Perspectives of hardwood research

State of research with examples from Germany and Switzerland

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Forests in Europe

Major terrestrial ecosystem

EU: **117** million ha, **42%** of land area

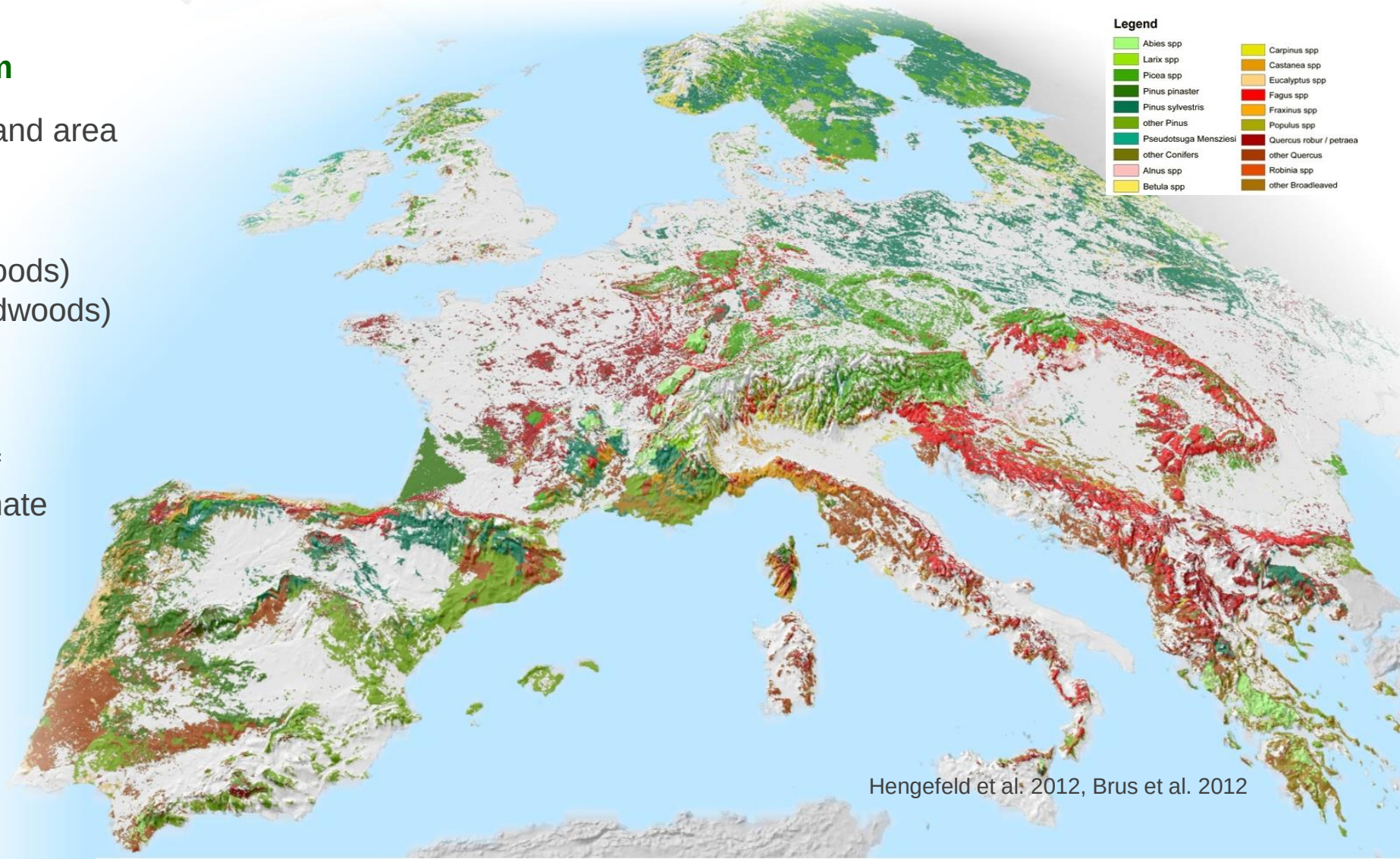
78 forest types with
more than **100** tree species*
- **16** main coniferous (softwoods)
- **95** main broadleaved (hardwoods)

Ecosystem functions

Key role for natural cycles of
soil, water, atmosphere, climate

Habitat for biodiversity

Socio-economic:
wood = raw material for the
forest-based sector



* San-Miguel-Ayanz et al. 2016

Hengefeld et al. 2012, Brus et al. 2012

Hardwoods availability and use

Wood resource trends: example of Germany

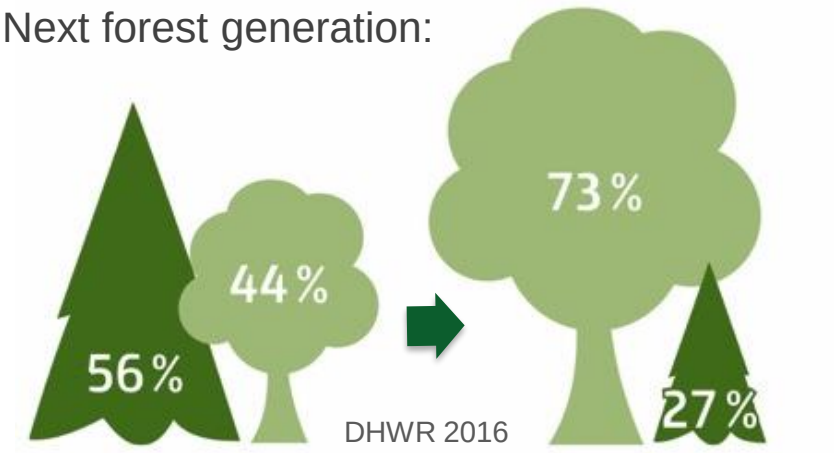
3rd German National Forest Inventory (BWI 3): changing trends since last 10 years (BWI2)

44% of forest soil stocked with hardwoods

Hardwoods / broadleaved **+ 7%**

Softwoods / coniferous **- 4%**

➢ Next forest generation:



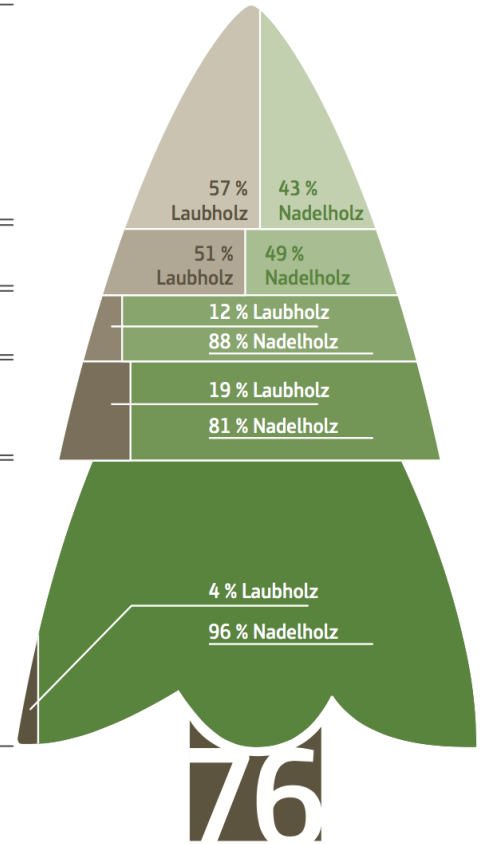
DHWR 2016

Energy use **34%**

Material use **66%**

Energy wood private	26%	20 Mio. m³ Brennholz für private Haushalte
Energy wood industrial	8%	6 Mio. m³ gewerbliches Energieholz
Pulp / paper	8%	6 Mio. m³ Zellstoff-/ Papierindustrie
Wood composites	12%	9 Mio. m³ Holzwerkstoff-industrie
Sawmills (construction timber)	46%	35 Mio. m³ Sägeindustrie (Bauholz)

Total annual harvest 76 million m³



Green= softwoods
Grey= hardwoods

76 Millionen m³ genutztes WALDHOLZ[1]

DHWR 2016

Climate change impacts on forests

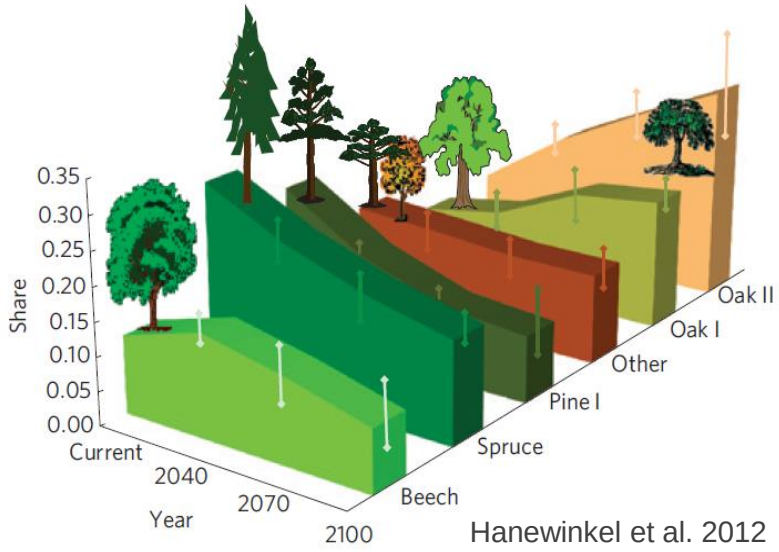
Long-term shift of ecological zones (precipitation, temperature)

Forest tree species composition will undergo large alterations

Decrease of cultivation areas for European conifers

Higher occurrence of disturbances

Droughts, fire, storms, pests = higher risks, lower productivity

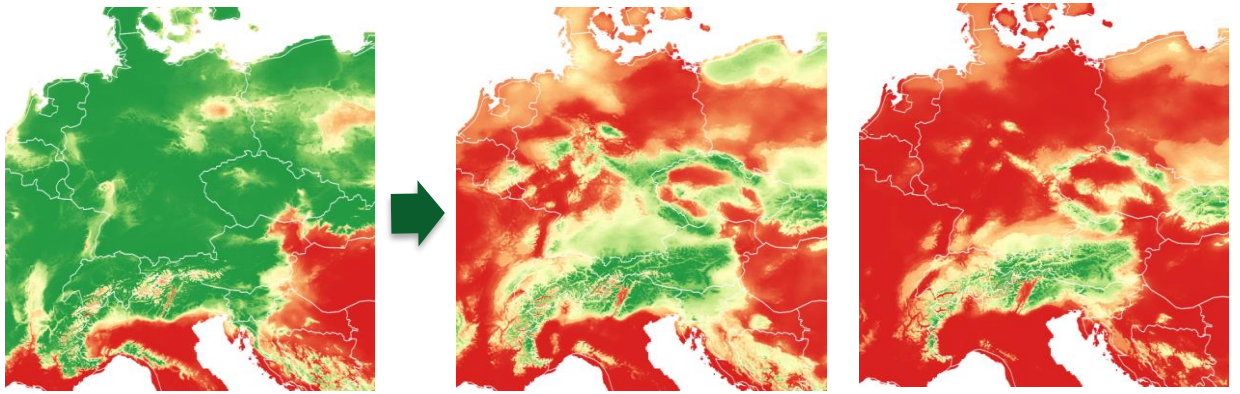


Hanewinkel et al. 2012

- Far-reaching adaptation of management systems to increase resilience of forest ecosystems is required
- Growing importance of hardwood research

Potential distribution area of spruce

1970-2000 | 2100: **+2°C** | 2100: **+4°C**



Schüler & Hoch - BFW 2019

Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

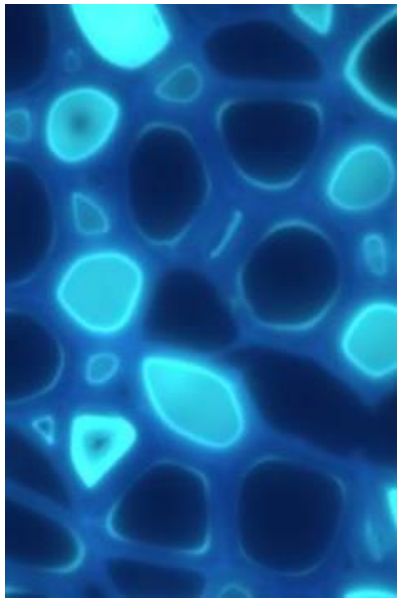
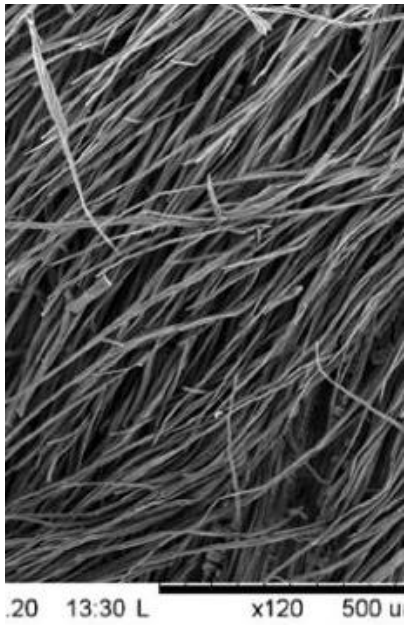
Hardwood research at the BFH in Switzerland

Dr. Frédéric Pichelin

Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

Bern University of Applied Sciences
Institute for Materials and Wood Technology

- Composite materials and furniture development
- Wood modification and surface treatment
- Adhesives Technology, Polymer Chemistry
- Wood chemistry and material emissions

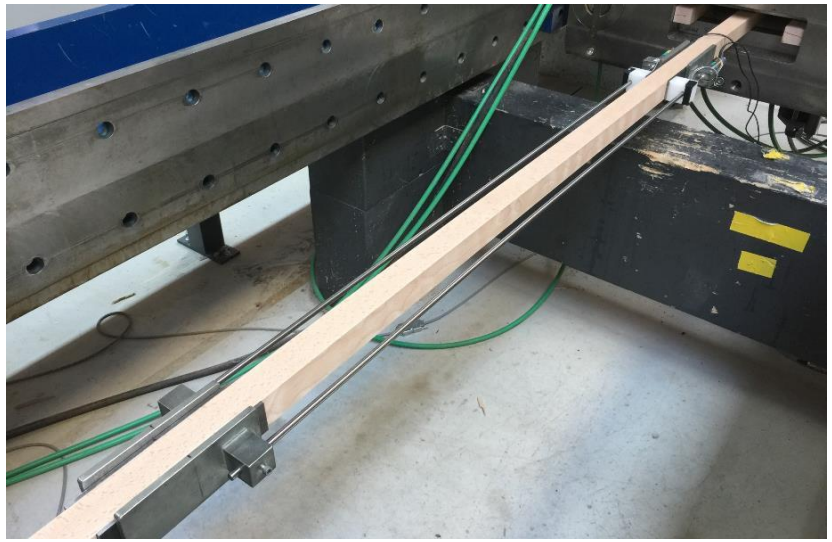
Use of hardwood for the production of engineered wood products

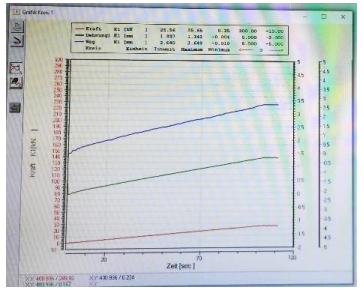
Fagus Suisse:
Engineered wood product made from beech

- Using the underexploited beech wood resource to produce a structural building material with very high strength (GL60)
- Developing a fully digitalized process to control the wood quality
- Use of the microwave technology to achieve a fast curing of the adhesive

Challenge 1: Wood sorting

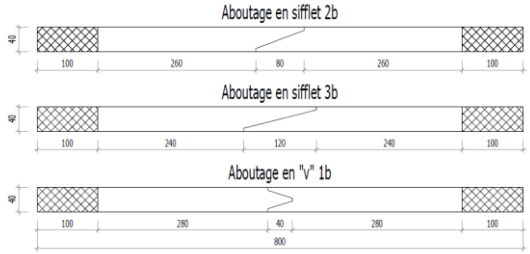
Visual analysis → dyn MOE → Tensile strength tests → Failure analysis

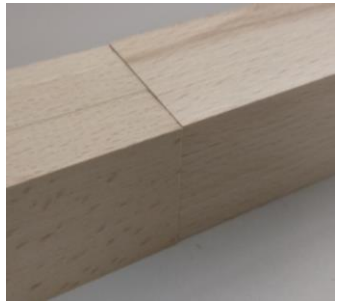


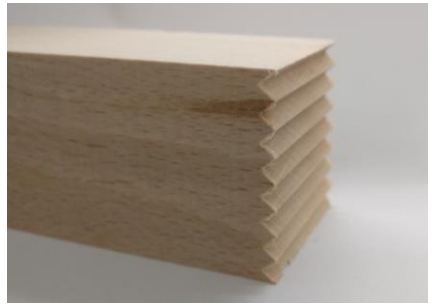


Challenge 2: Wood assembly

- Final selection for the mono-lamellas prototypes
  - Flat joint
  - Zig-zag joint
  - Classic panel joint
  - Round tip fingers joint
  - Narrow tip finger joint
  - Whistle 2b and 3b joint
  - « V » joint





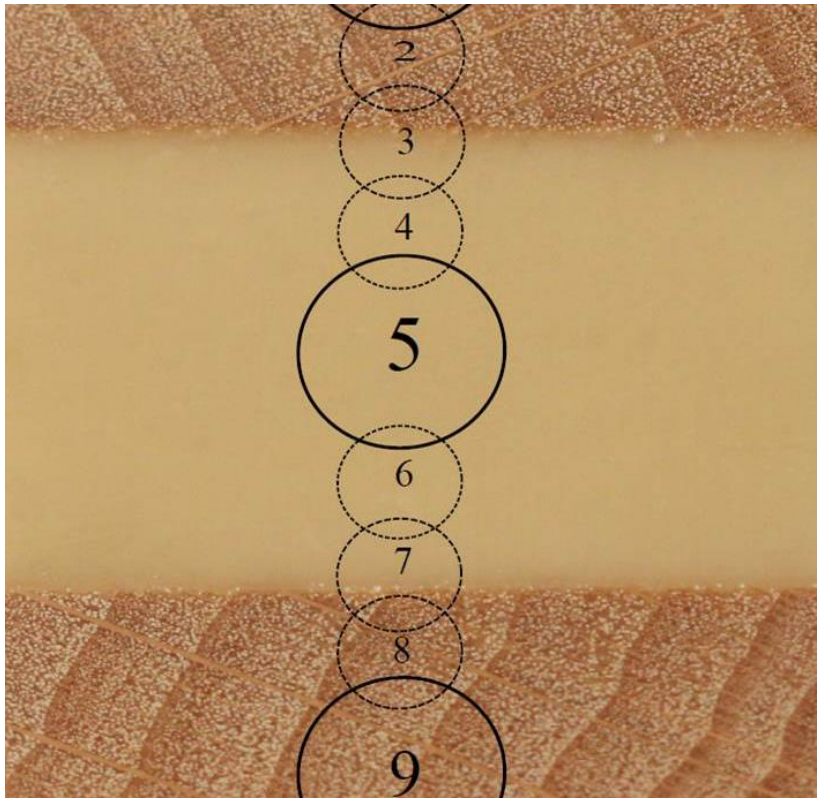


Bonding of hardwood

Influence of wood extractives on structural hard wood bonding with Two-Component Polyurethane

- Possible influence of extractives on wood bonding

- Surface contamination
- Wettability and permeability
- Chemical interactions

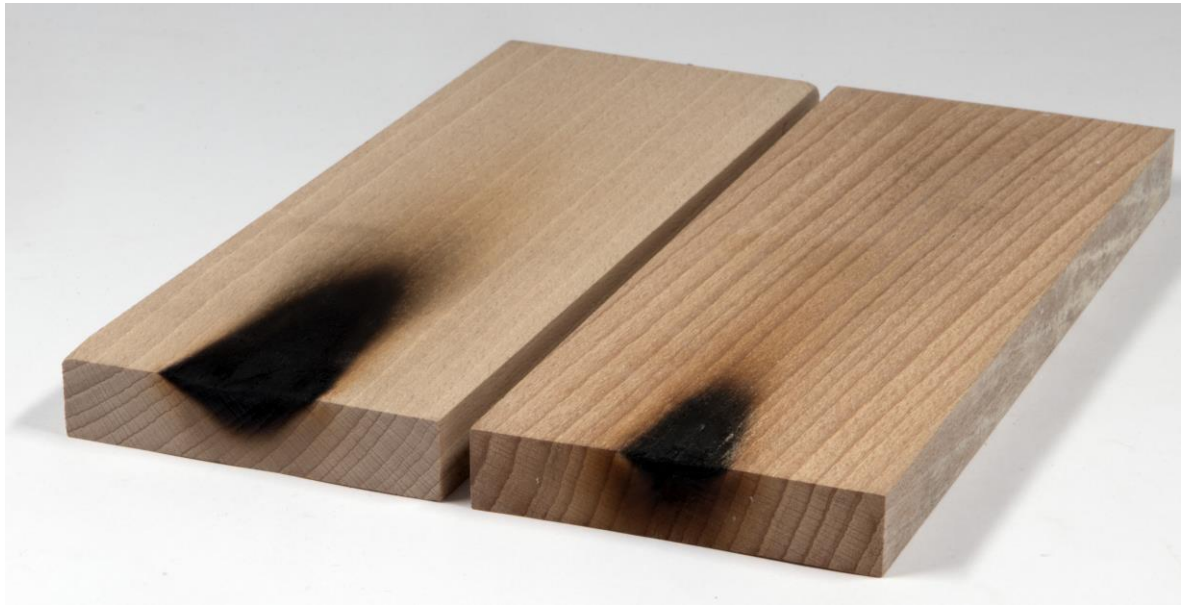


Are extractives responsible for common adhesion problems of polyurethane adhesives when bonding hardwoods?

According to Mara (1980)

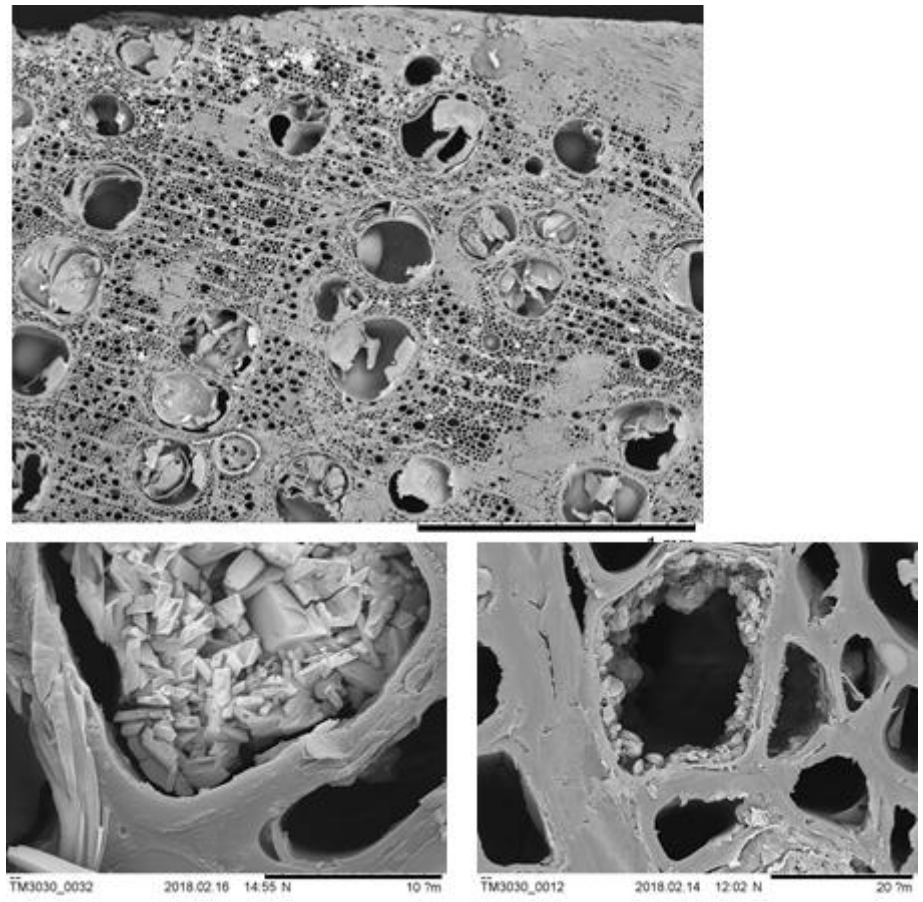
Modification of hardwood

Improving the fire resistance of beech and oak with a mineralization process



Fire resistance of beech with and without mineralization

CaOx Mineralization-distribution in European Oak



→ *Displayed specimen was impregnated with:*
Kox + $CaCl_2$;for 4h at 8 bar pressure

- Salts were found mainly in smaller vessels without tylosis **(a)**
- Relatively high amount of filled cell lumina serves as good indicator for a proper penetration of the mineralization agents **(a)**.
- Completly filled cell lumina **(b)**; as well as only deposits on the cell wall surfaces **(c)** were found

Use of hardwood for green chemistry

T-Rex

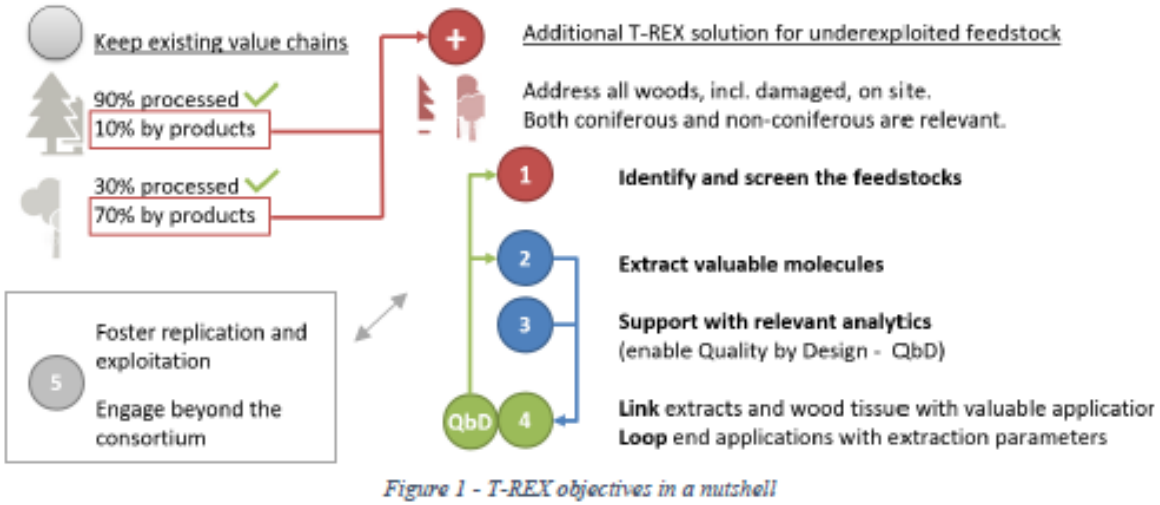
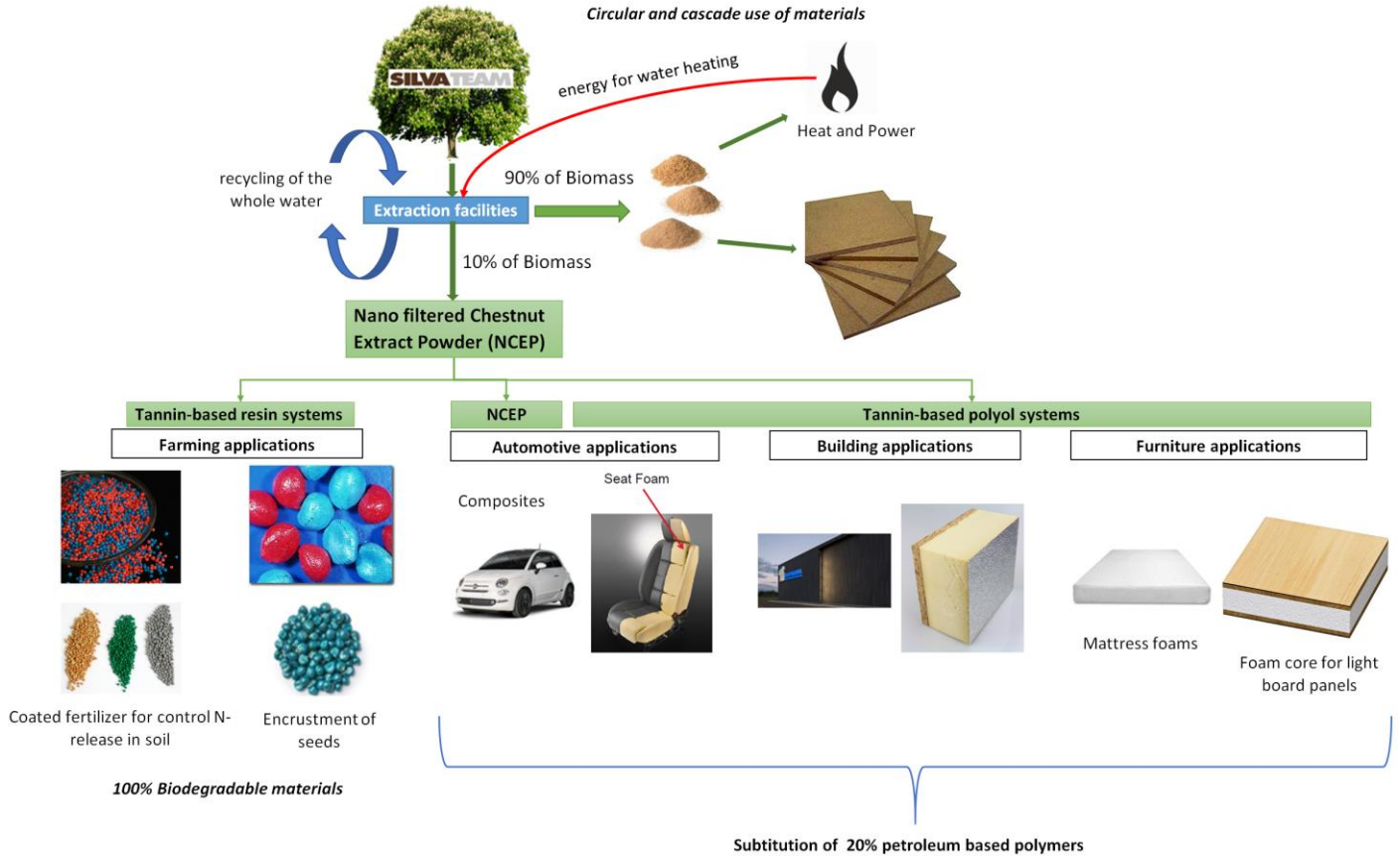


Figure 1 - T-REX objectives in a nutshell

T-REX provides a solution by a novel "Quality by Design" approach for production of target extractives (stilbenes, polyphenols, a.o.) and extractive-free fibers which both are essential for five new value chains created by T-REX.

Info clip: https://youtu.be/a34CoWQ0MRY

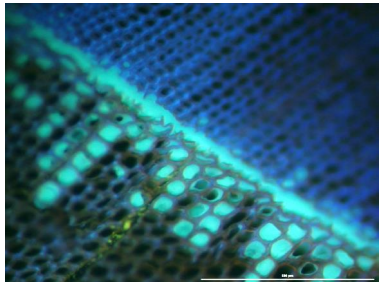
Tan-up
Scale-up of nanofiltered chesnut tannin production for valorisation into high added value markets



Hardwood research at University of Göttingen in Germany

Prof. Dr. Holger Militz

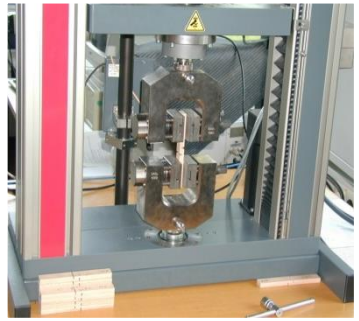


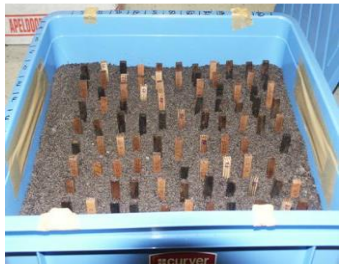


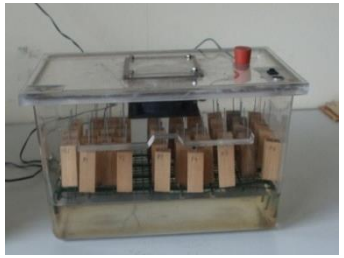
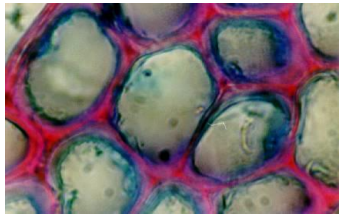
Department of Wood Biology and Wood Products

- Employees: ~ 45

- Research topics:
  - Wood protection and modification
  - WPC und wood composites
  - Biological degradation & weathering / UV-protection
  - Coating and gluing
  - