Lignin Seminar Day 2024: ”You can make anything out of lignin – also money”

Chunlin Xu & Patrik C. Eklund

February 6th, 2024

Åbo Akademi University, Finland

Agenda

9:30 Registration & coffee & welcome

10:00-12:00, Chair: Patrik Eklund

- Introduction to LigninReSurf, Chunlin Xu and Patrik Eklund, Åbo Akademi University (ÅAU)
- Fractionation of lignin, Luyao Wang and Minette Kvikant, ÅAU
- Lignin-based latex and coatings, Luyao Wang, ÅAU
- Lignin copolymers, Rupali Rajendra Bhadane, ÅAU
- Lignin composites and 3D printing, Ellen Sundström and Oskar Backman, ÅAU
- Industrial perspective and Ecosystem - ExpandFibre, Katariina Kemppainen, Metsä Group and Gomez Millan Gerardo, Fortum, (online)

12:00 – 13:15 Lunch (on own cost at cafeteria 1st floor) and LigninResurf additional Steering Group meeting (room 602)

13:15-17:00, Chair: Chunlin Xu

- Circularity aspects of lignin research, Timo Leskinen, University of Helsinki
- AI-driven Experimental Materials Engineering, Milica Todorovic, University of Turku
- Introduction to CoaST at DTU and highlights of lignin research, Narayanan Rajagopalan, Technical University of Denmark, (online)

Coffee break (30 min)

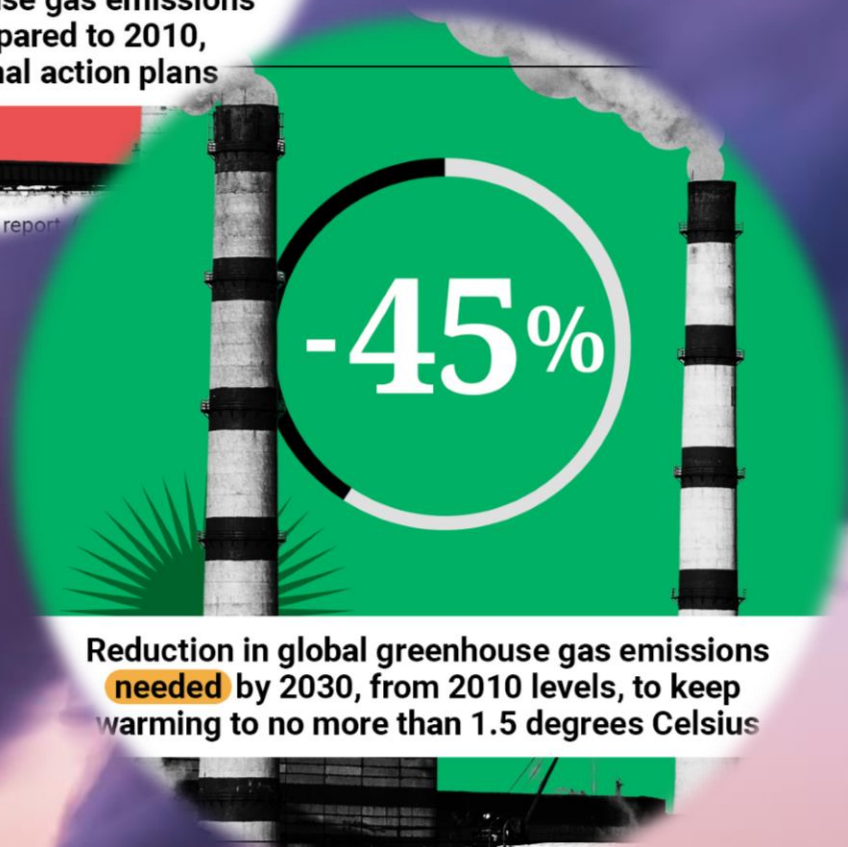
- Lignin analysis and chemistry at Austrian Biorefinery Infrastructure Center, Thomas Rosenau, BOKU Vienna
- Kraft lignin extraction and the recovery boiler – Implications for boiler operation today and future visions, Markus Engblom, ÅAU
- Lignin depolymerization (Depoly2ols), Henrik Grénman/Patrik Eklund, ÅAU
- Industrial perspective and Ecosystems: Shape, Markus Kass, Mirka

