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Accelerating circular bio-based solutions
integration in European rural areas

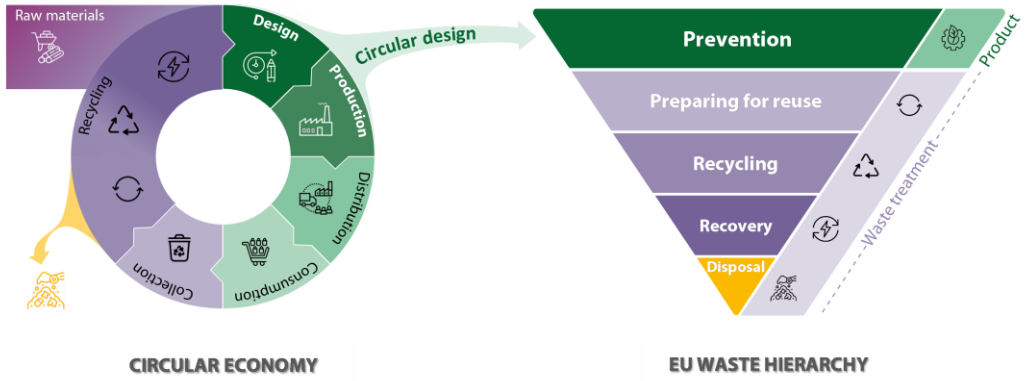
Structure and technological properties of biomass side streams: forestry & wood processing

Primož Oven
Ida Poljanšek, Viljem Vek

Univerza v Ljubljani
Biotehniška fakulteta

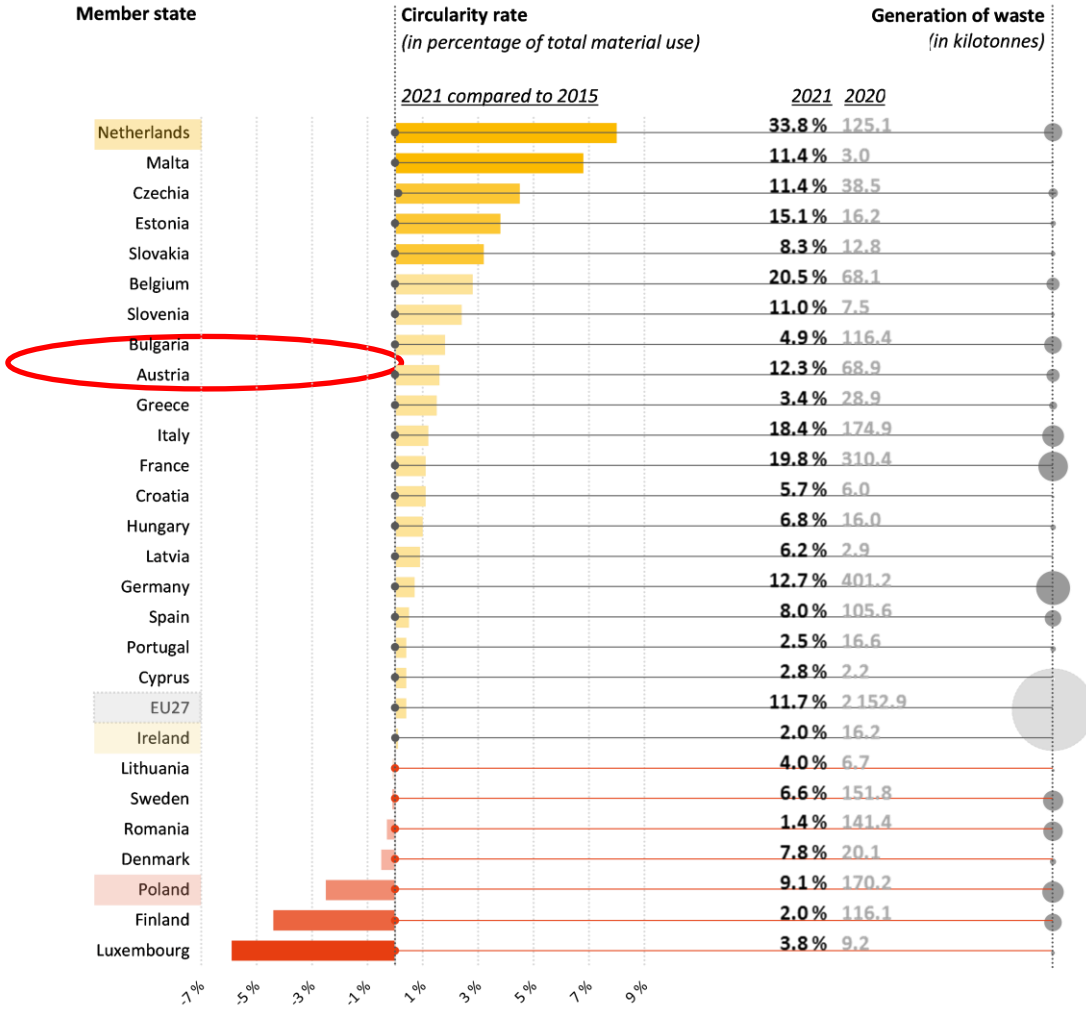
Circular bioeconomy

Krožno biogospodarstvo



Member states' progress towards circular economy 2015-2021

https://www.eca.europa.eu/en/publications/sr-2023-17



Sorces:
https://www.eca.europa.eu/en/publications/sr-2023-17
(Hetemäki et al 2017) https://www.semanticscholar.org/paper/Leading-the-way-to-a-European-circular-bioeconomy-Hetem%C3%A4ki-Hanewinkel/b35f31e1a085a06380fcae3e196fa14ea071eeb0

Content

- Biomass from forestry and wood industry
- Structure of woody biomass
  - Macrostructure
  - Anatomy
- Chemistry of woody biomass
  - Structural compounds
  - Nonstructural compounds
- Biorefining of woody biomass
- Production and use of extractives
- Nanocellulose production and application
- Conclusion

xx min

Biomass from forestry and wood industry

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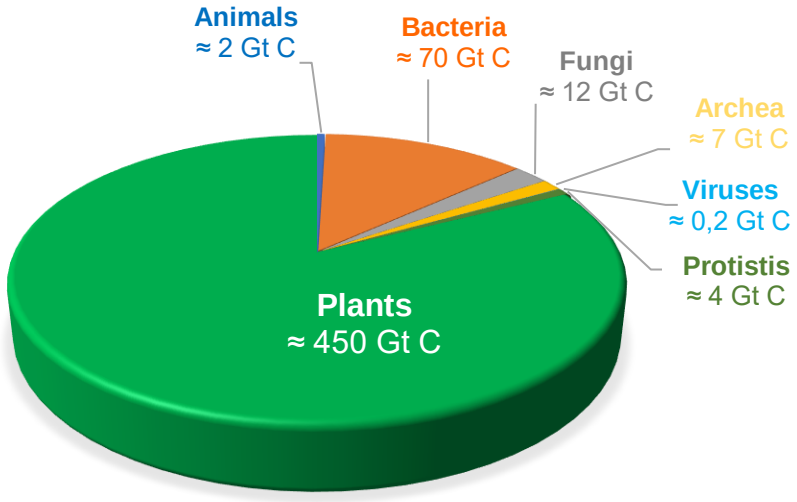
Origin of biomass

