

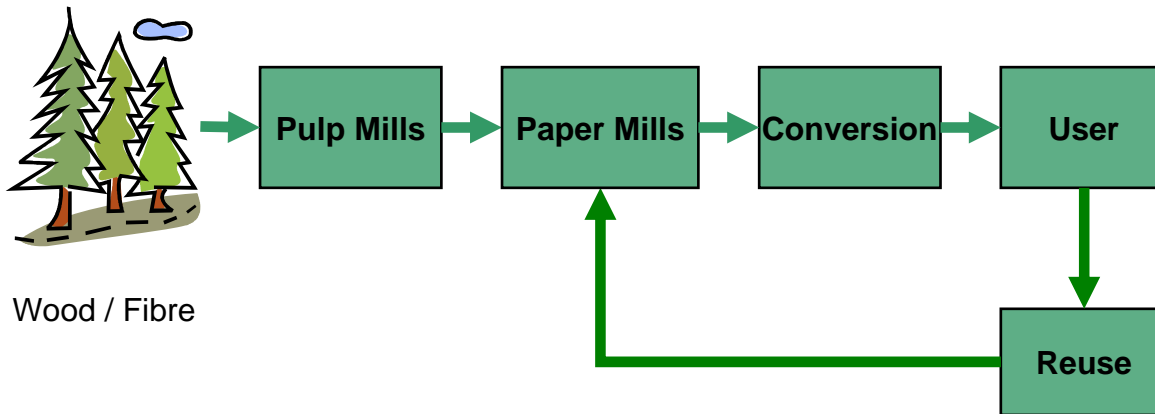


The future pulp mill – a biorefinery ?