Lab tour

Challenges

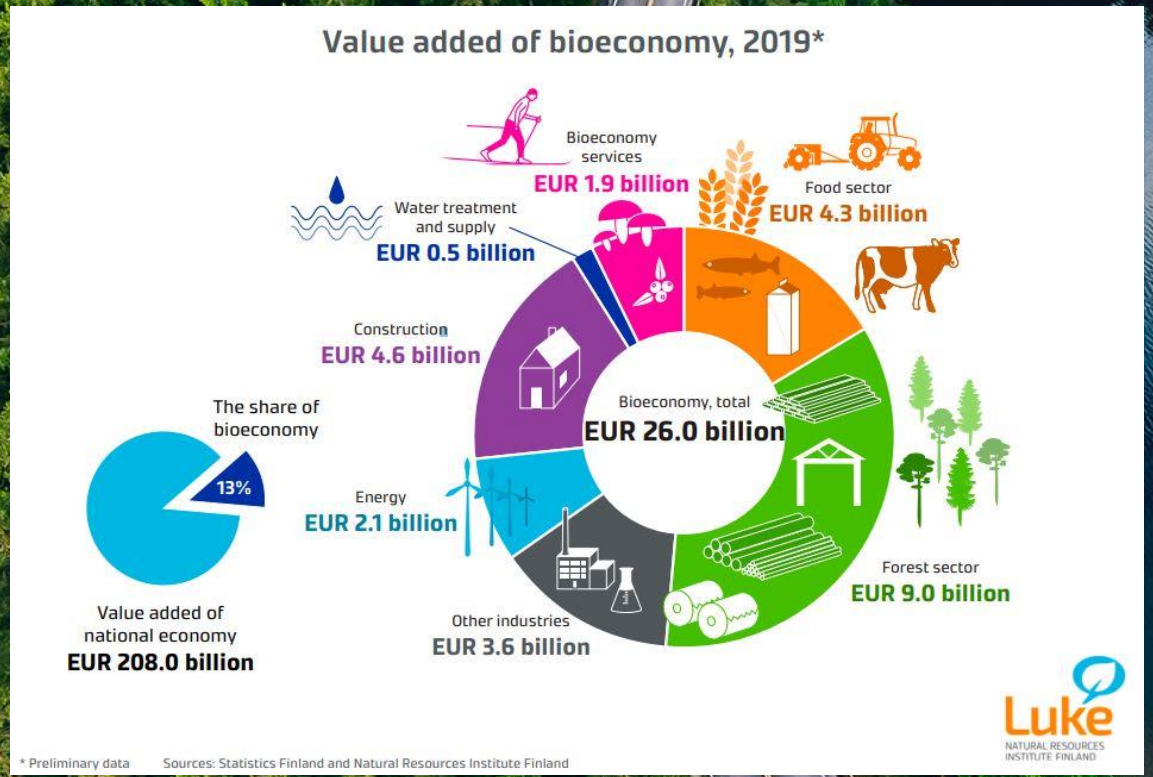
- Climate change
- Environmental issues
- Energy crisis
- Resource efficiency

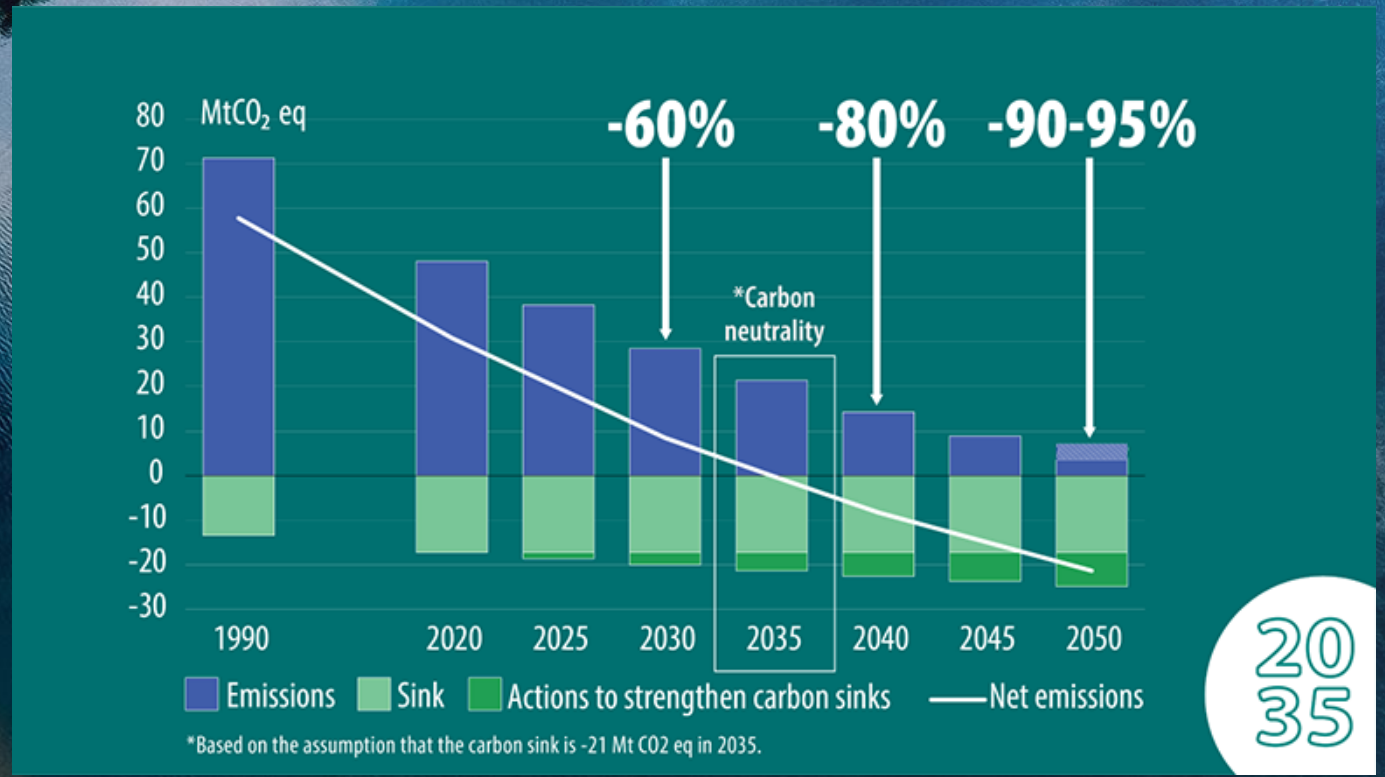
Urgent need in transition to a carbon-negative bioeconomy