The overall biomass composition of the biosphere ≈550 Gt C



(Bar-On et al. 2018)
https://doi.org/10.1073/pnas.1711842115

Primary biomass

- Lignocellulosic wood/ forestry
- Lignocellulosic form croplands and grassland
- Oil crops
- Starch crops
- Sugar crops
- Aquatic biomass

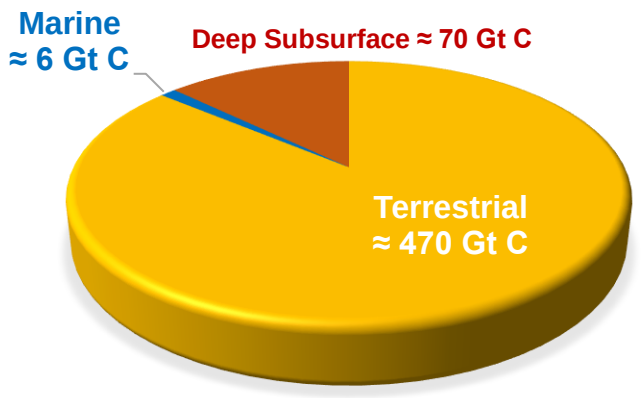
Secondary biomass

- Residues form forestry and forest-based industries
- Residues form agriculture
- Residues from landscape management
- Microbial biomass
- Other, municipal waste…

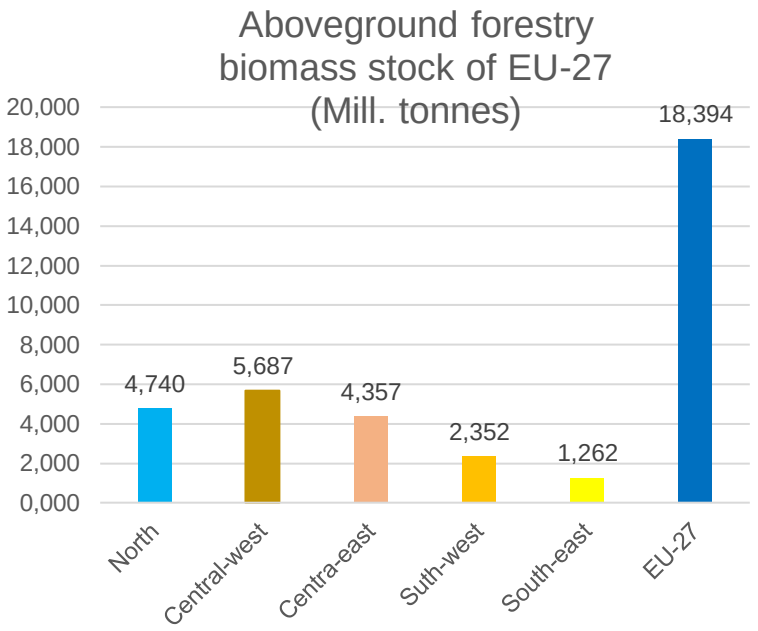
Source: EU Biorefinery Outlook to 2023
https://op.europa.eu/en/publication-detail/-/publication/7223cd2e-bf5b-11eb-a925-01aa75ed71a1