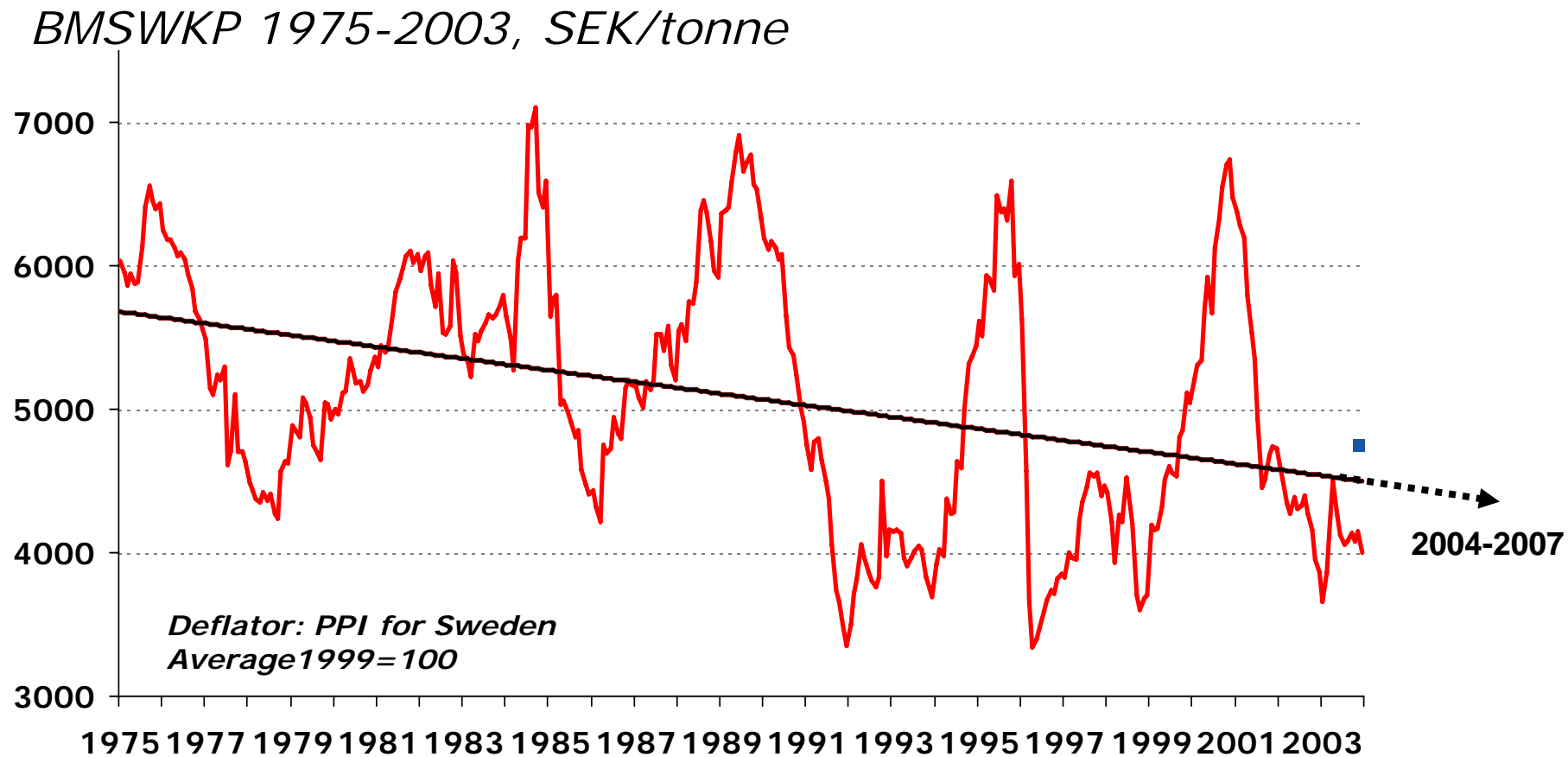
Peter Axegård, STFI-Packforsk

**Presentation at the 1st International Biorefinery
Workshop, July 20-21, 2005, Washington, D.C.**

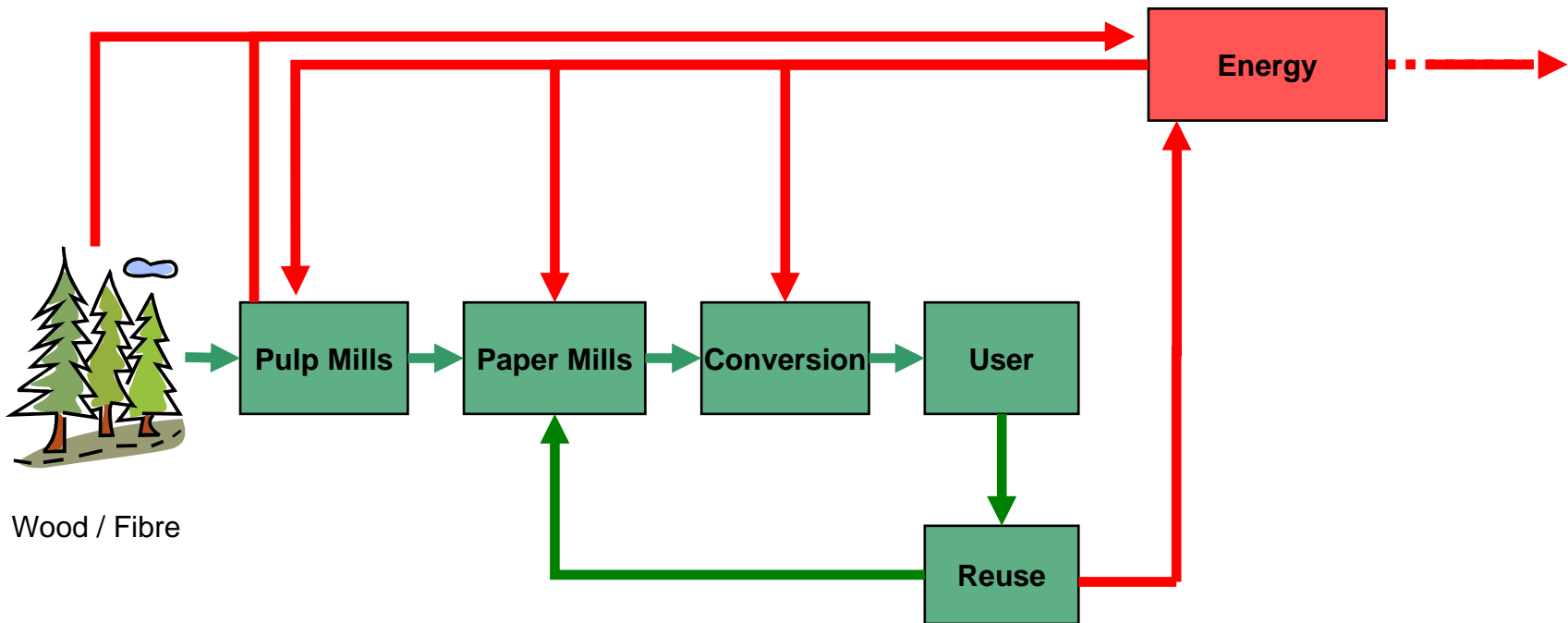
Fibre products from wood



Steady drop in market pulp prices...



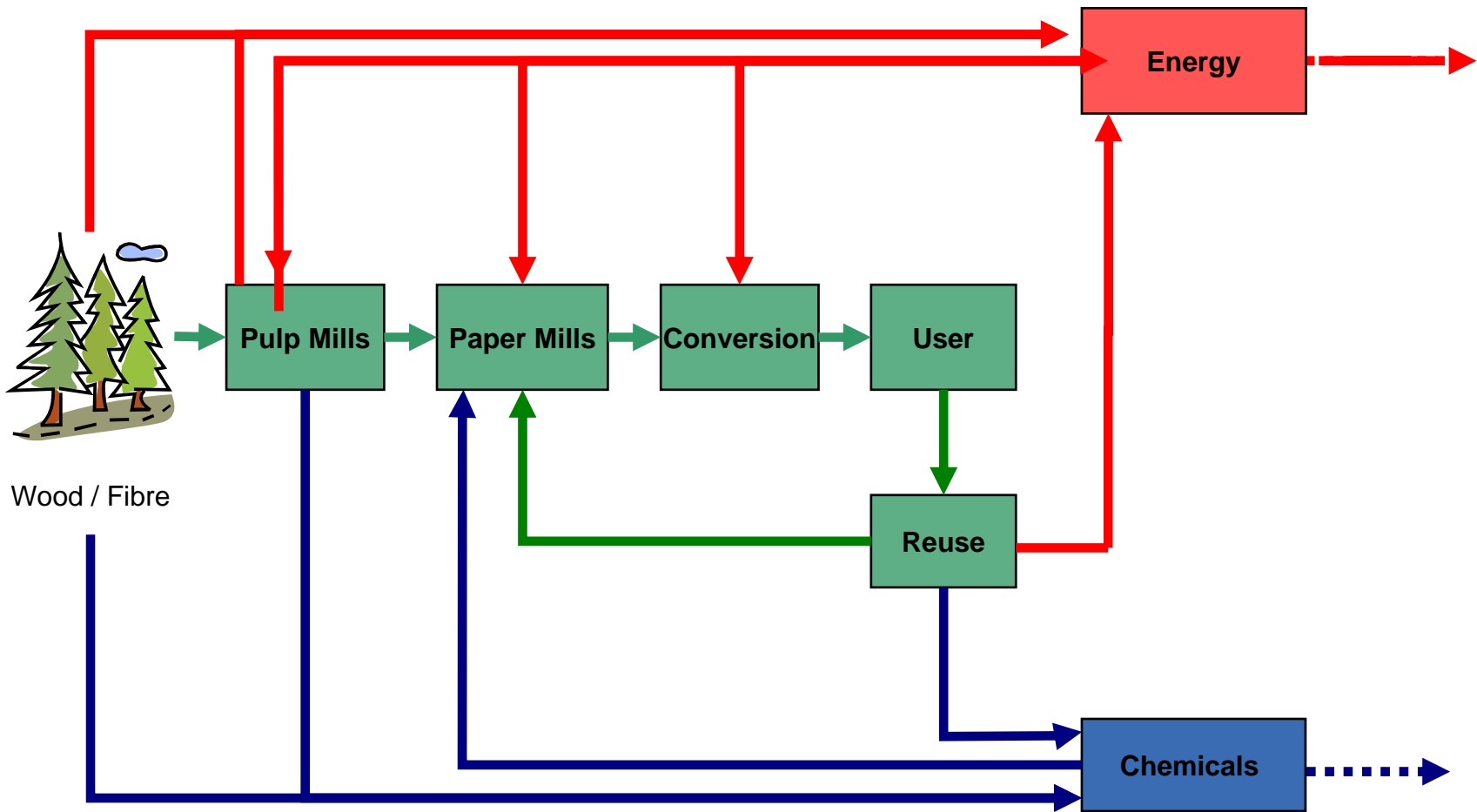
... and energy



Synthesis - Conclusions from KAM

Model Mill Case	Sold Fuel GJ/ADt	Sold power kWh/ADt	"Fossil" CO₂ kg/ADt
Reference Mill - ECF-bleaching	3.1	540	-260
Swedish average 2000	-0.6	-140	+320
Model mill 2. Export of excess lignin	7.3	70	-450
Model mill 3. Pressurized BLG with power generation	2.4	1040	-390
Model mill 4. Pressurized BLG - methanol production	8.9	-370	-400

... and chemicals



The pulp mill biorefinery

Definition

Full utilization of the incoming biomass and other raw materials, including energy, for simultaneous production of fibres for paper products, chemicals and energy

A modern SW kraft mill producing 630 000 t pulp/y yields as by-products

750 000 t of organic material in **black liquor**:

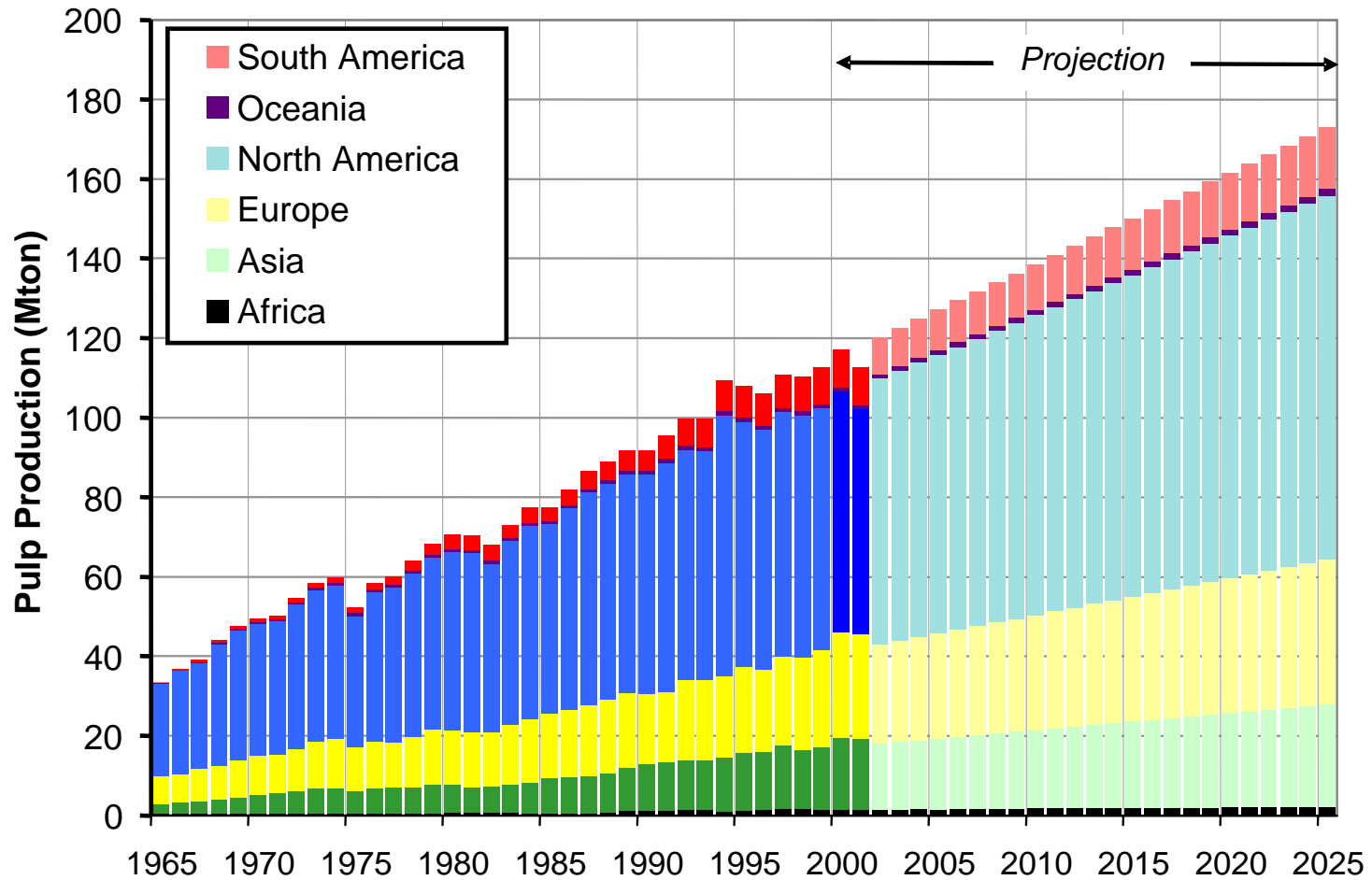
- 330 000 t lignin
- 220 000 t hydroxycarboxoylic acids
- 75 000 t extractives
- 37 000 t aliphatic acids
- 7 000 t methanol

120 000 t **bark**

22 000 t **tall oil**

2 600 t **turpentine**

Global production of kraft pulp



(Berglin, 2001, based on FAO statistics)

The pulp mill biorefinery

Main components in wood

Bark, branches, leaves/needles, knots, and normal wood
Cellulose, lignin, hemicelluloses extractives, minerals, proteins and water

Main process alternatives

Extraction, distillation, precipitation, membrane separation, pyrolysis, gasification, steam explosion, hydrolysis, chemical and enzymatic processing

Main process streams

Bark, knots, black liquor (BL), BL evaporation condensates, process stage filtrates, bio-sludge, green liquor dregs, lime mud

Pulp mill biorefinery

Definition

Full utilization of the incoming biomass and other raw materials, including energy, for simultaneous production of fibres for paper products, chemicals and energy

Boundary restrictions

- Normal wood to fiber products
- Possible to integrate with kraft and mechanical pulp mills
- Technically and economically viable and environmentally sound technical solutions

Biorefinery – on-going activities at STFI

- **Lignin separation and utilization**
 - Precipitation, membrane separation, washing, dewatering, fractionation, lignin, phenols, carbon fibers and high quality fuel
- **Hemicellulose separation and utilization**
 - Chip leaching, membrane separation, derivatisation, hydrogels, films and specialty chemicals
- **Bark and extractives utilization**
- **BLGCC and BLGMF**
- **Upgrading of forest residues**
- **Model mills**

- **Budget 2005 – 2007: 2.5 M€**

EU-project WaCheUp

Duration: 2005 - 2007

Budget: 2.8 M€

Partners:

STFI-Packforsk, VTT, Åbo Akademi, University of Aveiro, University of Lund, Chalmers University of Technology, Amorim, University of Minho

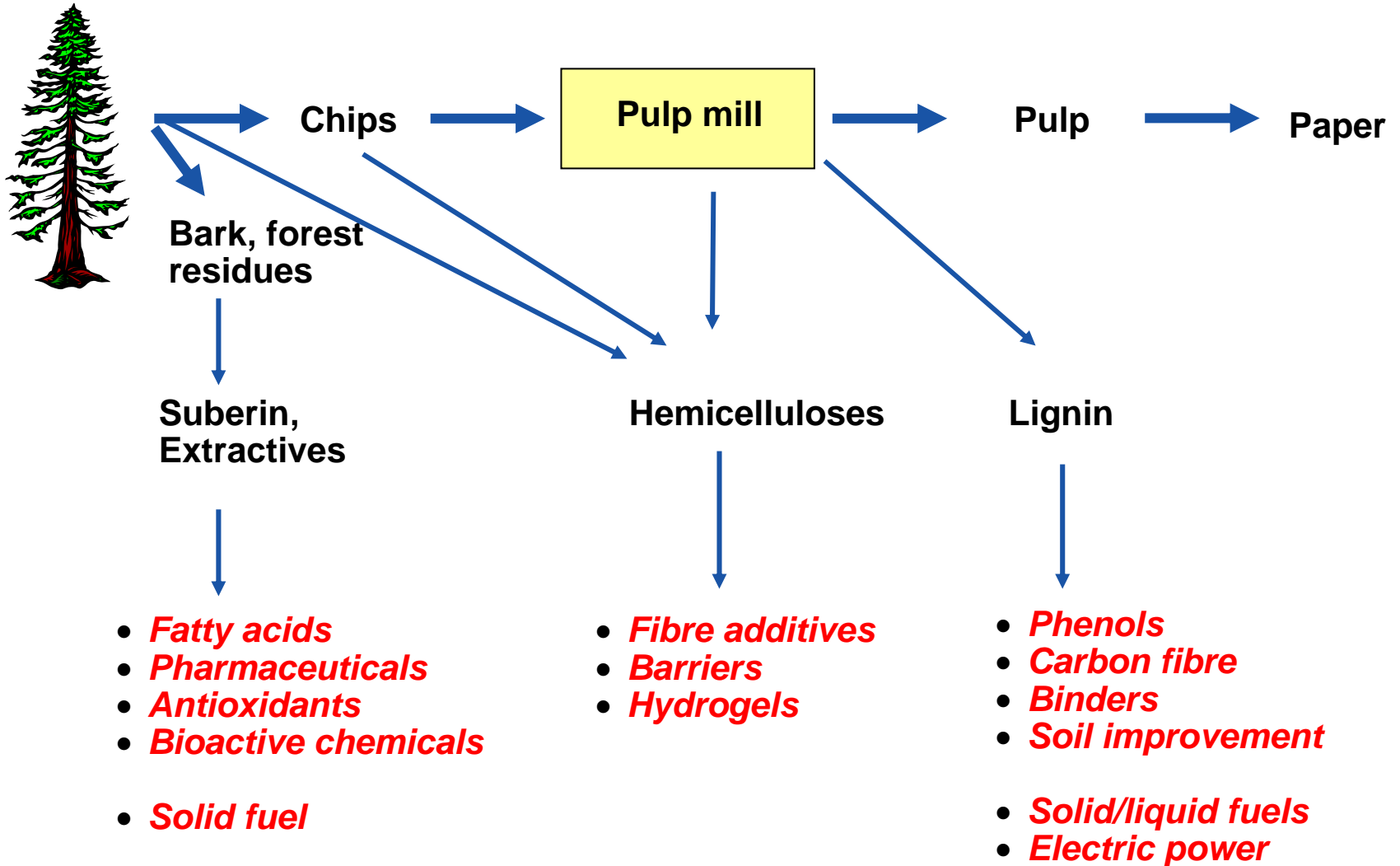
Industrial stakeholders:

M-Real, Södra Cell, Borregaard, Kemira, Sveaskog, Perstorp, UPM-Kymmene, Korsnäs, Frantschach, Kemira, Raisio Life Sciences, Bakelite

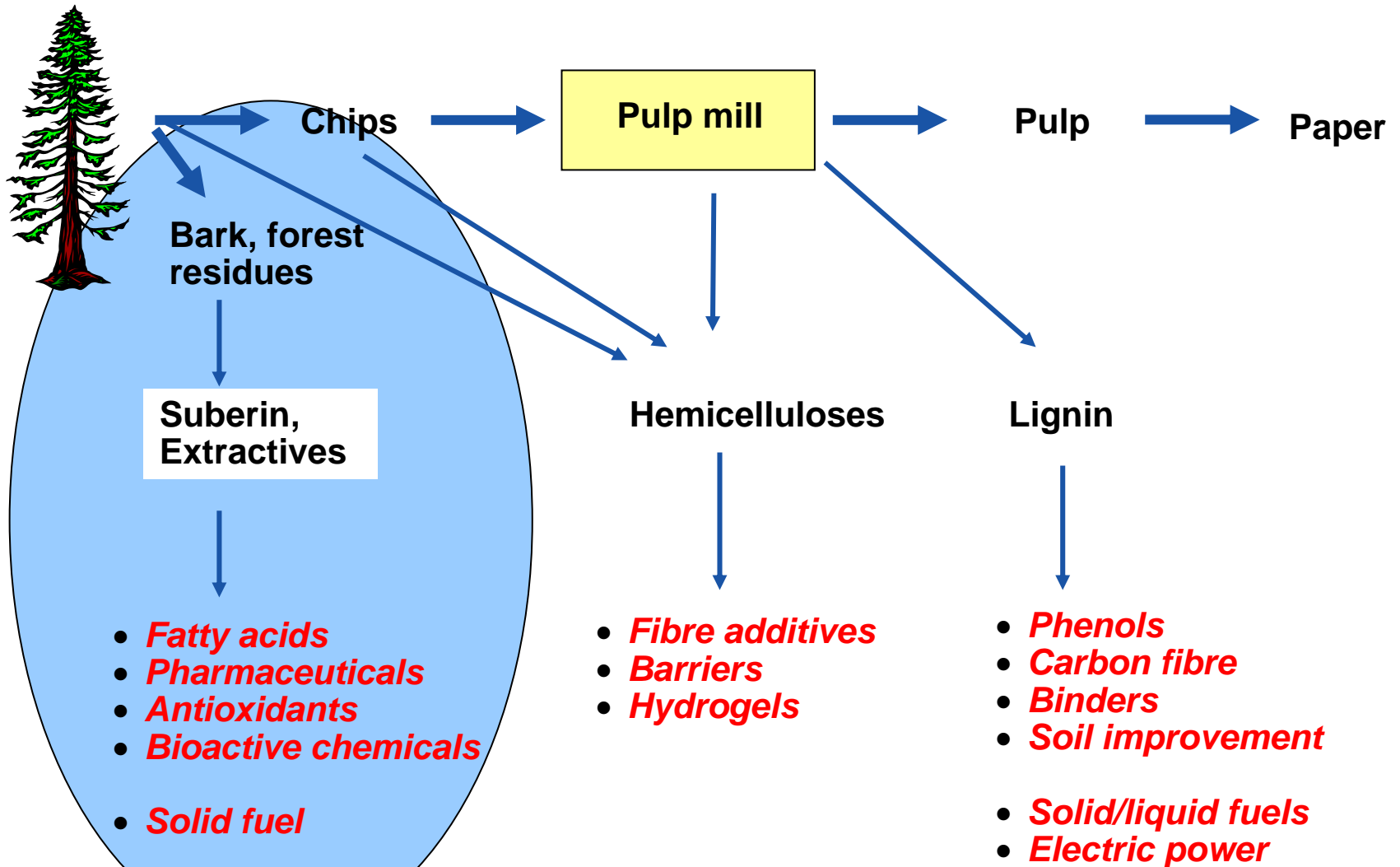
Three innovations from KAM and FRAM

- **Chip leaching** for removal of non-process elements from wood chips can also extract valuable hemicelluloses from wood chips
- Removal of **xylans** and high molecular weight **lignin** from cooking liquor circulations
- **High quality lignin** from black liquor evaporation

Possible products from a pulp mill biorefinery



Possible products from a pulp mill biorefinery



Leaching of forest residues



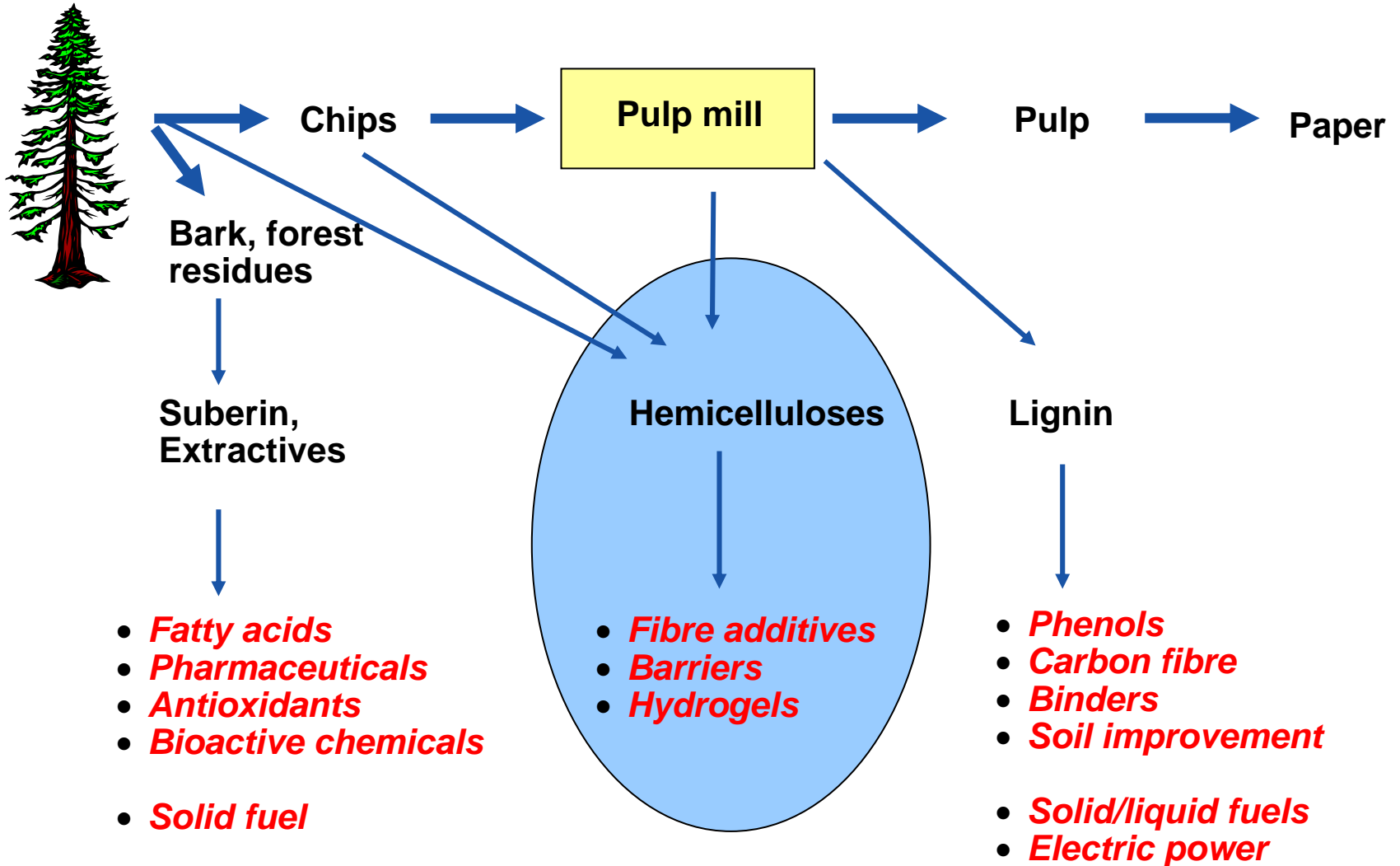
Leaching of forest residues

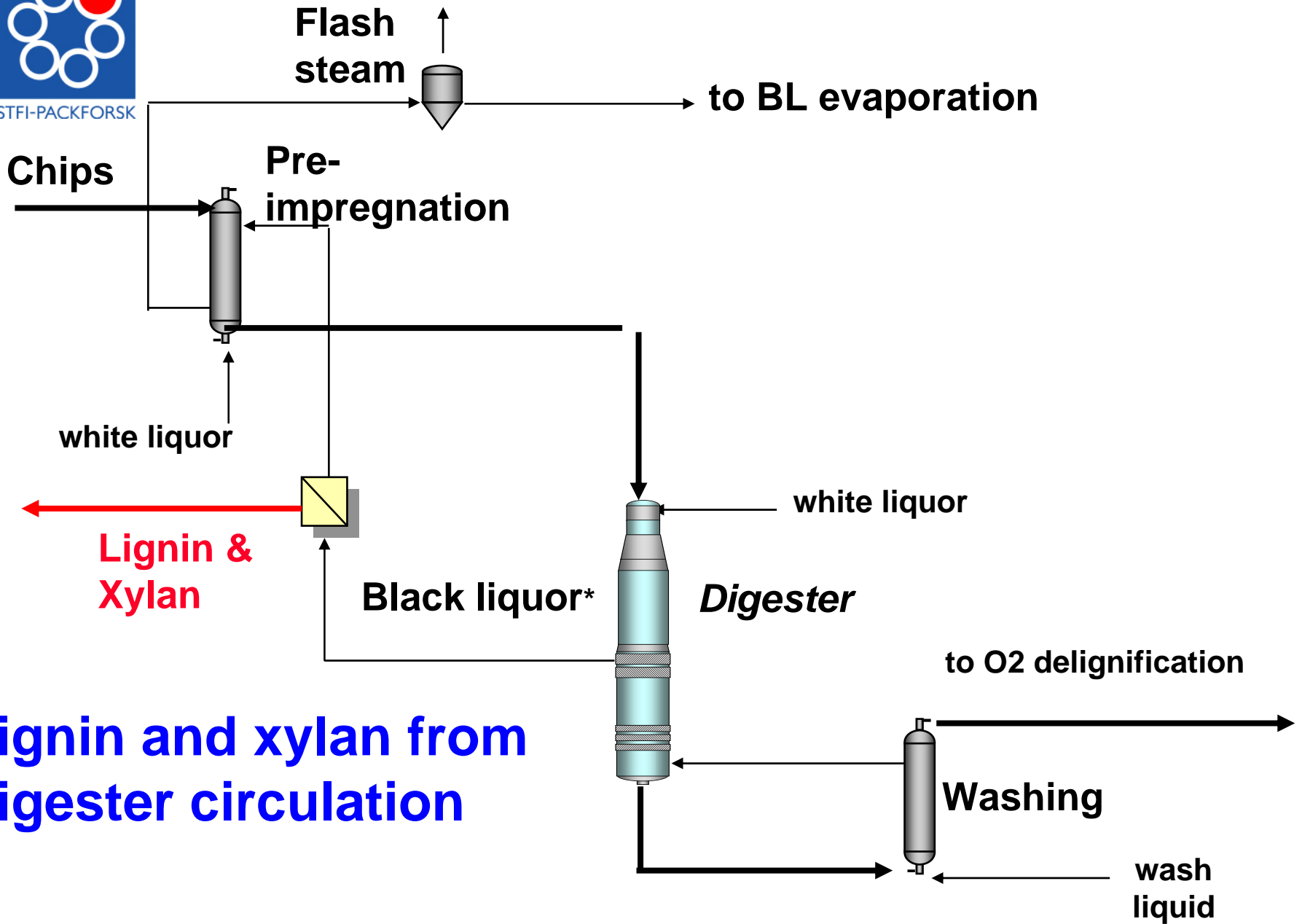
mg/kg	High quality biofuel	Forest residues	
		Untreated	Leached
Ash	<10 000	7 900	4 100
K	200 - 600	520	180
Na	20 - 75	20	3
N	3000	1 200	1 100
Cd	0.10 - 0.15	0.21	0.15
S	100 - 400	140	280

Interesting fatty acids in bark suberin

C ₁₆ -Family	C ₁₈ -Family
$\text{CH}_3-(\text{CH}_2)_{14}-\text{COOH}$ $\begin{array}{c} \text{CH}_2-(\text{CH}_2)_{14}-\text{COOH} \\ \\ \text{OH} \end{array}$ $\begin{array}{c} \text{CH}_2-(\text{CH}_2)_x-\text{CH}-(\text{CH}_2)_y-\text{COOH} \\ \qquad \qquad \\ \text{OH} \qquad \qquad \text{OH} \end{array}$	$\text{CH}_3-(\text{CH}_2)_7-\text{CH}=\text{CH}-(\text{CH}_2)_7-\text{COOH}$ $\begin{array}{c} \text{CH}_2-(\text{CH}_2)_7-\text{CH}=\text{CH}-(\text{CH}_2)_7-\text{COOH} \\ \\ \text{OH} \end{array}$ $\begin{array}{c} \text{CH}_2-(\text{CH}_2)_7-\text{CH}-\text{CH}-(\text{CH}_2)_7-\text{COOH} \\ \qquad \qquad \qquad \diagdown \quad \diagup \\ \text{OH} \qquad \qquad \qquad \text{O} \end{array}$ $\begin{array}{c} \text{CH}_2-(\text{CH}_2)_7-\text{CH}-\text{CH}-(\text{CH}_2)_7-\text{COOH} \\ \qquad \qquad \qquad \\ \text{OH} \qquad \qquad \text{OH} \qquad \text{OH} \end{array}$

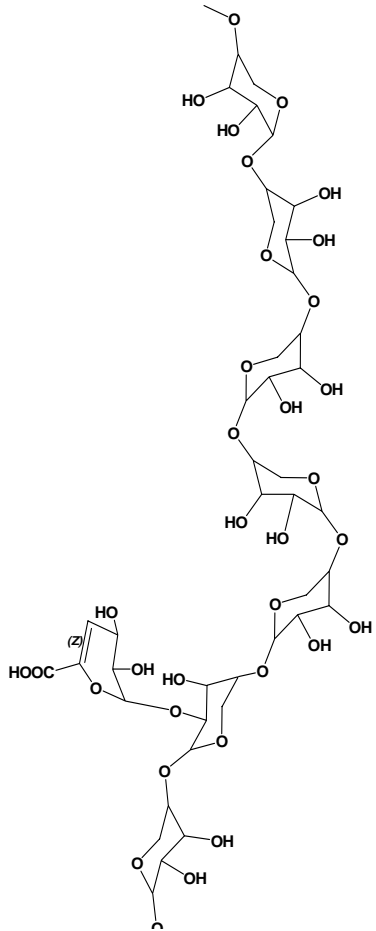
Possible products from a pulp mill biorefinery





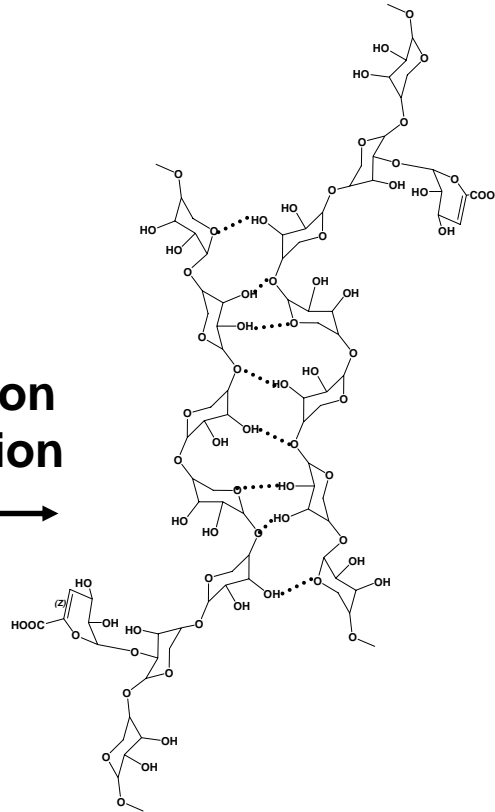
Lignin and xylan from digester circulation

