THE BIOREFINERY
PULP MILL

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Research Institutes of Sweden
Innventia/RISE BIOECONOMY
Three have become one - RISE

The Swedish RISE institutes Innventia, SP and Swedish ICT have merged in order to become a stronger research and innovation partner for industry and society.
Facts about RISE

- 2015 turnover over 3 billion SEK (55 % from industry)
- 2,200 employees, 30 % with PhD
- 2,800 incl Swerea)
- Over 100 test and demonstration facilities, open for industry, SMEs, universities and institutes
- RISE is owner and partner in 60 % of all T&D-facilities in Sweden
LET'S PUT OUR HEADS TOGETHER. TO KEEP AHEAD.

RISE DIVISION BIOECONOMY
RISE Bioeconomy is a merger of:

- Innventia incl.
  - LignoBoost Demo, PFI
- Energy Technology Centre AB (ETC)
- Processum
- SP section Combustion and aerosol technology
- SP section Biobased materials and products
- SP section Products and processes
RISE Bioeconomy
Division manager Birgitta Sundblad

- Biorefinery and Energy
- Biobased Materials
- Papermaking and Packaging
- Energy Technology Center (ETC)
- Paper and Fibre Research Institute (PFI)
- Processum
From a fossil-based economy... 

Our vision of the future

...to a bio-based
Current forest industry

- Pulp wood
- Forestry residues
- Round wood

CO2 uptake

- Solid wood products
- Paper, tissue packaging
- Products from residuals
- Heat & electricity
- Solid fuel

Saw milling

Residues

Pulping

Pulp fibres

Paper making
Forest based value chains

- Sawmill value chains
- The modern pulp mill value chains
- Cellulose value chains
- Lignin value chains
- Thermal value chains
- Sugar value chains
Global trends enhance the demand for sustainable pulp fibres

Textiles, non-wovens +4.4%/y (dissolving)

Hygiene +3.6%/y (fluff)

Tissue +2.9%/y

Cartonboard +2.1%/y

Paper -3%/y

To 2025...

Source: Pöyry Consulting Group, Hawkins Wright, Smithers Pira
Industrial infrastructure with many opportunities

- Certified and sustainable forestry
- Highly efficient logistics system
- Large and energy efficient infrastructure
- Possibilities to repurpose industrial infrastructure
  - Pulp mills - wood and plant polymers
  - Paper mills - planar products, paper for energy storage, solar cells, textiles etc.
- Future biobased economy
\[ 6 \text{ CO}_2 + 6\text{ H}_2\text{O} \rightarrow 3\text{ H}_2\text{O}_6 + 6\text{ O}_2 \]

Carbon dioxide + Water $\rightarrow$ Carbohydrates + Oxygen

1.5 kg + 0.6 kg $\rightarrow$ 1.0 kg + 1.1 kg
CO₂ production during drought

The weather is becoming drier in the Amazon. This slows the growth of plants and causes die-off, so that less CO₂ is stored while more is released.

0.9-1.8 Gton

35 Gton

CO₂ emissions by the Amazon in dry conditions (5-10 x the annual emissions of the Netherlands)

Annual global emissions of CO₂ from the burning of oil, gas and coal
Modern kraft kraft pulp mill

Pulp wood

1.4 million Tonnes/y

Kraft pulping

Cellulose pulp fibres

0.6 million Tonnes/y

Paper
Tissue
Packaging

Chemicals
& energy
recovery

Electricity
0.4 TWh/y

Forestry
residues

0.14 million Tonnes/y

Tall oil
0.25 TWh/y

1.4 million Tonnes/y

0.6 million Tonnes/y
Pulp mill based biorefinery

Round wood → Saw milling → Residues → Pulp mill biorefinery

Wood → Forestry residues → Agricultural feedstock → Pulp mill biorefinery

- Pulp fibres
  - Celluloses
  - Lignin
  - Upgraded residues
  - Residual streams

- Solid wood products
- Market pulp
- Paper, tissue & packaging
- Heat & electricity
- Cellulose, textile & composites
- Carbon fibres, transport fuels, materials & chemicals
- Solid fuel, transport fuels & chemicals
- Biogas, food & soil improvement
Cellulose value chains

Pulp wood → Kraft pulping → Cellulose pulp fibres → Celluloses

- Paper
- Tissue
- Packaging

- Textile materials
- Composites
- Fibrillar cellulose
- Barriers
- Heat & electricity

Forestry residues → Pulp mill biorefinery → Chemicals & energy recovery
Cellulose filaments
Forest cellulose based textile fibres produced in pulp mills

Production of adapted pulp
Dissolution
Fibre spinning
Fibrillar cellulose (CNC, CNF) - Potential applications

- **Paper and board**
  - Strength
  - Bulk
  - Coating
  - Barriers

- **New materials**
  - Nanopapers
  - Composites
  - Films
  - Foams

- **Other applications**
  - Food
  - Cosmetics
  - Paint
  - Life science
Mobile NFC demo plant

Production of NFC in mill trials for testing on paper and board machines.

Two containers

Developed in cooperation with BillerudKorsnäs

Financing from Vinnova
CNC pilot Testbed

- TinyBTalented – testbed for CNC applications of crystalline

Industrial partners

Holmen
Melodea
Organofuel
S2Medical
SEKAB
Tetra Pak.
Lignin value chains

Pulp wood -> Kraft pulping -> Cellulose pulp fibres

Pulp mill biorefinery -> Chemicals & energy recovery

Chemicals & energy recovery -> Lignin processing

Lignin processing -> Paper, Tissue, Packaging

Lignin processing -> Heat & electricity

Lignin processing -> Diesel, gasoline, Aviation fuel, Carbon fibre, Chemicals, Advanced materials
Lignin is a new kraft pulp mill product

Typical composition, %

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition</th>
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<tbody>
<tr>
<td>C</td>
<td>64 - 66</td>
</tr>
<tr>
<td>Na</td>
<td>0.05 - 0.4</td>
</tr>
<tr>
<td>Ash</td>
<td>0.3 - 1</td>
</tr>
<tr>
<td>S</td>
<td>1 - 3</td>
</tr>
<tr>
<td>N</td>
<td>0.1</td>
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Commercial LignoBoost installations

Domtar, Plymouth, USA
Start: 2013

- Pulp capacity: 466 000 t/y
- Lignin capacity: 25 000 t/y (54 kg/ADt)

Stora Enso, Sunila, Finland
Start: 2015

- Pulp capacity: 370 000 t/y
- Lignin capacity: 50 000 t/y (135 kg/ADt, 22%)
The first commercial LignoForce System™

West Fraser, Hinton, Canada
Start: 2016

Pulp capacity: 350 000 t/y
Lignin capacity: 10 000 t/y (28 kg/ADt)
Carbonised lignin based carbon fibres

Carbon content 90-97%
Demonstrators for softwood lignin based carbon fibre

- Toy car roof
  - lignin-based carbon fibre epoxy composite
  - lignin-based rechargeable battery
  - Partners: Innventia, Swerea, Blatraden and KTH

Epoxy carbon fibre laminate on balsa wood
Thermally induced lignin foaming
Volume expansion for SW lignin
Water soluble modified kraft lignin

Kraft lignin → Modified lignin → Fully water soluble lignin
Lignin of tomorrow

Utilising a greater part of wood and producing marketable products other than pulp has become a focus recently for the pulp and paper industry. Lignin is one of the non-traditional products produced today from wood biomass on a commercially-viable scale.

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There are many potential markets for lignin. Refined lignin can be used for replacement of phenols that are used in resins for adhesives in, for example, plywood and veneer applications. Stora Enso’s Sunila Mill in Finland is the world’s first integrated lignin extraction plant to produce dry kraft lignin and...
Lignin as phenol replacement offers us big potential with attractive margins

Example from cellulose modification and pulp process by-products cluster

Total market for phenols:
9.4 Mt

- Phenolic Resins: 2.8 Mt
- Other: 6.6 Mt

Potential Market Value for Lignin: ~1.7 B EUR
4% CAGR
Stora Enso lignin production 40Kt

Key value proposition:
- Environmental
- Reduction of hazardous material
- Cost stability

Source: ADL (Arthur D’Little), IHB, Mckinsey, Stora Enso Experts
1. Lignin from black liquor

2. Lignin converted to biooil

3. Biooil co-processed with crude oil in Preem`s oil refinery in Lysekil
Thermal value chains

- Forestry, agricultural & other residues
  - Renewable electricity
    - Pre-treatment
      - Thermal processing
        - Gasification
        - Pyrolysis
        - Liquefaction
        - Torrefaction
      - Upgrading
        - Diesel & gasoline
        - Aviation fuel
        - Biooil & chemicals
        - Carbonized materials
  - Combustion
    - Heat & electricity
    - Hydrogen & oxygen

- Forestry, agricultural & other residues
Sugar value chains

Pretreatment
- Mechanical
- Thermal
- Chemical

Lignin processing

Fractionation Separation

C5/C6 sugar processing
- Enzymatic
- Chemical
- Catalytic

Lignin products
- Chemicals & polymers
- Gasoline & diesel
- Aviation fuel
- Protein

Forestry, agricultural & other residues
Conclusions

- Pulp mills are well positioned to be nodes for new value chains
- Countries with large forest assets and pulp mills will benefit
- Several biorefining processes under development
- Momentum for a forest-based economy
- Value added products
THANK YOU!

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