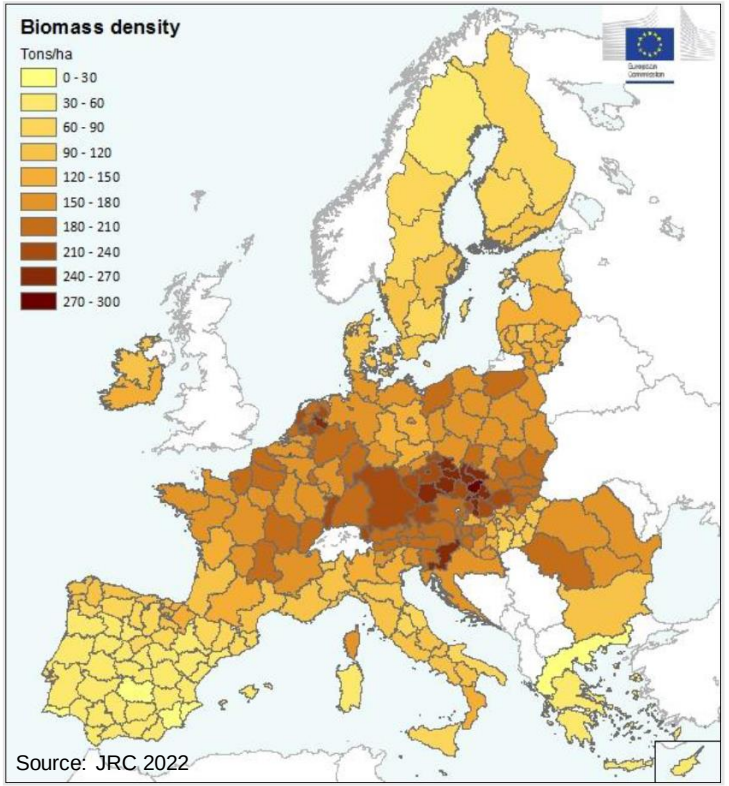
Forestry biomass

Biomass in different environments



(Bar-On et al. 2018)
https://doi.org/10.1073/pnas.1711842115

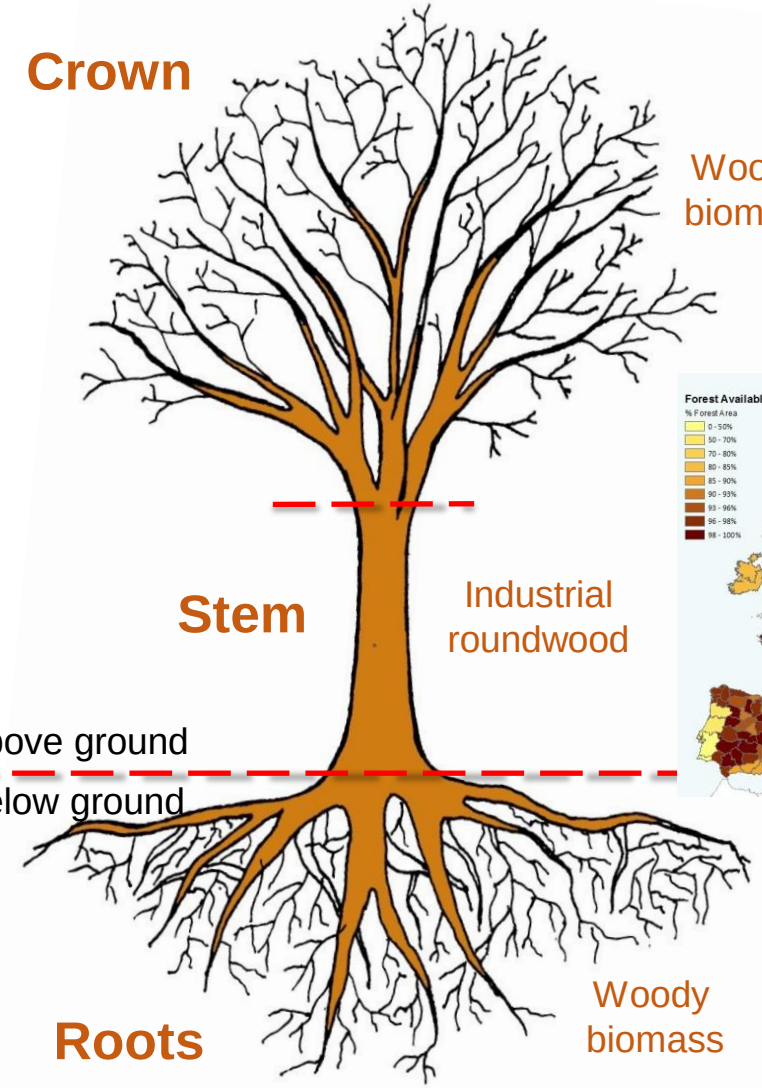




The total living aboveground biomass stock of the EU forests estimated for the year 2020 is equal to 18.4 billion tonnes of dry matter.

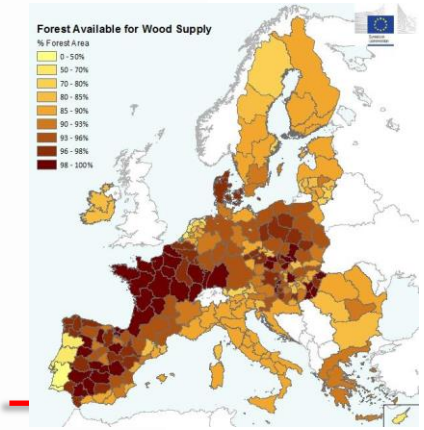
https://publications.jrc.ec.europa.eu/repository/handle/JRC106502

Biomass from forestry and wood industry



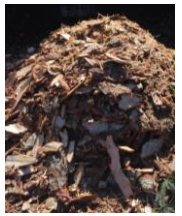
Forests, plantations,…

Wood processing

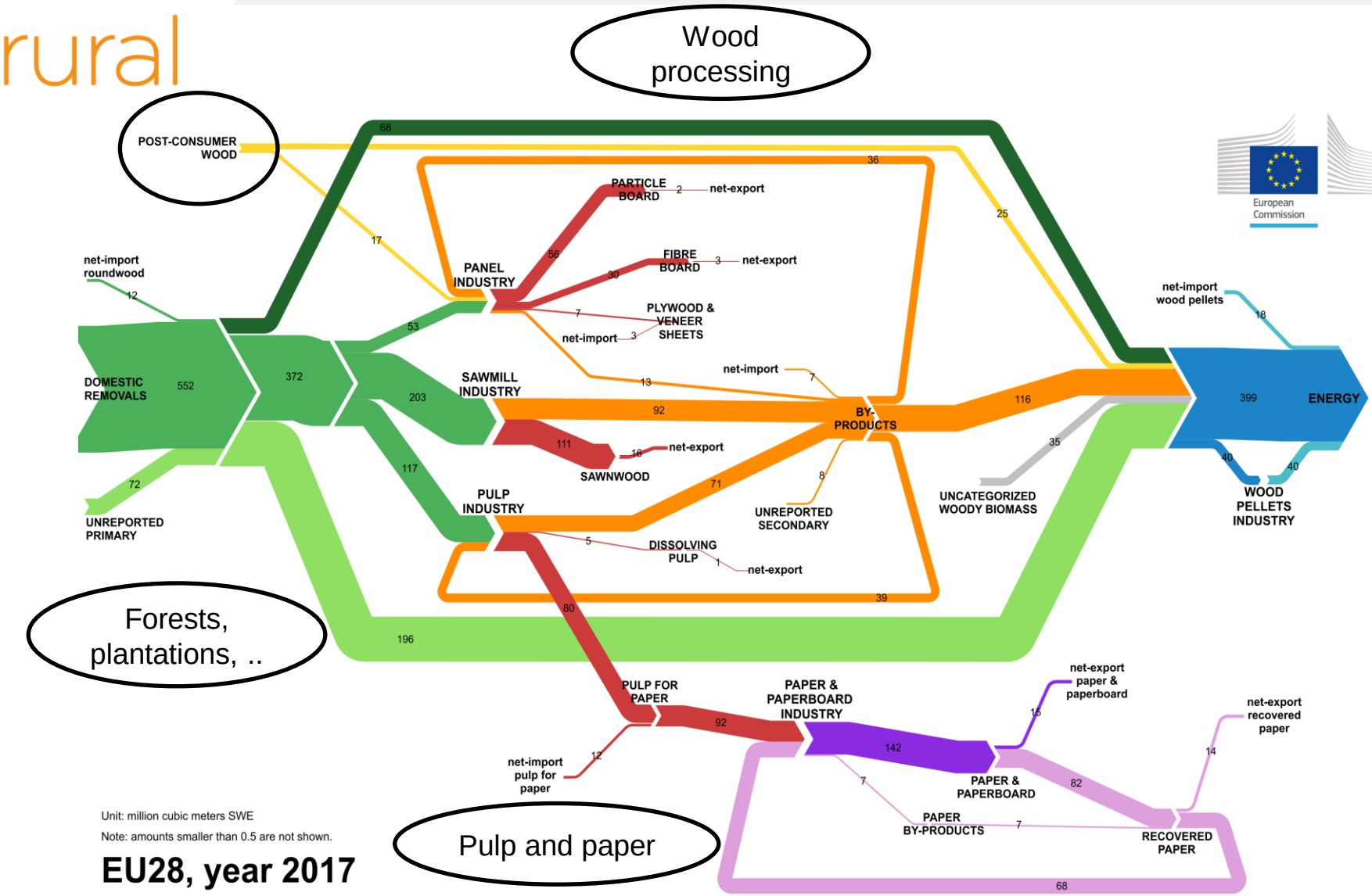


Softwoods (Gymnospermae)