Xylan sorption onto fibres

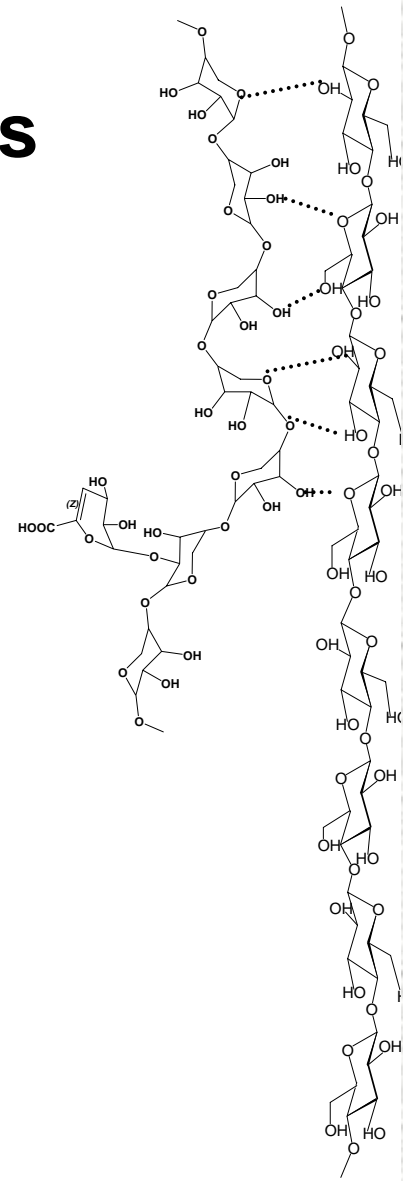


Debranching of xylan in the cooking liquor

Aggregation and sorption

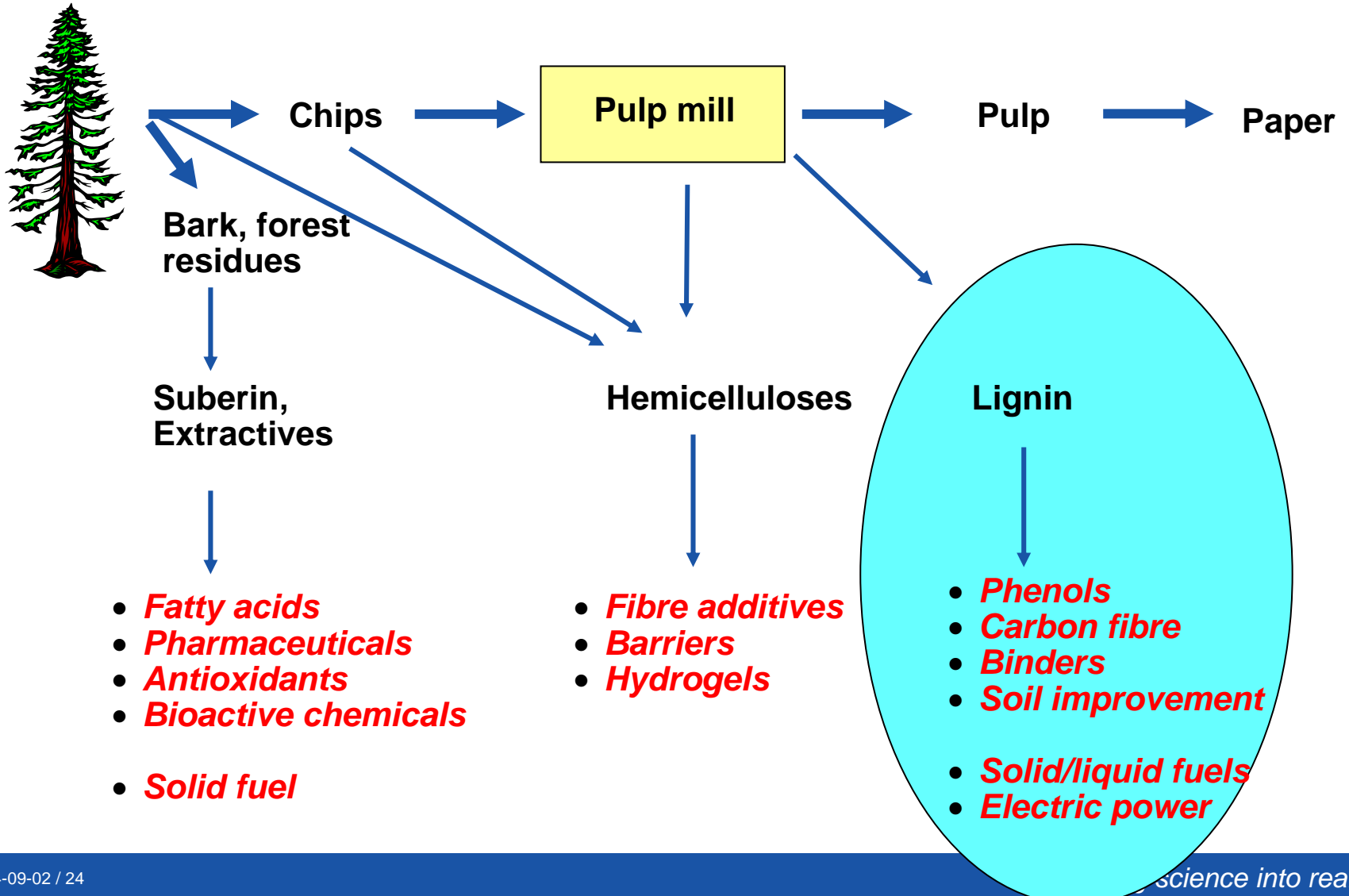


Aggregation of xylan polymers



Sorption of xylan onto fibre surface

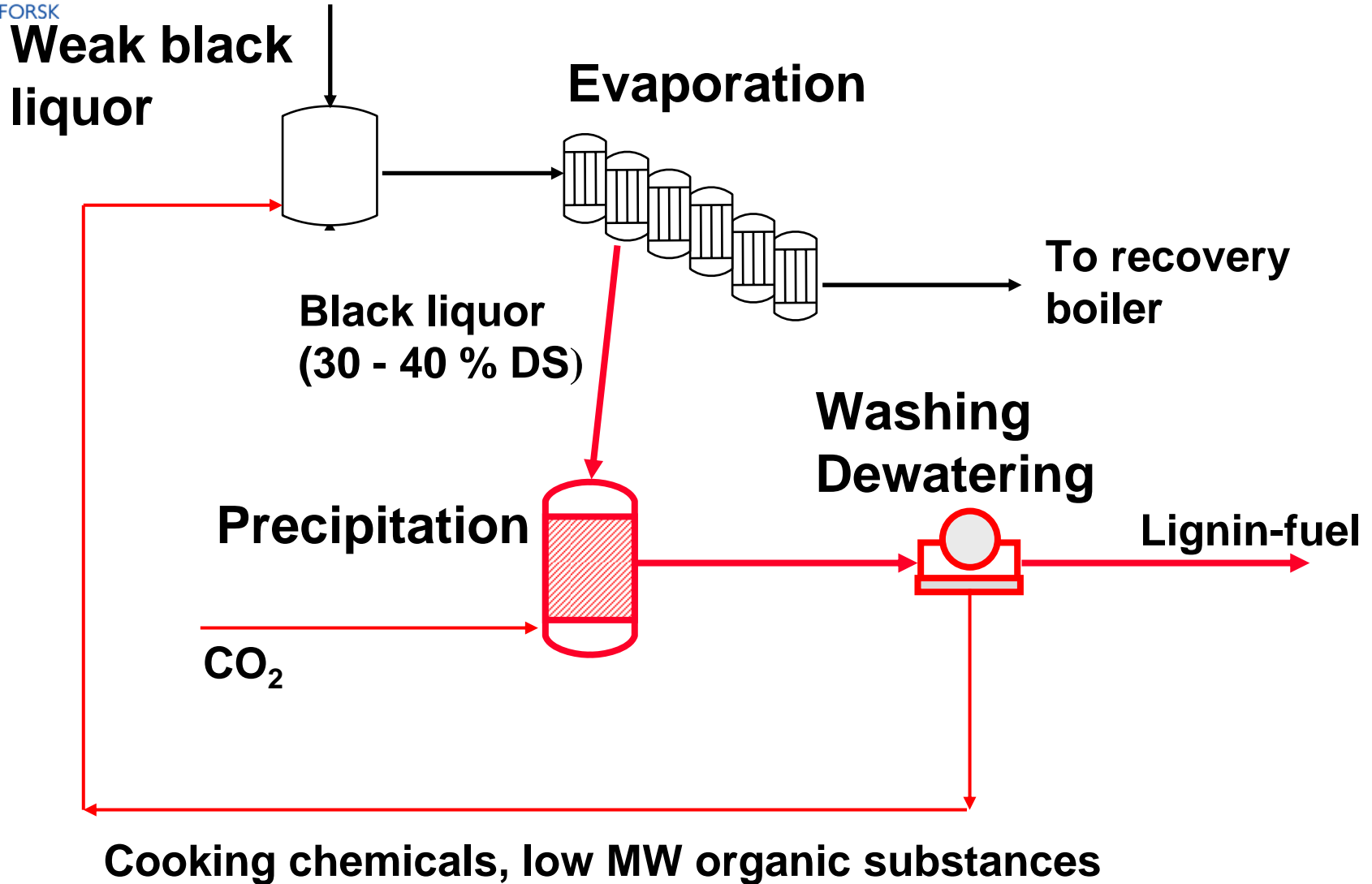
Possible by-products from a pulp mill biorefinery



