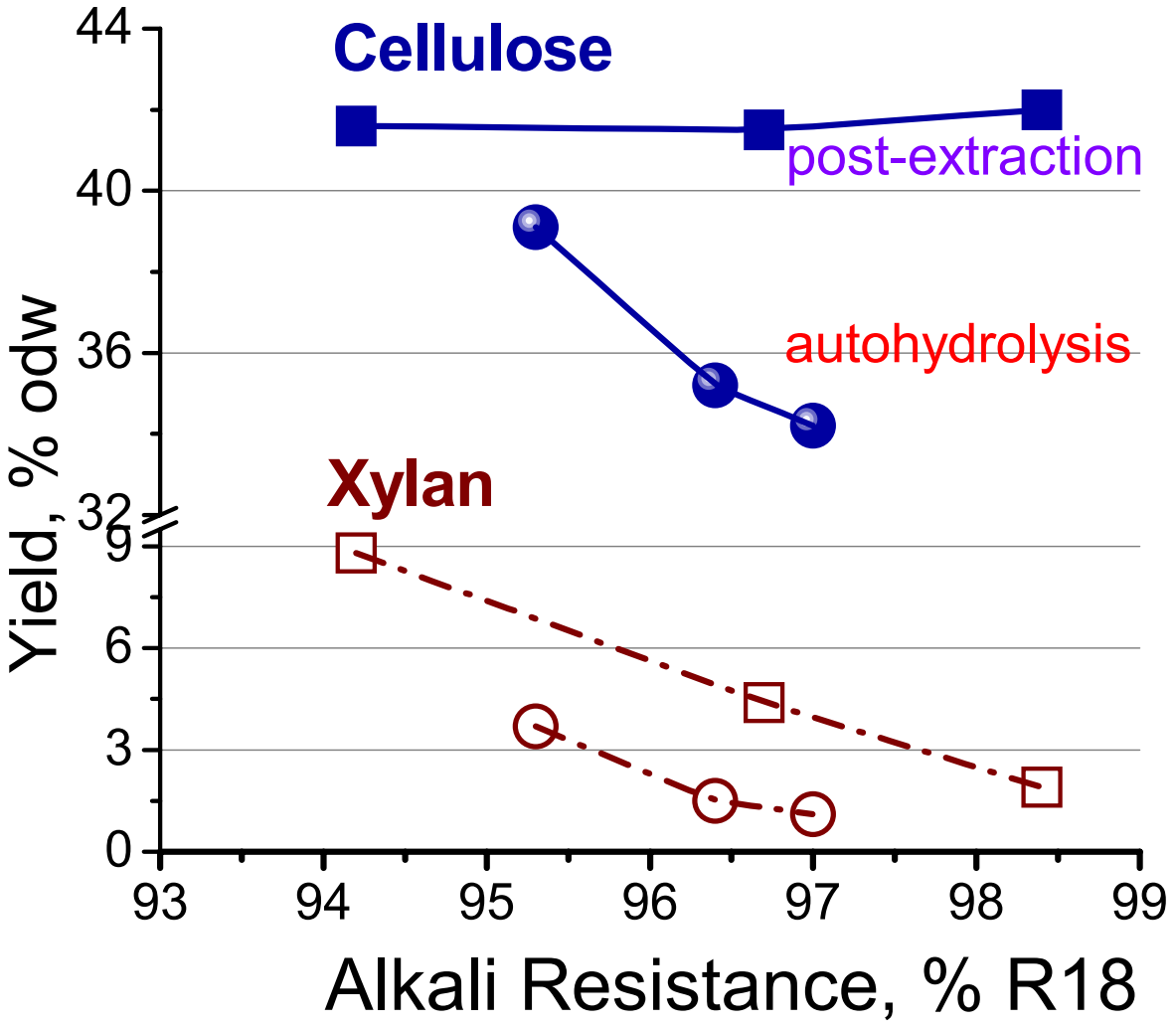




Single Line: Recycling of caustic through membrane separation process.