Hardwoods (Angiospermae)



Woody biomass flow – EU member states



https://knowledge4policy.ec.europa.eu/visualisation/interactive-sankey-diagrams-woody-biomass-flows-eu-member-states_en

Source: JRC 2022

xx min

Structure of woody biomass

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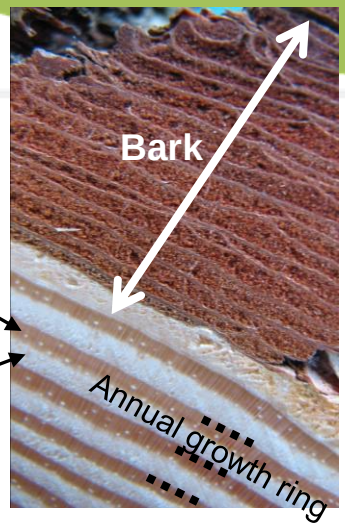
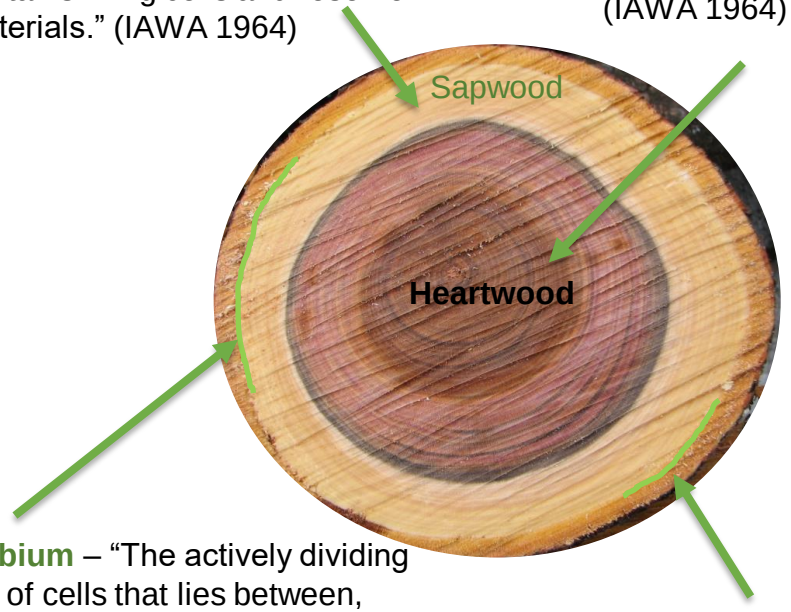
Macrostructure of woody biomass

Heartwood – "The inner layers of wood which, in the growing tree, have ceased to contain living cells and in which the reserve materials (e.g. starch) have been removed or converted into heartwood substances. It is generally darker in colour than sapwood, though not always clearly differentiated" (IAWA 1964)



Sapwood – "The portion of the wood that in the living tree contains living cells and reserve materials." (IAWA 1964)



Cambium – "The actively dividing layer of cells that lies between, and gives rise to, secondary xylem and phloem (vascular cambium)." (IAWA 1964)

Bark – "A nontechnical term used to cover all the tissues outside the xylem cylinder…" (IAWA 1964)

Spruce affected by bark beetles

Knots

Reaction wood

Discolored wood

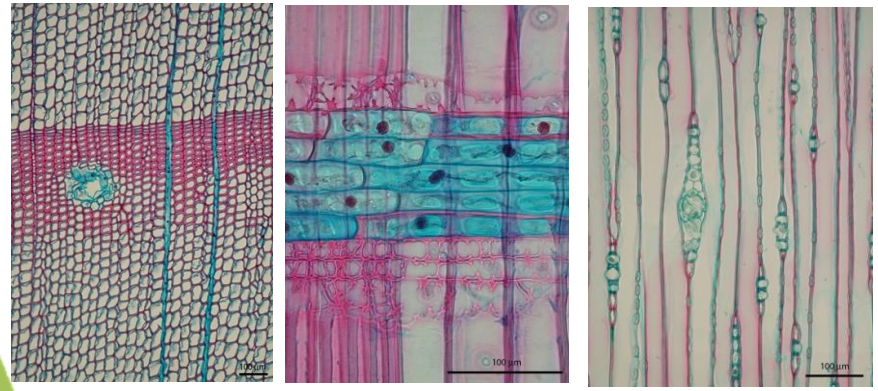
Abiotic and biotic damage

Multilingual Glossary of Terms Used in Wood Anatomy (1964)
http://www.jwrs.org/kenkyu/wa_wp/glossary/IAWA_glossary.pdf.

Anatomy of woody biomass

Softwoods

	Cells	Functions
Axial	Tracheids	Support, transport, protectio
	Parenchyma (rare)	Storage, defense
	Epithelial cells,resin canals	Synthesis, excretion, protection
Radial	Ray parenchyma	Storage, transport, protection
	Ray tracheids	Transport
	Epithelial cells,resin canals	Synthesis, excretion, protection

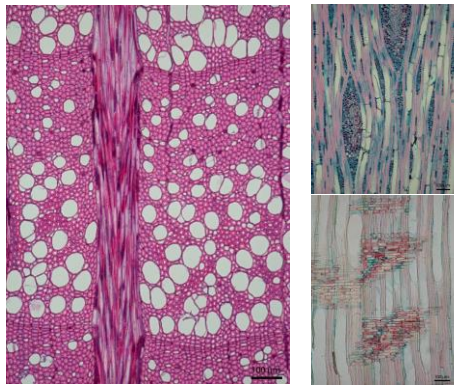


Scots pine (*Pinus sylvestris*)

Hardwoods

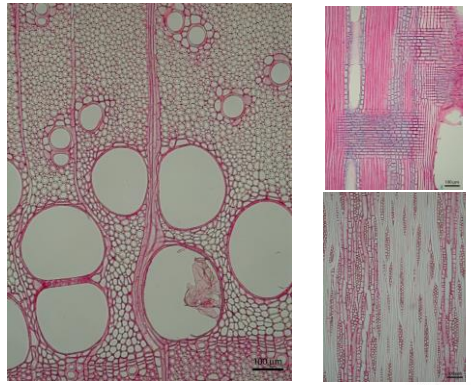
	Cells	Functions
Axial	Vessels (pores)	Transport of water, protection
	Different types of tracheids	Support, transport, protection
	Different types of fibers	Support, transport, protection
	Parenchyma	Storage, transport, defense
Radial	Ray parenchyma	Storage, transport, defense

