THE FUTURE FOREST BASED BIOREFINERY

Peter Axegård
Vice president Bioeconomy Strategy
peter.axegard@ri.se

Research Institutes of Sweden
RISE BIOECONOMY
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 % industry)
- 2 200 employees, 30 % PhD
- 2 800 incl Swerea
- Over 100 test and demonstration facilities, open for industry, SMEs, universities and institutes
RISE Research Institutes of Sweden

Divisions

- Bioeconomy
- Built Environment
- ICT
- Bioscience and Materials
- Safety and Transport
- Certification

Business and Innovation areas

- Sustainable Cities and Communities
- Mobility
- Life Science
- Digitalization
- Energy and Biobased Economy
From a fossil-based economy...

...to a bio-based

Our vision of the future
The forest sector in Sweden

<table>
<thead>
<tr>
<th>Product</th>
<th>Unit</th>
<th>Value</th>
<th>Export Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulp and paper</td>
<td>million t/y</td>
<td>14.4 (export 13.0)</td>
<td></td>
</tr>
<tr>
<td>Solid wood products</td>
<td>million m3/y</td>
<td>17.5 (export 12.3)</td>
<td></td>
</tr>
<tr>
<td>Gross export value</td>
<td>billion/y</td>
<td>€ 13</td>
<td></td>
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</table>
Current forest industry

CO2 uptake

Round wood → Saw milling → Residues → Pulp fibres → Paper making → Paper, tissue packaging

Pulp wood → Pulping → Residues

Forestry residues

Solid wood products

Products from residuals

Heat & electricity

Solid fuel
A circular forest industry

- CO2 from used products is taken up by the growing trees
- Mill operations are highly circular as regards water, energy and materials
- Used products are recycled into new products in several cycles
Modern kraft pulp mill

Pulp wood

1.4 million tonnes/y

Kraft pulping

Cellulose pulp fibres

0.6 million tonnes/y

Paper
Tissue
Packaging

Forestry residues

0.14 million tonnes/y

Chemicals & energy recovery

Electricity
0.4 TWh/y

Tall oil
0.25 TWh/y

1.4 million tonnes/y

0.6 million tonnes/y
The pulp mill biorefinery
Major wood components

- Cellulose 40 – 50 %
- Hemicellulose 20 – 30 %
- Lignin 20 – 30 %
- Extractives 1 - 5 %
Cellulose value chains

**Kraft pulping**

- Cellulose pulp fibres
  - Paper
  - Tissue
  - Packaging

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

**Pulp wood**

- Pulp mill biorefinery
- Chemicals & energy recovery

**Forestry residues**
Kraft cellulose products

- Kraft pulp fibres
- fibre PLA composite
- Transparent films
- NFC
- NCC

Textile fibres from regenerated cellulose
Forest cellulose based textile fibres produced in pulp mills

Production of adapted pulp

Dissolution

Fibre spinning
Cellulose filaments
Fibrillar cellulose (CNC, CNF) - Potential applications

Paper and board
- Strength
- Bulk
- Coating
- Barriers

New materials
- Composites
- Films
- Foams

Other applications
- Food
- Cosmetics
- Paint
- Life science
CNF Pilot plant in Stockholm (100 kg/day)
Mobile CNF demo plant

Production of NFC for testing in paper mills
CNC pilot in Örnsköldsvik

- Industrial partners
  Holmen
  Melodea
  Organofuel
  S2Medical
  SEKAB
  Tetra Pak
Lignin value chains

- Pulp wood
- Kraft pulping
- Cellulose pulp fibres
- Heat & electricity
- Paper, Tissue, Packaging
- Pulp mill biorefinery
- Chemicals & energy recovery
- Lignin processing
- Diesel, gasoline
- Aviation fuel
- Carbon fibre
- Chemicals
- Advanced materials

Forestry & agricultural residues
**Commercial LignoBoost installations**

Domtar, Plymouth, USA  
2013 -  
Pulp capacity: 466 000 t/y  
Lignin capacity: 25 000 t/y (54 kg/ADt)

Stora Enso, Sunila, Finland  
2015 -  
Pulp capacity: 370 000 t/y  
Lignin capacity: 50 000 t/y (135 kg/ADt)
The LignoBoost process

LignoBoost® process schematic provided by Valmet Inc.

Scale
- gram in laboratory
- kg in mobile pilot
- ton in demo plant
Lignin is a new kraft pulp mill product

Typical composition, %

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<td>64 - 66</td>
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<td>O</td>
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<tr>
<td>H</td>
<td>5 – 7</td>
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<td>0.3 - 1 (0.01% with extensive washing)</td>
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Carbonised lignin based carbon fibre
D **emonstrators for lignin based carbon fibre**

**To**y **car roof**
- lignin-based carbon fibre epoxi composite
- lignin-based rechargeable battery
- Partners; Innventia, Swerea, Blatraden and KTH

Epoxy carbon fibre laminate on balsa wood
Lignin can make pulp fibres and paper hydrofobic
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

LVL by Stora Enso

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

Source: ADL (Arthur D’Little), IHB, Mckinsey, Stora Enso Experts
How to use forestry residues, saw dust, energy wood, etc?

- **Heat**
- **Electric Power**
- **Pellets**
- **Biocoal**
- **Pyrolysis oil**
- **2G sugar for chemicals**

- Leaf Resources (Solvents)
- Remondis/BASF (Supercritical)
- Virdia/StoraEnso (Strong acid)
- SEKAB (Steam explosion)

Further conversion with catalysts/enzymes
- Virent/Coca Cola
- GF Biochemicals
- Avantium/BASF
- DuPont/ADM
- Global Bioenergies

Use as fuel oil or conversion in oil refineries
How to use forestry residues, saw dust, energy wood etc?

- Heat
- Electric Power
- Pellets
- Pyrolysis oil
- Biocoal
- 2G sugar for chemicals
- Methanol/DME
- Chemicals from syngas
- Hydrothermal liquefaction
  - Licella/Canfor
- Further conversion to chemicals & biodiesel
Pulp mill based biorefinery

Forestry residues

Round wood

Wood

Agricultural feedstock

Saw milling

Residues

Pulp mill biorefinery

Pulp fibres

Celluloses

Lignin

Upgraded residues

Mill residual streams

Solid wood products

Market pulp

Paper, tissue & packaging

Heat & electricity

Nanocellulose, textile, composites

Carbon fibre, transport fuel, chemicals

Solid fuel, transport fuels & chemicals

Biogas, food, soil improvement
The challenge
Biorefining - what feedstock and where?

Northern Pine and Spruce
2 tDS/ha/year

Brasilian Eucalyptus urograndis
20 tDS/ha/year

Vignis
“Energy sugar cane”
60 tDS/ha/year
Conclusions

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

Contact
Dr Peter Axegård
peter.axegard@ri.se

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RISE Bioeconomy
EXTRA SLIDES

Research Institutes of Sweden

Bioeconomy
Sugar value chains

Forestry, agricultural & other residues

Pretreatment
- Mechanical
- Thermal
- Chemical

Fractionation
Separation

C5/C6 sugar processing
- Enzymatic
- Chemical
- Catalytic

Lignin processing

Lignin products

Chemicals & polymers
Gasoline & diesel
Aviation fuel
Protein
Thermal value chains

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