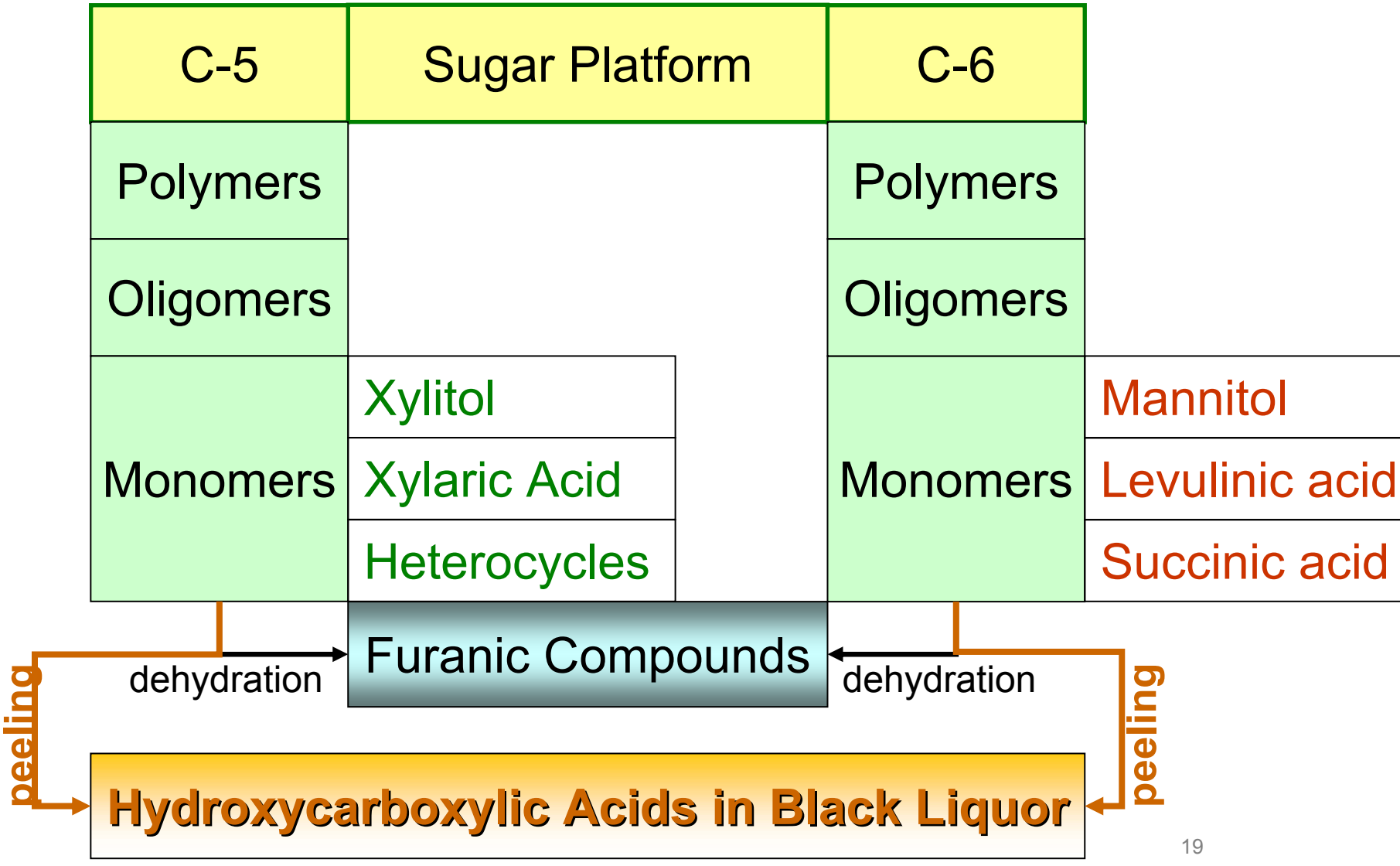
Double Line: Hemi-enriched WL from CCE stage supplies paper line with alkali.

Yield Advantage through Post-Extraction



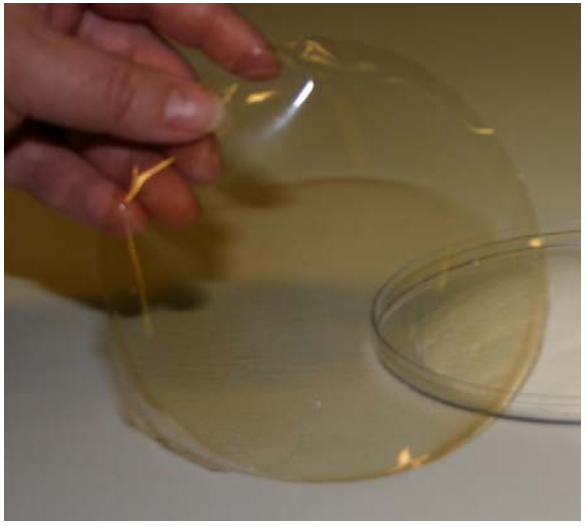
Eucalyptus Globulus

Biomaterial Pathway



Films, Barrier Material

Xylan pre-extracted from *Eucalyptus globulus* by the **Alkali Pre-Extraction Process** with a DP_w ~ 100:



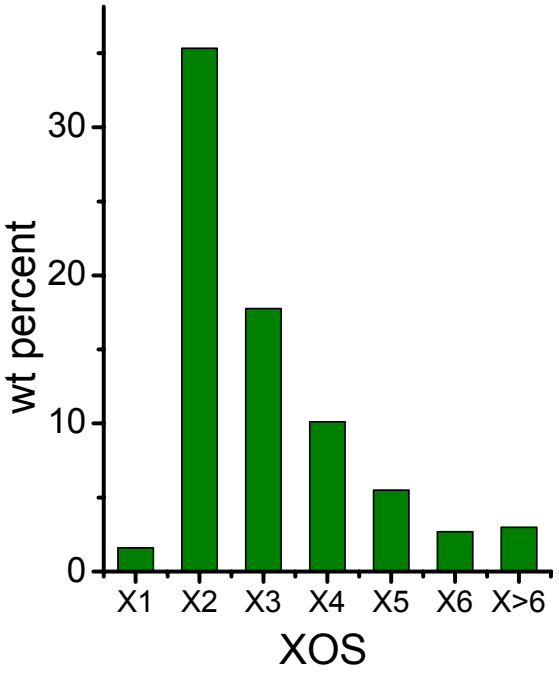
Film casted from dia-retentate of the alkali extract with a xylan-to-NaOH ratio of ~ 2 in an acid precipitation bath.

XOS – food additive

hiseido Medical: Dietary Supplement (tablets) with a variety of minerals, vitamins, extracts and 0.4 g XOS or detoxifying and retuning the body

Drinking yoghurt with XOS, FOS, polydextrose and lactobacillus

XOS from soy bean (50%). good for the intestines



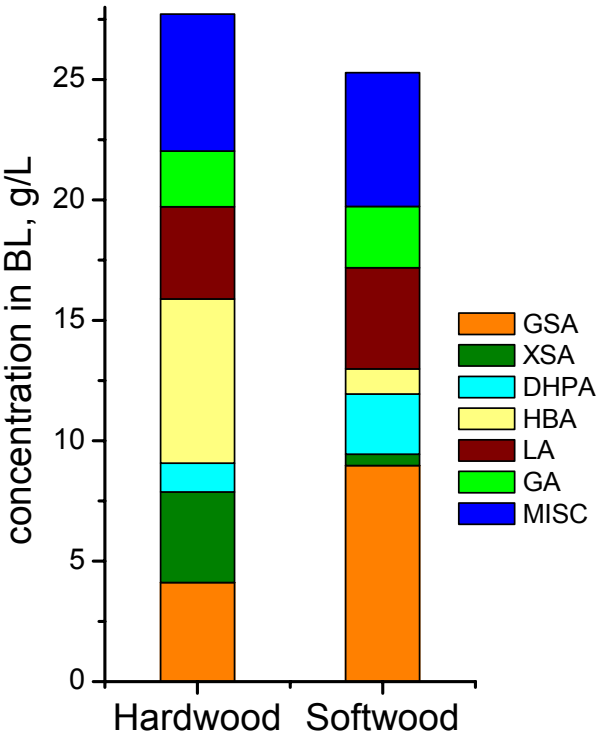
70 wt% neutral XOS
30 wt% acidic XOS

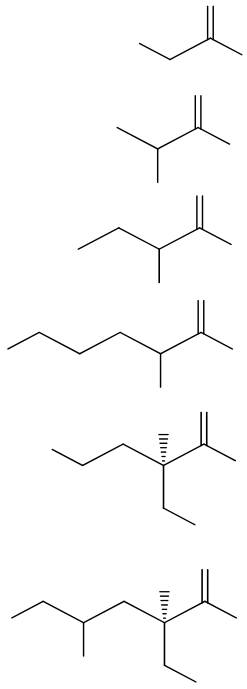
Colon simulation results show
Superior prebiotic properties for XOS:
beside the increase in *bifidobacteria*
also *B. lactis* growth is positively affected.

This synbiotic effect differentiates XOS from FOS.

Hydroxycarboxylic Acids

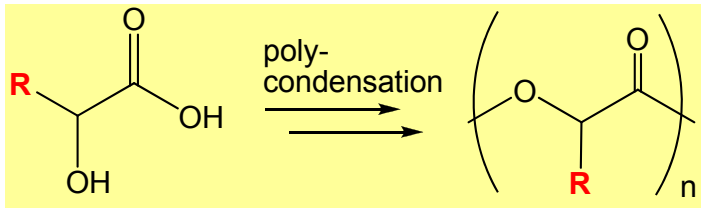
HCA in Black Liquor:
120 – 180 kg/odt wood





Crude hydroxy acid mixture can be prepared after separation of lignin and salts.

Purification of single HCA possible.