Åbo Akademi

Finland targets for carbon neutrality in 2035





Forest reserves and wood species

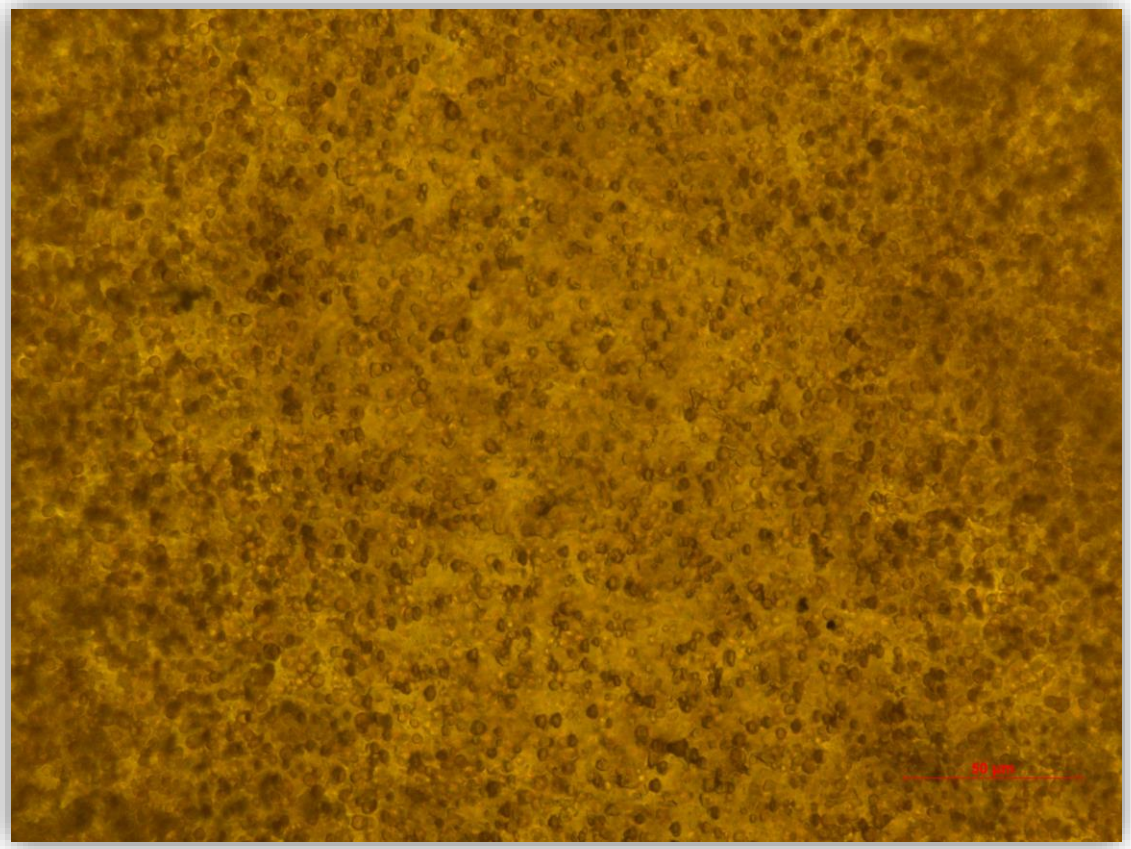
- Finland:
  - Growth larger than harvesting
  - Harvested after 40-75 years
- Globally:
  - Areas with a lack of forests
  - Southern pine, Eucalyptus, Acacia harvested even after 6-8 years (e.g. in South America)
- New species due to climate change
  - Commercially used species: ~100 in USA; ~20 in Europe; ~3 in Finland

Pine Spruce Birch
50% 30% 20%

Source: NFI12(2014-2016)/Luke

Fate of lignin

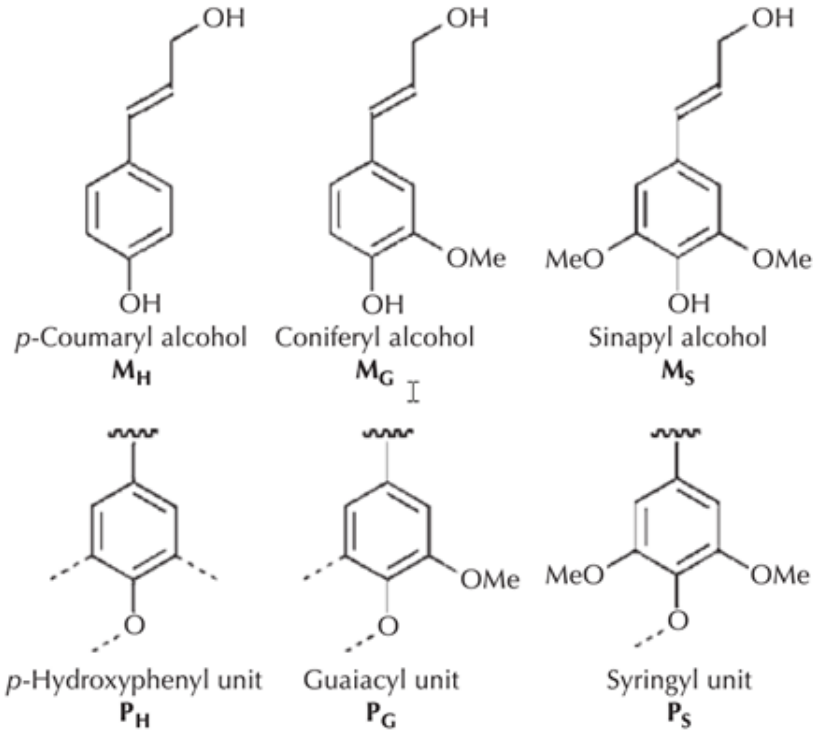
- The most abundant aromatic polymer in nature
- Total lignin production capacity: ~70 million tonnes, annual
  - Kraft lignin: 60 million tons
  - Lignosulfonates: 4 million tons



Lignin from wood

- Kraft lignin (Na_2S and NaOH)
- Lignosulfonates (sulfite process)
- Soda lignin (alkaline, NaOH)
- Organosolv lignin (EtOH, formic acid, etc)
- Hydrolysis lignin (a byproduct from cellulosic ethanol plants)

Lignin building blocks



Reference: Cereal straw as a resource for sustainable biomaterials and biofuels – Chemistry, extractives, lignin, hemicellulose and cellulose

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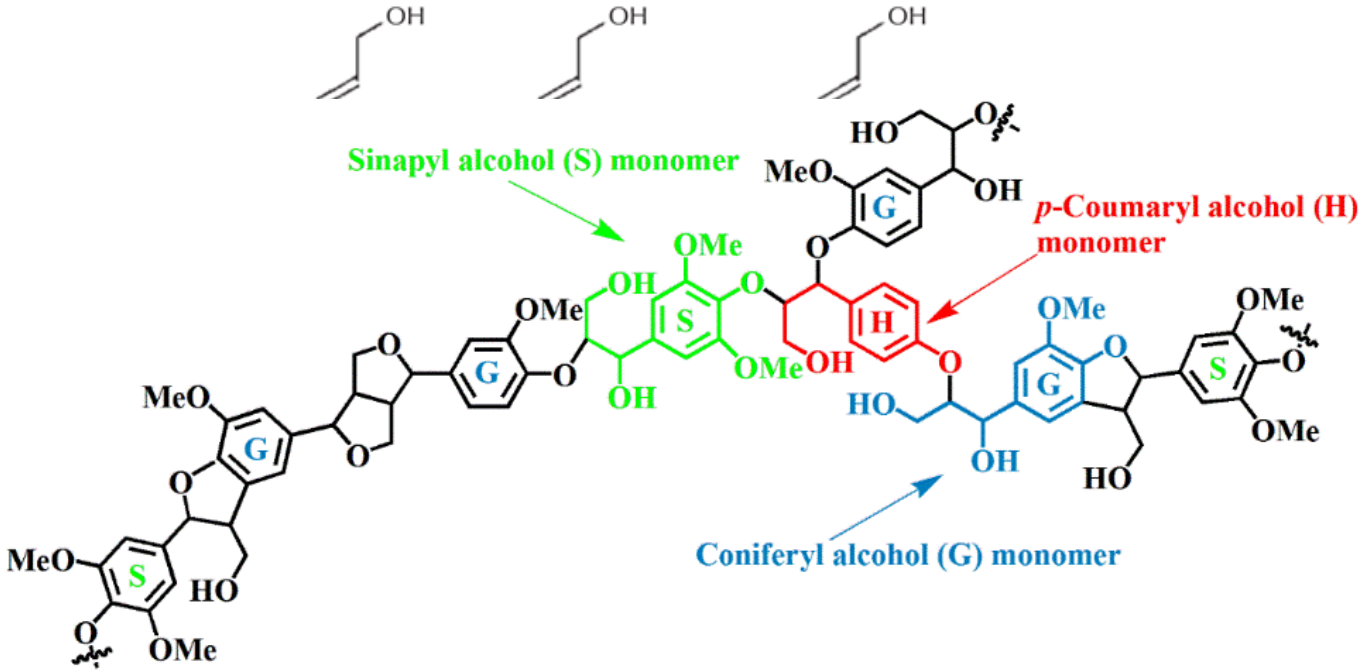


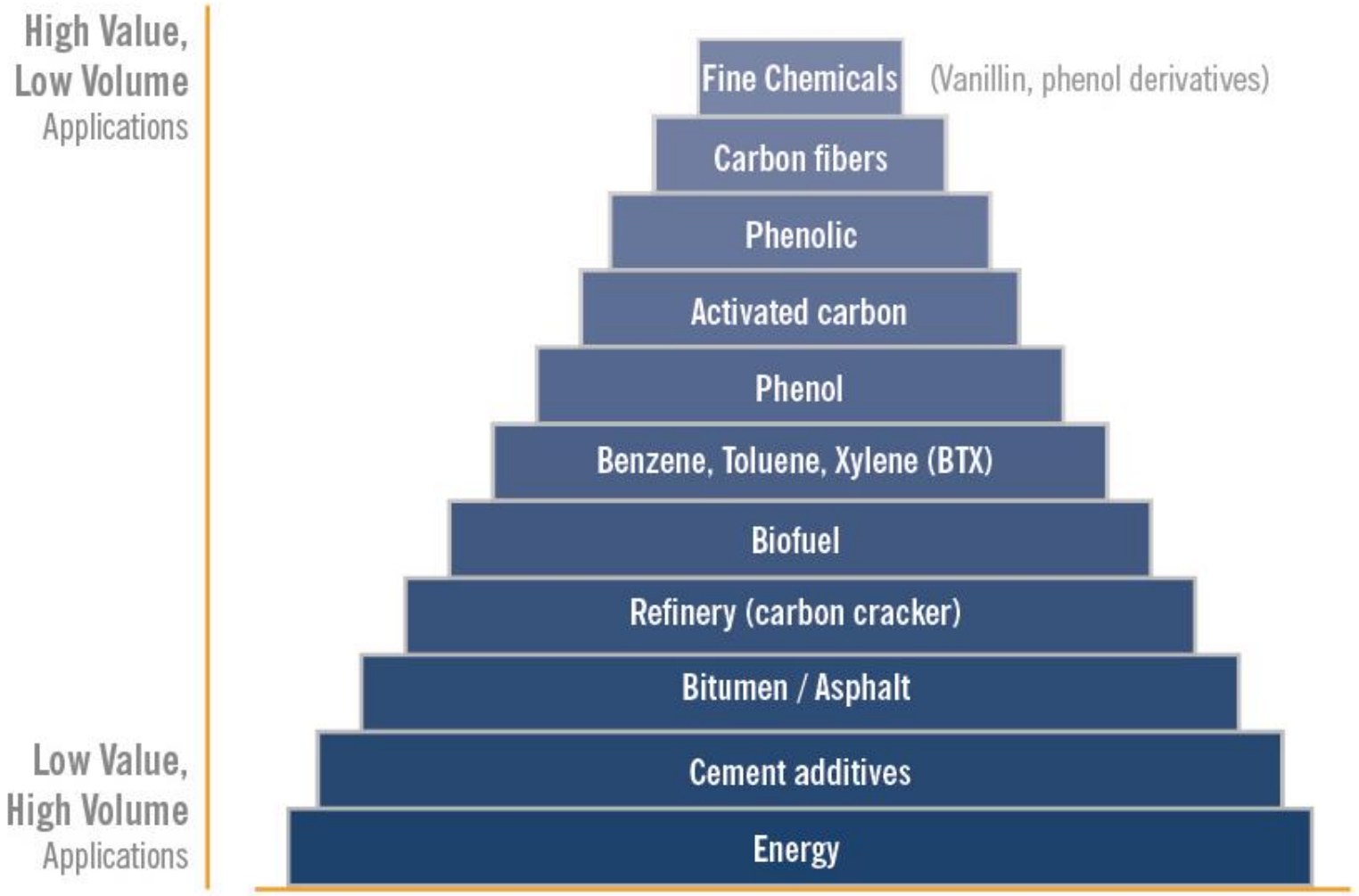
Reference: Cereal straw as a resource for sustainable biomaterials and biofuels – Chemistry, extractives, lignin, hemicellulose and cellulose

Challenges with lignin today

- Most of lignin is used to produce process steam and energy
- Only a very small amount is used for production of valuable and sustainable products
- Sulphur-free lignins are not yet commercialized due to lack of suitable extraction processes

➢Complexity in the structure and the composition of lignin restricts their applications

Lignin is the second most abundant biopolymer



Adapted from 'Lignin: Technology, Applications, and Markets/RISI'

Lignin producers

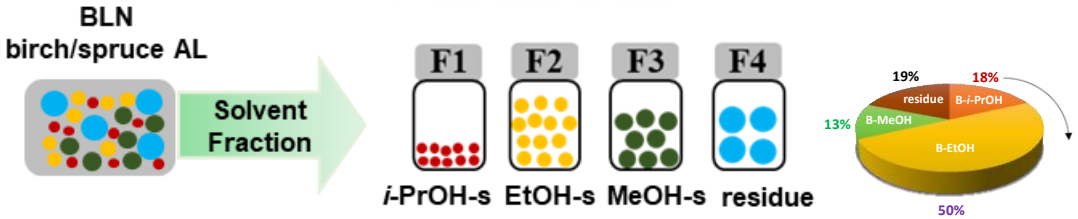
Result from LignoCost (2023), COST is supported by the EU Framework Programme Horizon 2020

Novel Fiber Surfaces Functionalized by Lignins Refined and Engineered from Finnish Biorefinery Processes-LigninReSurf 2021-2023, Business Finland Co-Research

Åbo Akademi University

BUSINESS FINLAND

- Fractionate lignin to a set of products with consistent specifications
- Chemical integration to functional materials: Investigate lignin structure-property-performance correlations
- **Goal:** to develop high-performance lignin-based copolymers and materials:
  - New **aqueous dispersion coating** formulations,
  - New **thermoplastic materials**, and
  - Novel **bio-based porous membranes**



Metsä EXPANDFIBRE fortum

LIGNIN
to complete the full bio-based value-chain

CH BIOFORCE · BOKU · Åbo Akademi University · iemi Institut Européen des Membranes · 3DTECH

st1 · METGEN · kemira Where water meets chemistry™ · MIRKA

Renewable and Sustainable sources - Chemistry and Technology Innovation - New Bioproducts

Specific topics for RTO and academy-led projects without parallel company projects