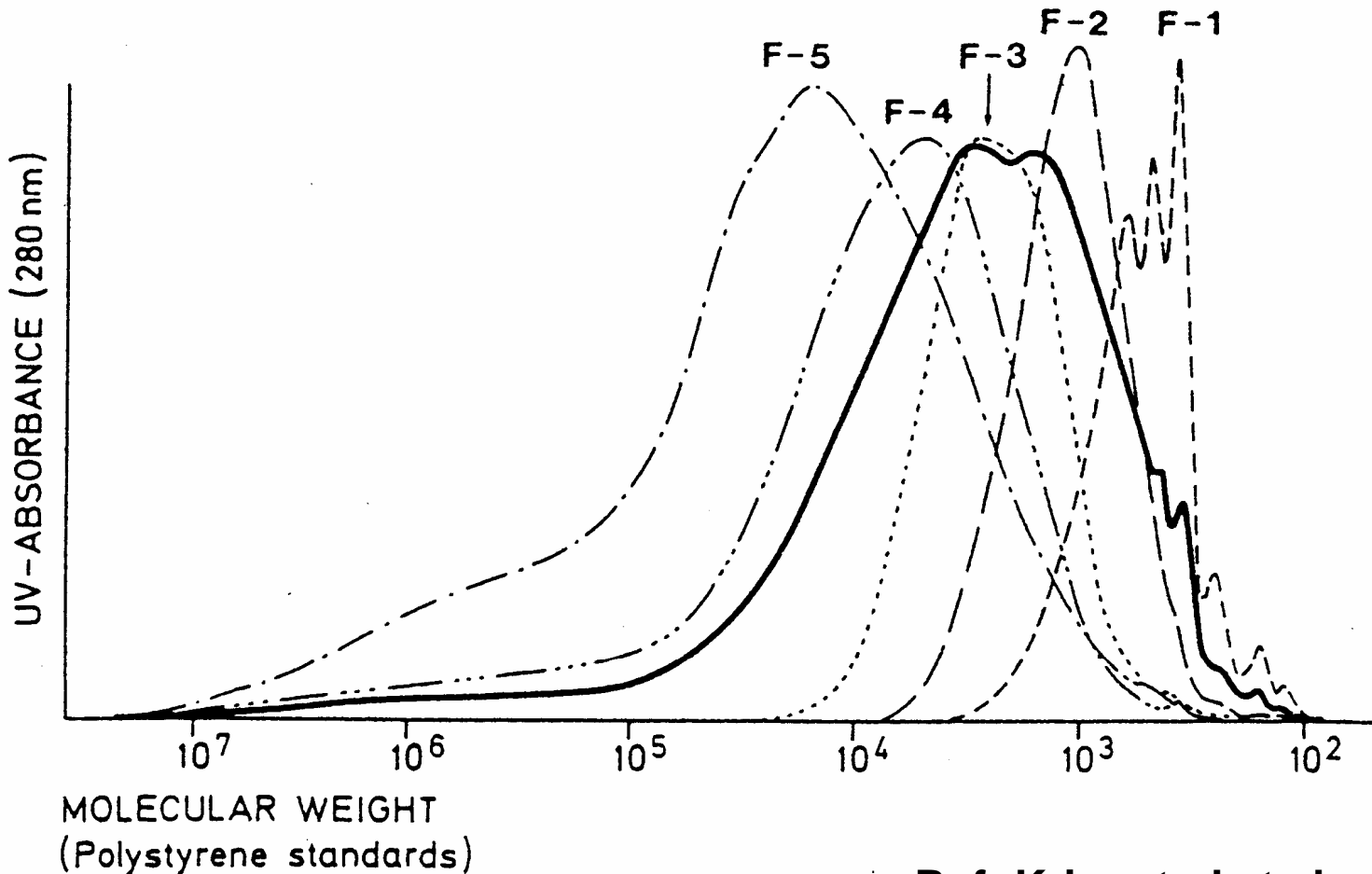
Removal of lignin can give ...

- **Higher pulp output with recovery boiler "bottleneck"**
- **Higher energy efficiency with energy excess**
- **Promising fuel**
- **Interesting chemical feed-stock**

Lignin precipitation



Molecular weight kraft lignin fractions from solvent fractionation



Ref: Kringstad et al

Large filter pilot for lignin production



Lignin properties - pilot plant trials

Production of 8 tonnes lignin

- **Total moisture content** **30 - 40 %**
- **Ash content, % on dry weight** **0.2 - 0.5 %**
- **Sodium , % on dry weight** **0.1 - 0.4 %**

- **1st estimated production cost: 100-150 SEK/MWh**

Lignin pellets



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The future pulp mill – a biorefinery?

- Negative trend price on pulp
 - New revenues needed
 - Infrastructure exists
 - Large potential for energy and chemicals
-
- Electricity, methanol/DME, solid fuel (bark, lignin, forest residues)
 - Chemicals from bark, black liquor and forest residues