Beech (*Fagus sylvatica*)



Diffuse-porous woods
(birches, willows, maples, …)

Ash (*Fraxinus excelsior*)



Ring-porous woods
(oaks, elms, sweet chestnut..)

xx min

Chemistry of woody biomass

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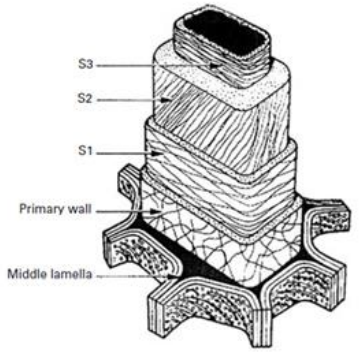
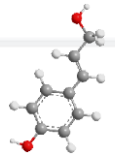
Chemistry of woody biomass

- Chemistry
  - Structural compounds
    - Cellulose
    - Hemicelluloses
    - Lignin
  - Nonstructural compounds
    - Organic- Extractives
    - Inorganic - Ash

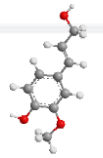


(Butterfield 2003)

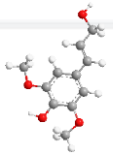
Lignin



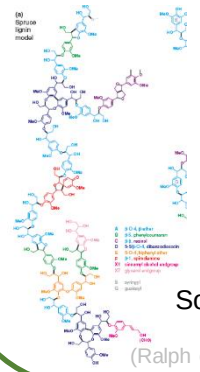
p-Coumaryl alcohol
H lignin



Coniferyl alcohol
G lignin

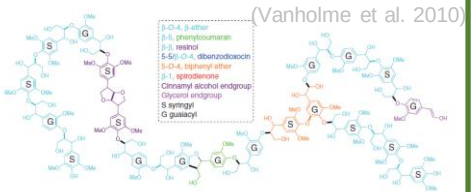


Sinapyl alchol
S lignin



(Ralph et al. 2007)

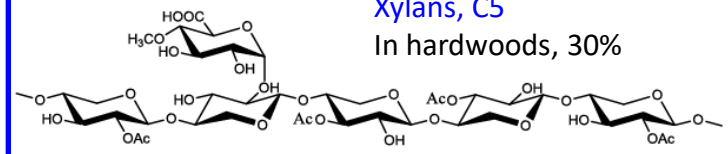
Softwoods, G lignin 30%



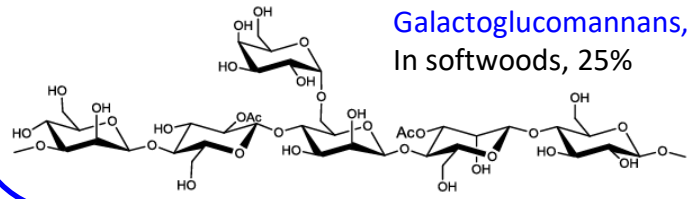
(Vanholme et al. 2010)

Hardwoods, GS lignin 25%

Hemicelluloses

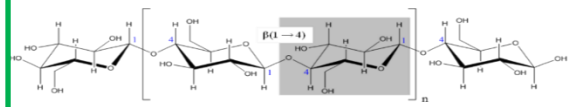


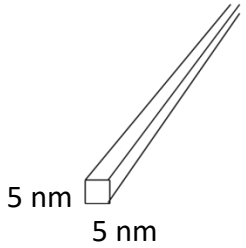
Xylans, C5
In hardwoods, 30%

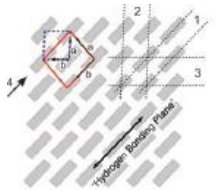


Galactoglucomannans, C6
In softwoods, 25%

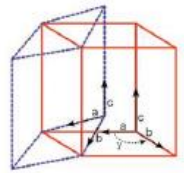
Cellulose, C6



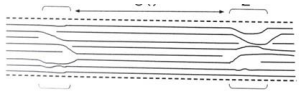




(Moon et al 2011)



I_α I_β

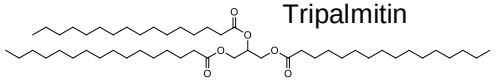


60 nm

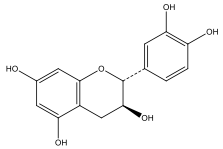
Extractives

Aliphatic and alicyclic compounds

- Terpenes and terpenoids (including steroids and resin acids)
- Esters of fatty acids (fats, waxes)
- Fatty acids
- Alkanes



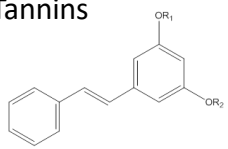
Tripalmitin



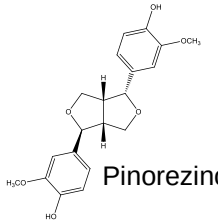
Flavan-3-ol
(+)-catehin

Phenolic comounds

- Simple phenols
- Stilbeni
- Lignans
- Flavonoids….
- Tannins



Pinosilvin: $R_1 = R_2 = H$
pinosilvin monometil eter : $R_1 = H$, $R_2 = CH_3$



Pinorezinol

Other

- Sugars
- Cyclitols
- Tropolones
- Alcaloids
- Kumarins
- Kinones…

(Alen 2011)

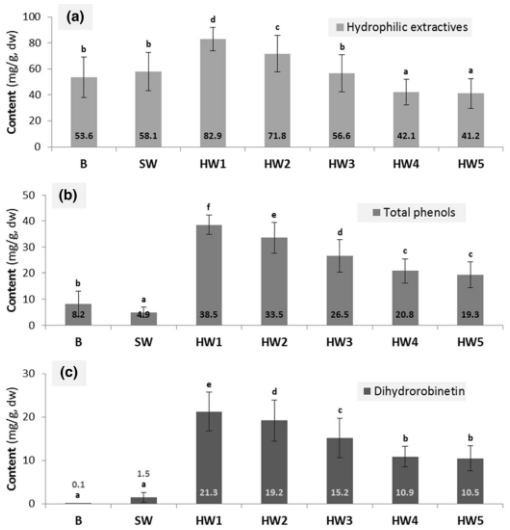
Location in wood	Compounds
Parenchyma	Strarch, fats, fatty acids, steryl esters,…
Resin	Resin acids, monoterpenes, ...
Heartwood	Polyphenols, terpenoids, fatty acids…
Cambial zone	Glycosides, carbohydrates, proteins…
Trees sap	Inorganics, sugars…