			
Textiles, Biocomposites, Packaging and Other fibre products	**Lignin products**	**Hemicellulose products**	**Sourcing & fractionation of straw**
• Advances in fibre-based material modeling • Digital tools for re-designing fibre properties • Understanding molecular level interactions between pulp fibres, water and novel chemistry • Development of solvent insensitive carbohydrate analysis methods • Flow rheology of cellulose-containing solutions and dispersions	• Lignin based carbon-materials for e.g. energy storage • Understanding of lignin chemical structure versus material properties via analytical tools • Potential technologies to influence lignin color	• Protein and prebiotics for feed and food • Specialty sugar (bio)chemistry for e.g. food, feed, pharma, or biosurfactants • Sustainable food production, end-of-life and recycling of nutrients • Utilization for fertilizers	• Products from biorefinery side streams e.g. extractives, cellulosic fines, salts, silica

EXPANDFIBRE fortum Metsä

LigninReSurf team at ÅAU


Prof. Chunlin Xu


Prof. Patrik Eklund


Prof. Thomas Rosenau


Dr. Xiaoju Wang


Dr. Luyao Wang


Dr. Lucas Lagerquist

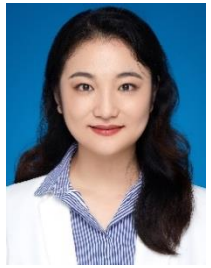

MSc. Liqiu Hu


M. Pharm.
Rupali Bhadane


MSc. Minette Kvikant


MSc. Ellen Sundström


Oskar Backman


MSc. Lulu Zhu


MSc. Tim Salomäki


Ann-Louise Hakalax


MSc. Banchamlak
Bemerw Kassaun

Industrial partners and collaborators

Åbo Akademi University

CH BIOFORCE

Lari Vähäsalo

kemira Where water meets chemistry™

Anna-Stiina Jääskeläinen
Tiina Liitiä

METGEN

Petri Ihalainen
Liji Sobhana Seleenmary Sobhanadhas

BOKU

Thomas Rosenau

st1

Timo Leskinen
Anu Kinnunen

MIRKA

Markus Kass

3DTECH

Tomi Kalpio

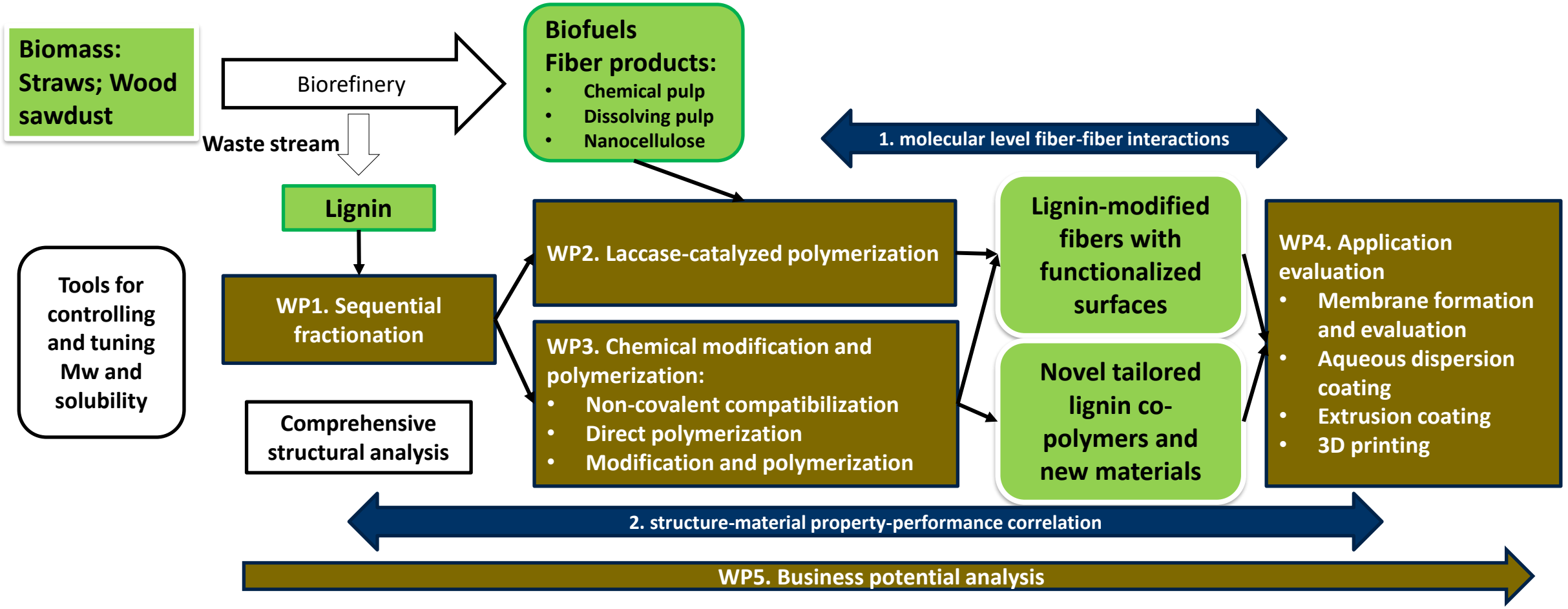
iem Institut Européen des Membranes

Denis Bouyer

Metsä EXPANDFIBRE fortum

Heli Virki, Hanne Wikberg, Olesya Fearon

Existing and new value chains



General update

- Project webpage: news and outcomes
- LigninReSurf public report will be published in the spring 2024

Webpage of LigninReSurf

Consortium workshop,
17.05.2023, Hosted by Kemira

Åbo Akademi

BUSINESS FINLAND

LigninRESurf

Project report 2021–2023

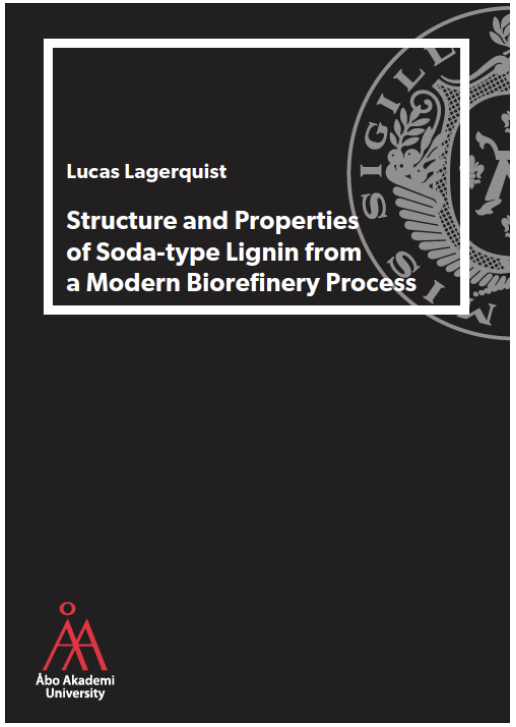
"Kumppanuusmalli – Novel Fiber Surfaces Functionalized by Lignins Refined and Engineered from Finnish Biorefinery Processes (LigninReSurf)" (43674/31/2020)

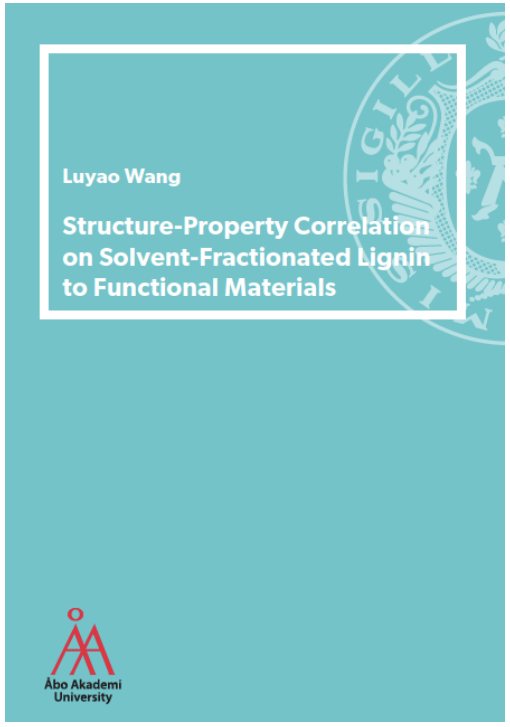
Research outcomes

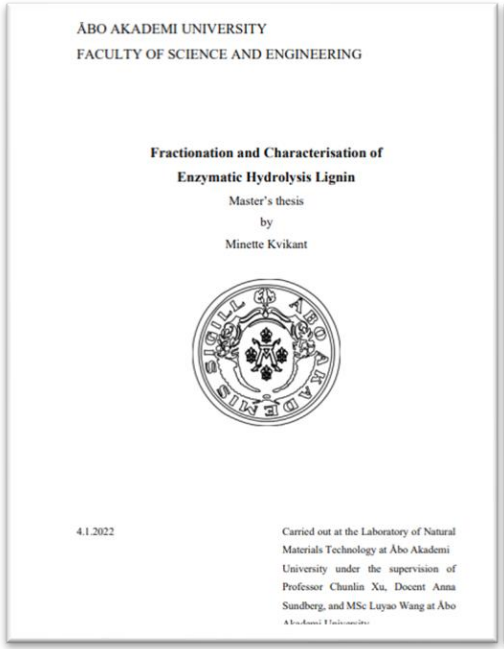
- Research publications: **4** published +**2** submitted + **6** under drafting
- Oral presentations at conferences & seminars (**9**)
- Poster presentations at conferences & seminars (**3**)

Research outcomes, cont.

- Doctoral thesis (2)
- Master thesis (3 + 1)





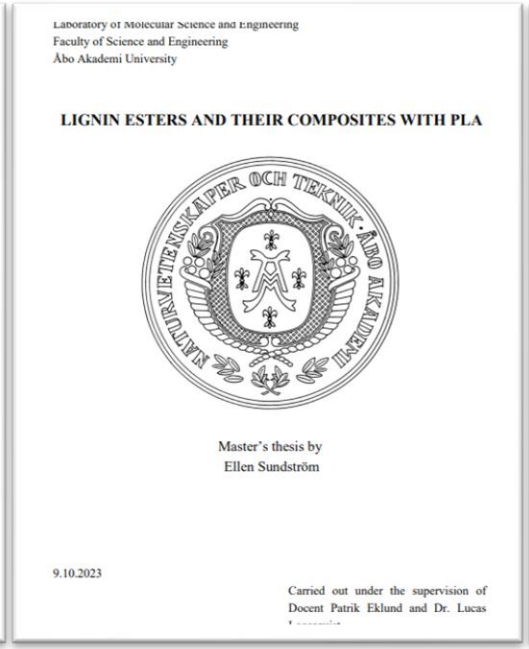

ÅBO AKADEMI UNIVERSITY
FACULTY OF SCIENCE AND ENGINEERING

Fractionation and Characterisation of Enzymatic Hydrolysis Lignin

Master's thesis
by
Minette Kvikant

4.1.2022

Carried out at the Laboratory of Natural Materials Technology at Åbo Akademi University under the supervision of Professor Chunlin Xu, Docent Anna Sundberg, and MSc Luyao Wang at Åbo