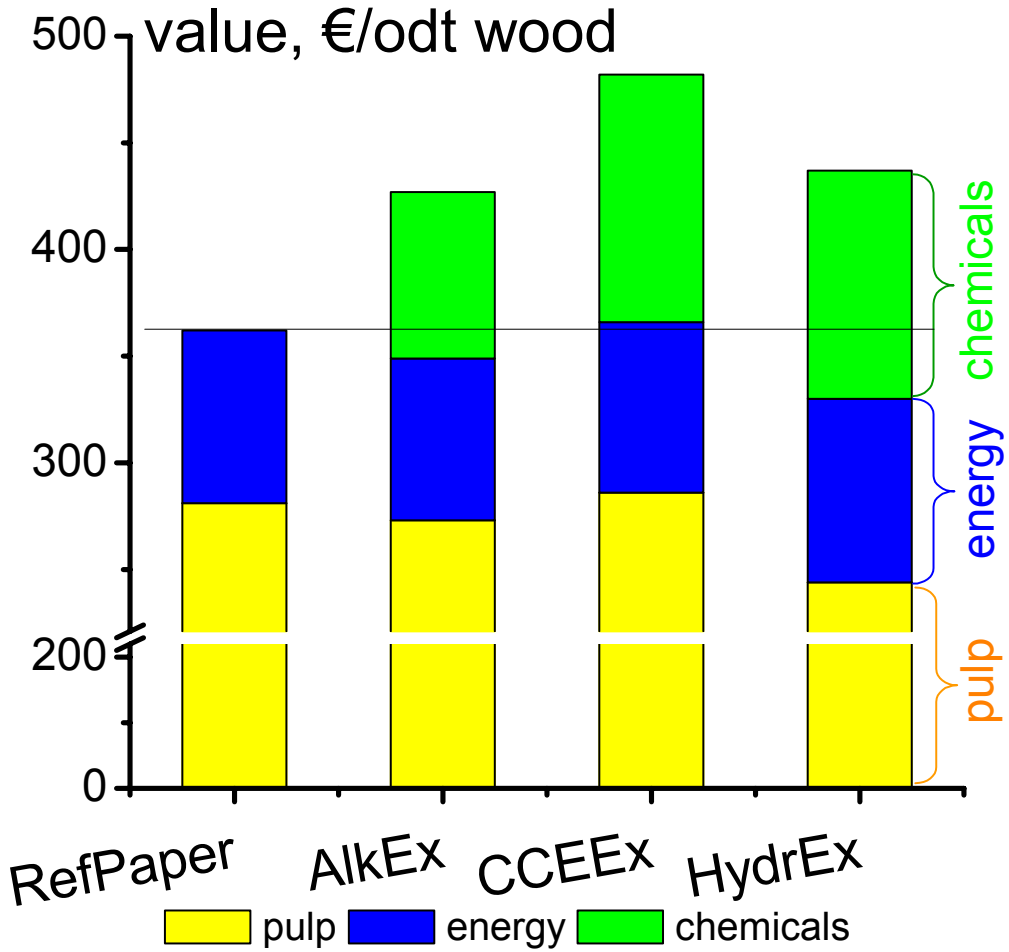
Plastic-like, transparent polymers

Functionalities like softening,

Adhesive and barrier

HO

Comparative Evaluation of *Modified* Kraft Processes



Added Value Factor
(Europe)

- 3 – 4 old
- 4.5 – 5.5 new*

Added value increments*
60 – 120 €/odt wood

CCEEx, HydrEx
as dissolving pulps

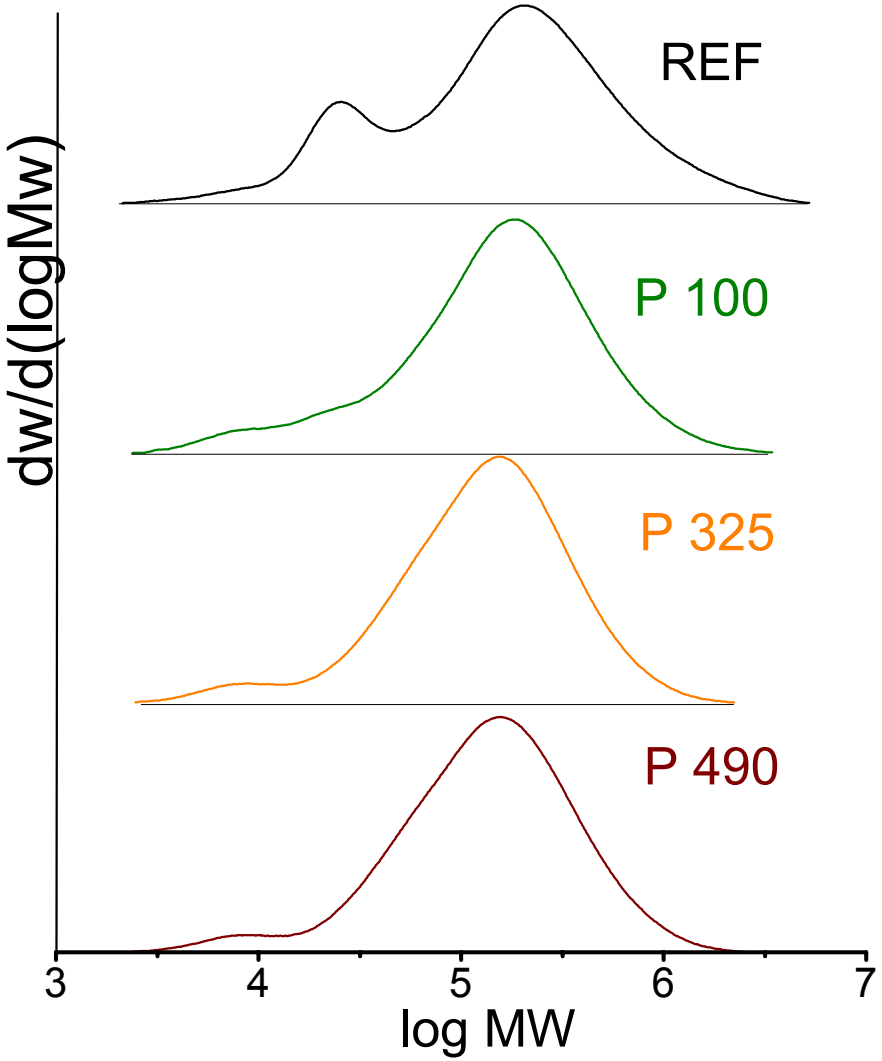
*ucalyptus Globulus

* with the pulp prices unchanged!

Pulp&Cellulose Products

1. Regenerated Cellulose Fibres
2. CMC reinforced Kraft paper pulp
3. Nanocellulose

Effect of Autohydrolysis on MWD



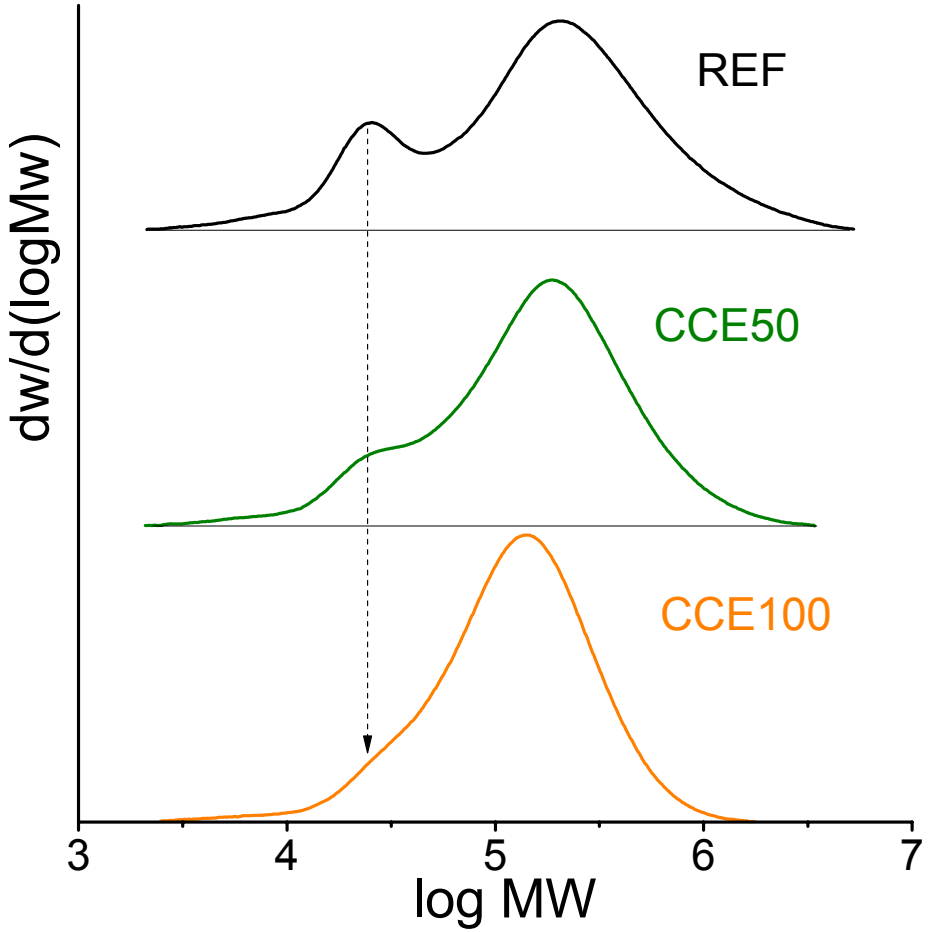
Mild autohydrolysis significantly affects polydispersity:

$$PDI = 5.0 \xrightarrow{P-factor\ 100} PDI = 3.9$$

$$\xrightarrow{P-factor\ 490} PDI = 3.1$$

Eucalyptus Globulus (Uruguay)

Effect of Post-Extraction on MWD



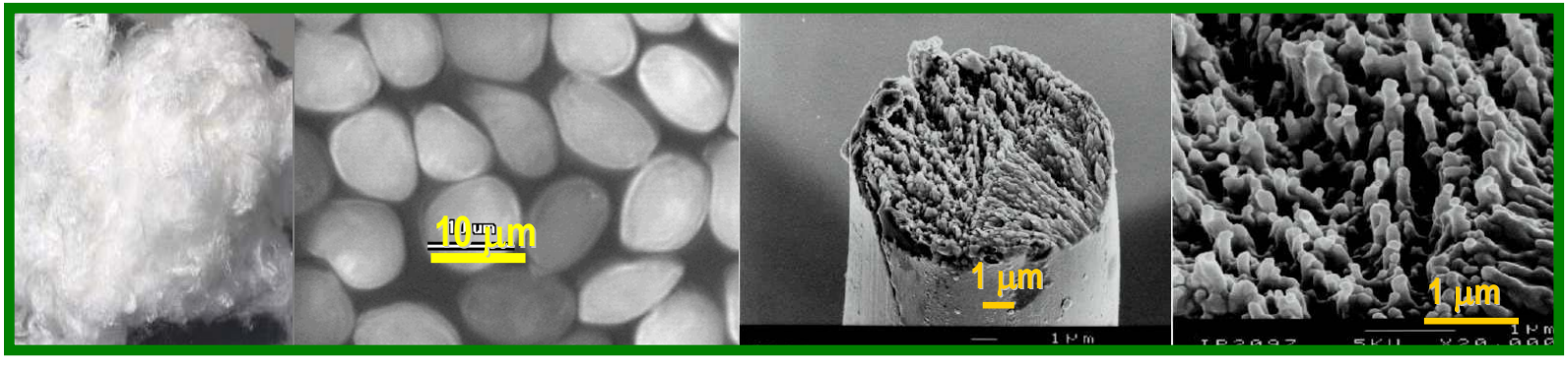
Post-extraction is even more efficient in reducing polydispersity!

$$PDI = 5.0 \xrightarrow{CCE\,50} PDI = 3.5$$

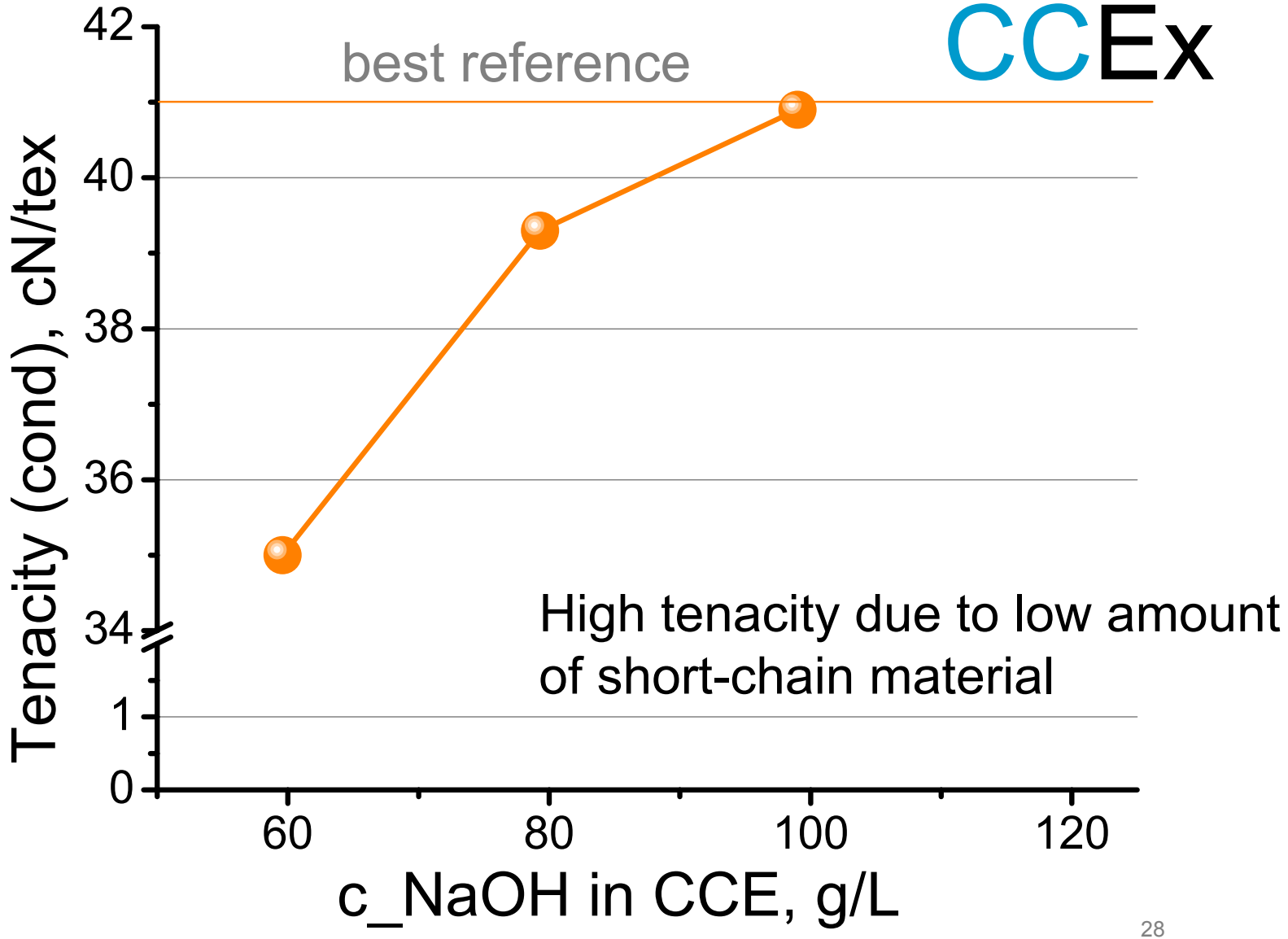
$$\xrightarrow{CCE\,100} PDI = 2.3$$

Eucalyptus Globulus

Lyocell Fibres (CLY)



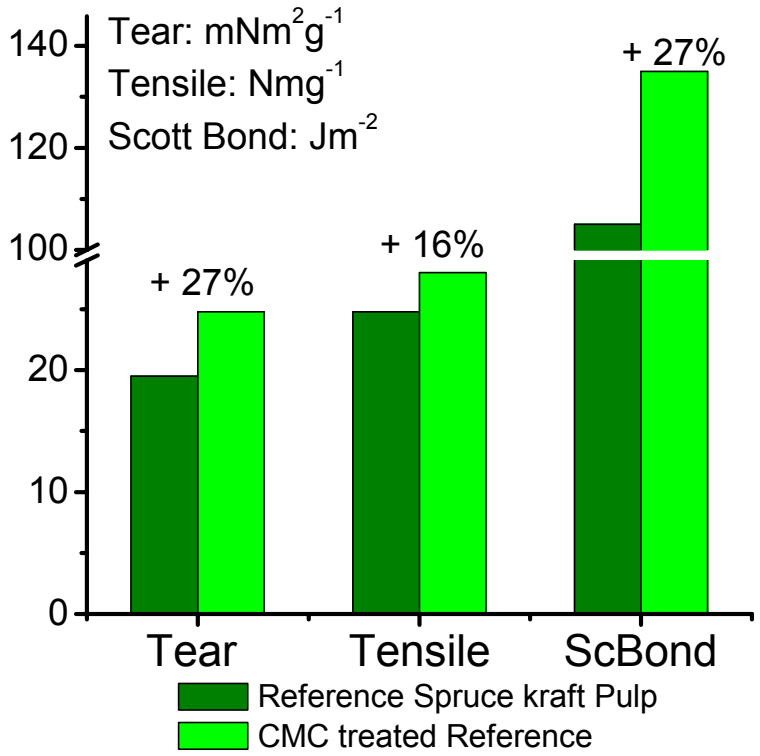
Conversion to Lyocell Fibres (1.3 dtex)



CMC-Kraft Pulp

In O-Delignification of SW-Kraft CMC, DS=0.2, is added after dissolution in NaOH*:

8 bar O_2, 2.5% NaOH, 100ºC, 1% $MgSO_4$, 1% CMC

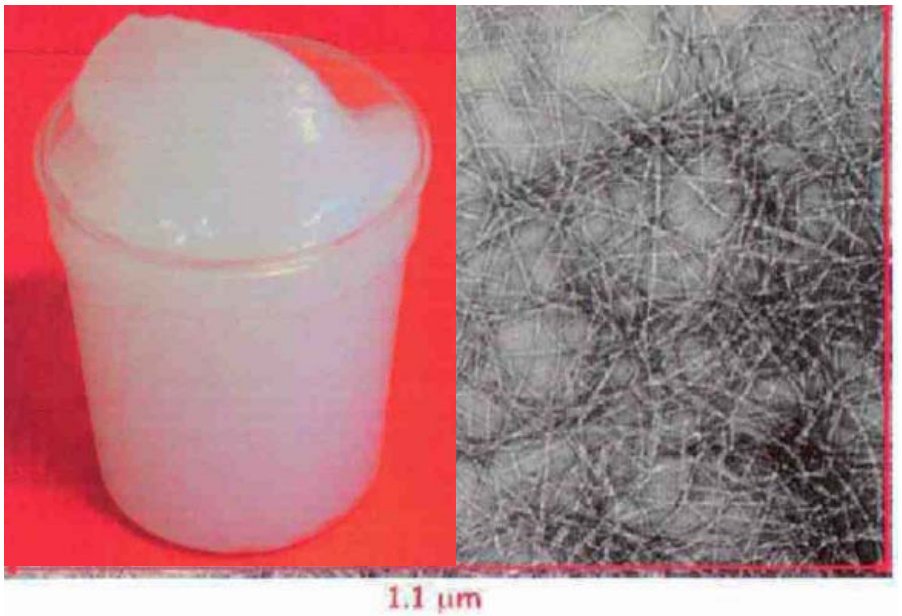


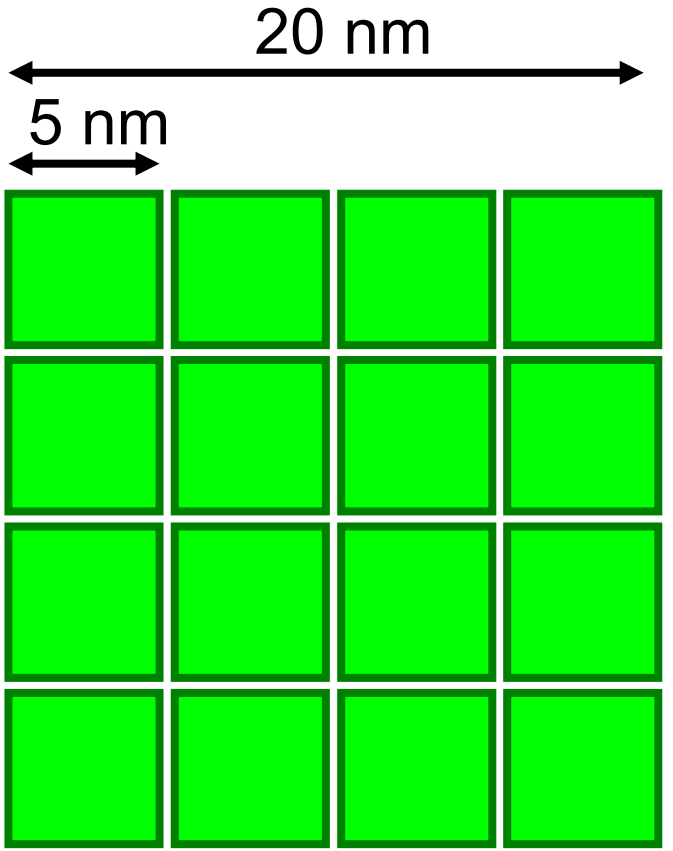
- Significant improvement of paper-making properties
- Fiber-fiber bond is strengthened while the amount of bonds remians unaffected.

NanoCellulose

Dimensions:

- TEM: width 10-30 nm
- AFM: width 10-30 nm
- CP/MAS NMR: width 17 nm
- Length = 100 – 1000 nm





Properties, Potential Applications

Pulp	Stress at brake MPa	Young's modulus GPa	Strain at break %
Nanocellulose	~ 200	10 - 20	6 - 12
SW Kraft	54	5	5
HW Kraft	34	4	4

- Nanocoatings/barriers for paper
- Dry strength agent for paper
- Films
- Cosmetics
- Hygiene
- Food additives
- Pharmaceutical applications

Conclusions

- New fractionation concept fully compatible with the **kraft process**.
- Combined production of **paper&dissolving pulps** and **high-value added chemicals** based on hemicelluloses (and lignin).
- Manufacture of **high-value added cellulose** products will be integral part of future pulp mills.

Annex

Product Balance

E.glob **Pulps**	Bleached Yield, %	Sugar products, kg/odtw					Heat to Steam	
		Acetic Acid	Xylitol			XOS	GJ/odtw	% of lignin
RefPaper	50,3	0	0			0	8,1	66
CCEEx	42,5	0	40	or		33	8,0	66
AlkEx	48,8	26	32	or		18	7,6	72
HydrEx	36,2	12	7	and		28	8,6	60