(Fengel & Wegener 1989)

Scots pine (*Pinus sylvestris*)*

- Sapwood 3,1 %
- Heartwood 5,35 %
- Knots 24,6 %
- Stumps 18,7 %
- Roots 6,4 %
- Bark 25,9 %
- Needles 40,6 %

*(Different sources)



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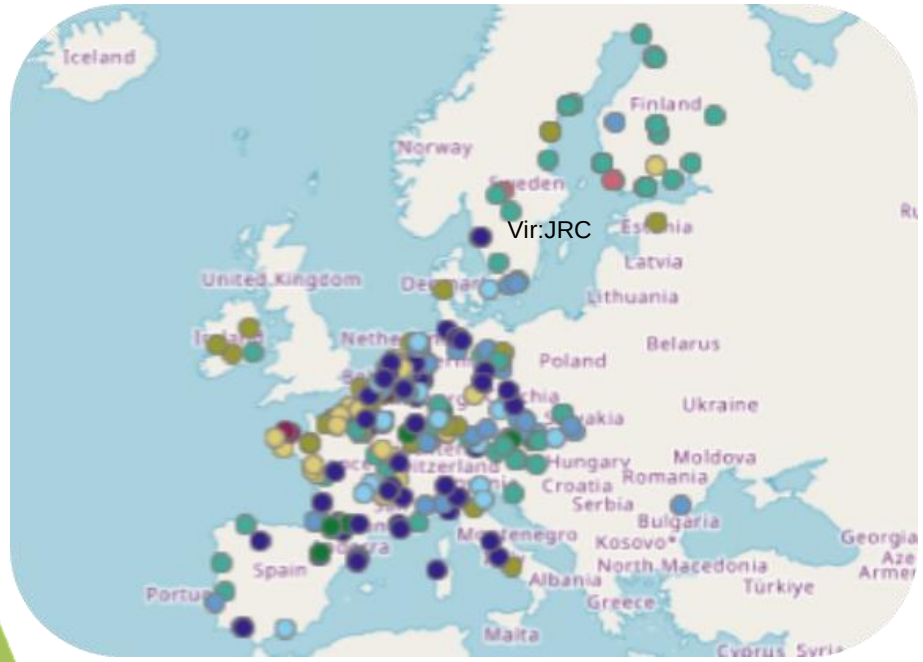
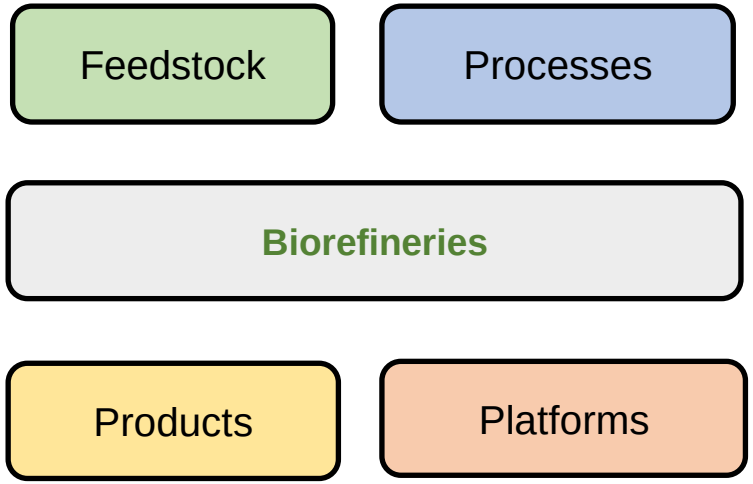
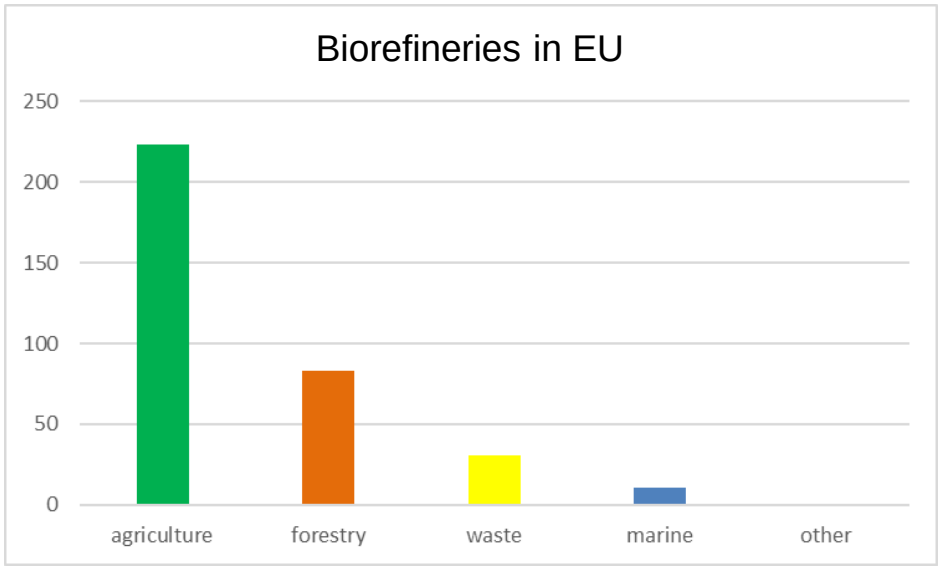
Biorefining of woody biomass

- **Biorefining** is the sustainable processing of biomass into bio-based products such as food, feed, chemicals, materials and bioenergy.
- Two presentations on the topic will follow toward the end of this webinar. Recommended!!!