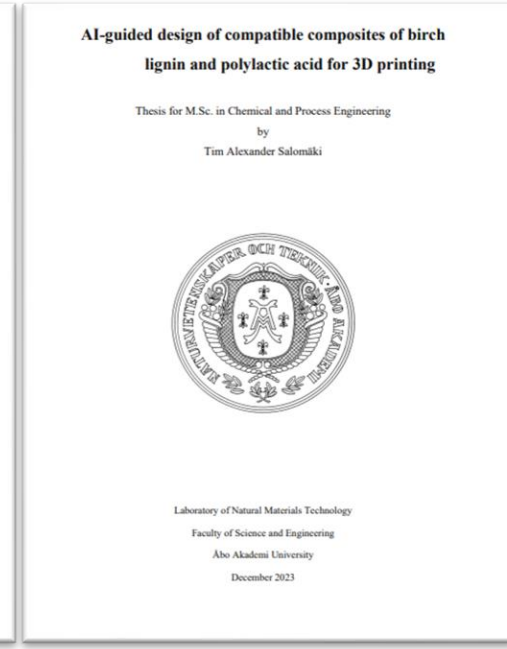

Laboratory of Molecular Science and Engineering
Faculty of Science and Engineering
Åbo Akademi University

LIGNIN ESTERS AND THEIR COMPOSITES WITH PLA

Master's thesis by
Ellen Sundström

9.10.2023

Carried out under the supervision of Docent Patrik Eklund and Dr. Lucas


AI-guided design of compatible composites of birch lignin and polylactic acid for 3D printing

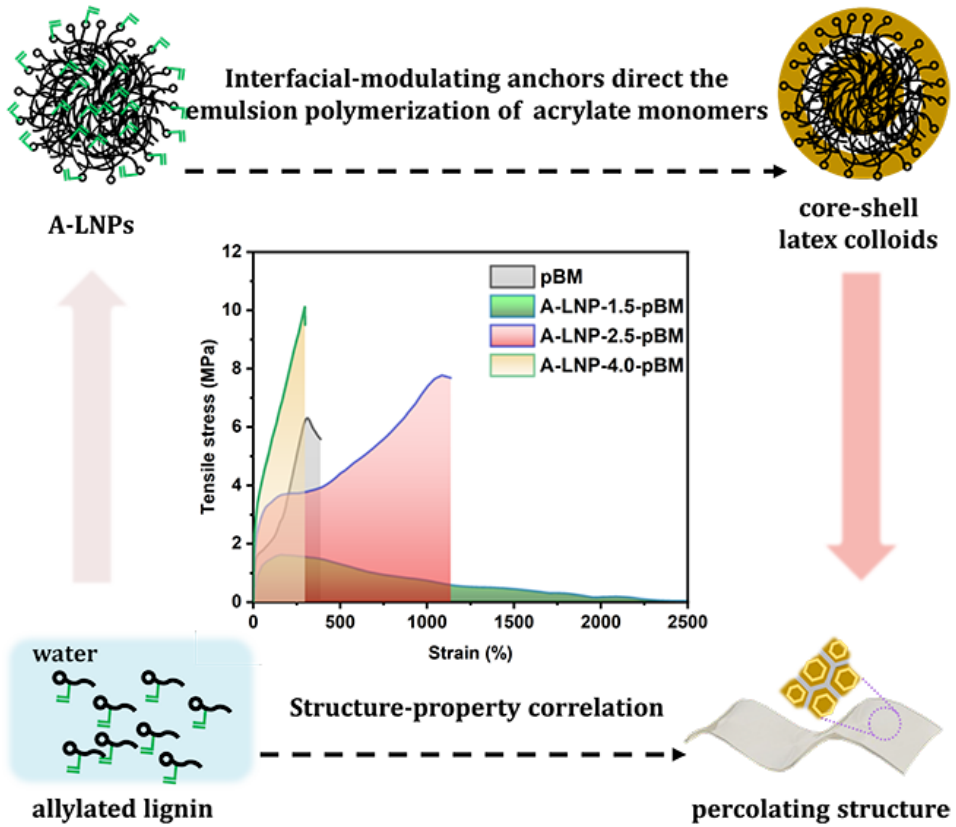
Thesis for M.Sc. in Chemical and Process Engineering
by
Tim Alexander Salomäki

Laboratory of Natural Materials Technology
Faculty of Science and Engineering
Åbo Akademi University
December 2023

Research outcomes, cont.

Invention disclosure & patent application

- Luyao Wang, Xiaoju Wang, Patrik Eklund, Rajesh Koppolu, Martti Toivakka, Chunlin Xu. **Method for preparation of lignin-based latex for binding and coating applications.** Finnish Patent and Registration Office. Patent application number 20225569.



Know more about the publication!

EWLP 2024
17th European Workshop on Lignocellulosics and Pulp
26-30 AUGUST 2024
Åbo Akademi University, Finland

https://ewlp2024.fi/