Vir:JRC





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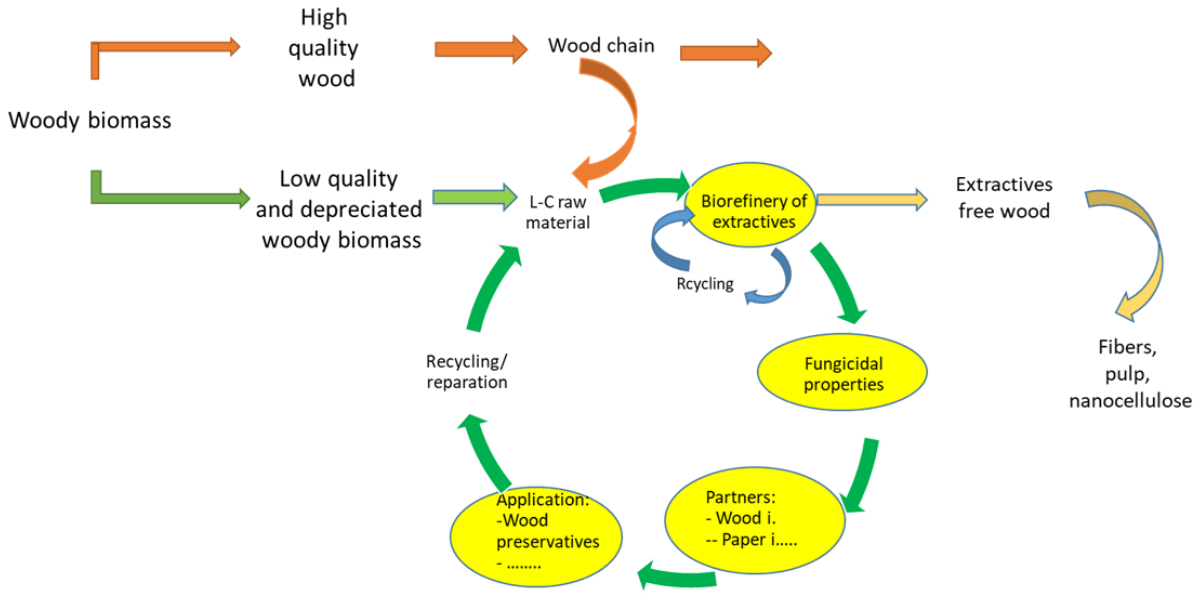
xx min

Cascading use of biomass

Extractives and nanocellulose production



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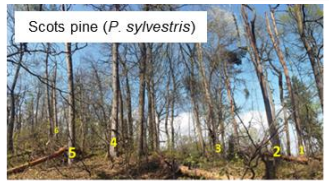
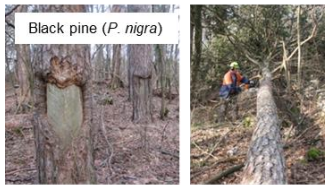
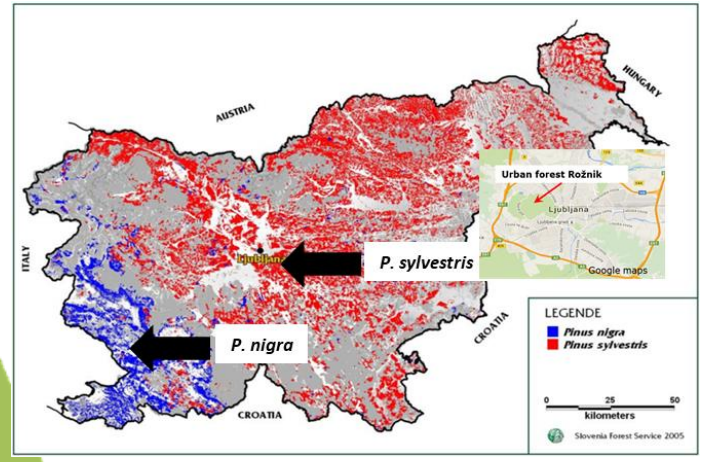
Production of extractives





Extraction of depreciated woody biomass



Woody biomass

↓

Separation and mechanical disintegration

↓

Extraction-solvents or water

↓

Crude extract → Application

↓

Separation and purification

↓

Isolated compounds → Application

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Application of extractives

Wood Science and Technology (2020) 54:1645–1662
https://doi.org/10.1007/s00226-020-01229-7

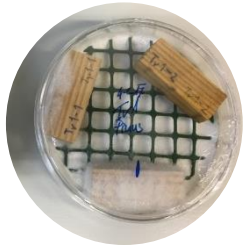
ORIGINAL

Check for updates

In vitro inhibition of extractives from knotwood of Scots pine (*Pinus sylvestris*) and black pine (*Pinus nigra*) on growth of *Schizophyllum commune, Trametes versicolor, Gloeophyllum trabeum* and *Fibroporia vaillantii*

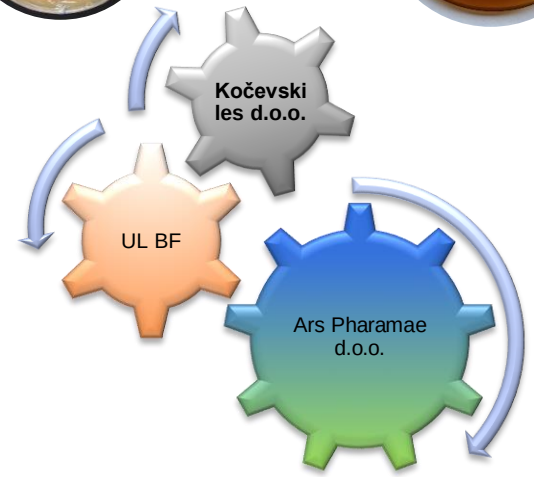
Viljem Vek[1] · Ida Poljanšek[1] · Miha Humar[1] · Stefan Willför[2] · Primož Oven[1]

Bio-based protection of wood



Antimicrobial formulations

Functional materials



molecules — MDPI

Article

Wood Extractives of Silver Fir and Their Antioxidant and Antifungal Properties

Viljem Vek [1,*], Eli Keržič [1], Ida Poljanšek [1], Patrik Eklund [2], Miha Humar [1] and Primož Oven [1,*]

Food supplements

Presentation
26. 10. 2023!!!

Extract of siver fir bark Abigenol®

Extract of silver fir knots

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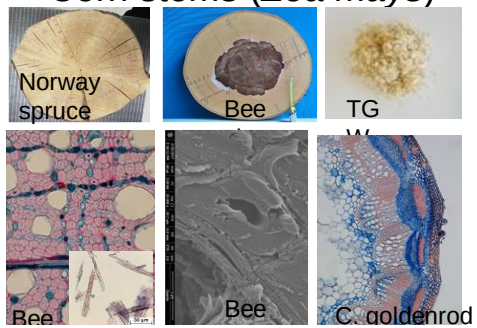
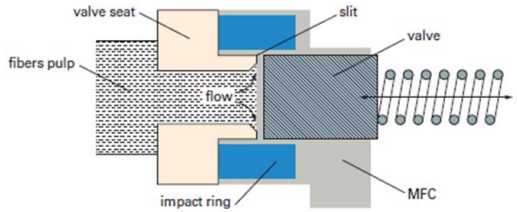
www.biorural.eu

Nanocellulose production

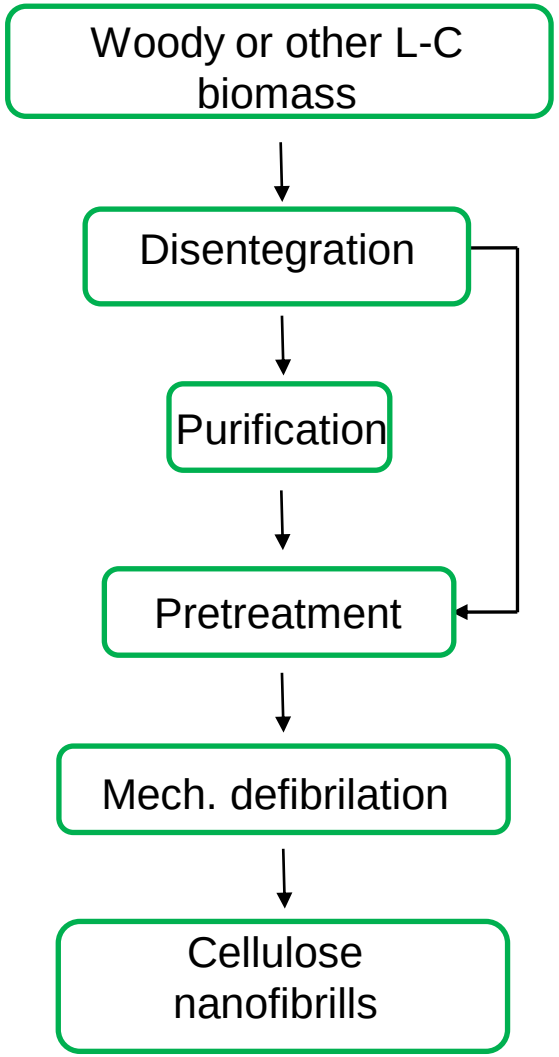
Nanocellulose raw material

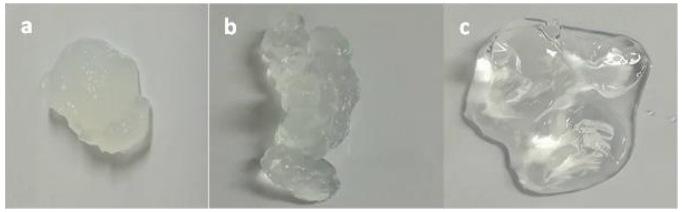
- Spruce (*Picea abies*)
- Beech (*Fagus sylvatica*)
- Fir (*Abies alba*)
- Groundwood (GW)
- Kraft cellulose
- *Japanese knotweed (Fallopia japonica)*
- Canafda goldenrod (*Solidago canadensis*)
- Corn stems (*Zea mays*)

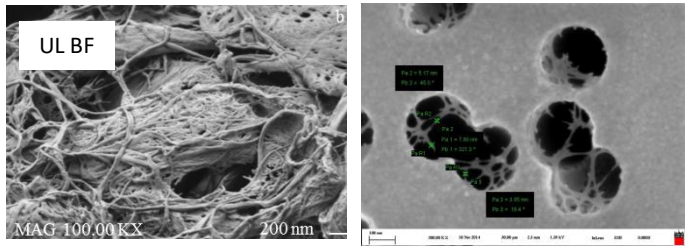




(Source: Dufresne 2012)







d = 5 – 60 nm, L = < 1 µm

- Properties of NC
  - Renewable, sustainable, biodegradable
  - Good mechanical properties;
    - E-module ~ 150 GPa,
    - σ = 7.5 GPa,
  - Low density, ρ_0 = 1.5 g / cm3
  - Good thermal stability
  - Favorable d / L ratio
  - Hydrophilic material
  - Possibility of chemical surface modification
  - Available in aqueous medium
  - Suitable for developing new materials or improving the properties of existing ones

Nanocellulose application

Physical, Rheological and Mechanical Properties of Alkali Activated Hydrogels Based on Nanofibrillated Cellulose

Vesna Žepič, Primož Oven, Matjaž Čop, Viljem Vek, Biljana Janković & Ida Poljanšek

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To link to this article: https://doi.org/10.1080/15440478.2022.2123879

Biomass

Isolation of CNF

Cellulose (2020) 27:2053–2068
https://doi.org/10.1007/s10570-019-02947-3

ORIGINAL RESEARCH

Stable nanocellulose gels prepared by crosslinking of surface charged cellulose nanofibrils with di- and triiodoalkanes

Jaka Levanič · Martin Gericke · Thomas Heinze · Ida Poljanšek · Primož Oven

DE GRUYTER DOI 10.1515/hf-2013-0132 — Holzforschung 2014; 68(6): 657–667

Vesna Žepič, Erika Š. Fabjan, Marta Kasunič, Romana C. Korošec, Aleš Hančič, Primož Oven, Lidija S. Perše and Ida Poljanšek*

Morphological, thermal, and structural aspects of dried and redispersed nanofibrillated cellulose (NFC)

CNF (bio)based (nano)composites

- Transparent wood
- Physical and Chemical modification of CNF
- Wood based panels NFC or formaldehyde
- Casted films
  - PLA/NFC
  - PVA/NFC
  - Biobased matrix/NFC/extr
- Extruded composites
  - PHB/NFC
- All cellulose composites
  - Cell. fibers/NFC
- Hydrogels
  - Nanocelluose II based
  - NFC/alkanes reinforced

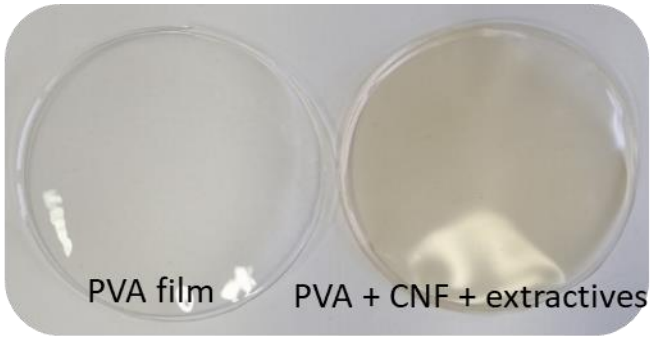

Foto: Osolnik

Foto: Osolnik

Foto: dr. Levanič

Univerza v Ljubljani
Biotehniška fakulteta

Wrap up

Woody biomass is a renewable and highly versatile feestock

It can be used and reused in different cascade processes

In addition to traditional processing of wood, woody biomass has high potential for diversified small scale biorefining processes in rural areas

Univerza v Ljubljani
Biotehniška fakulteta

Thank You!

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Bibliography

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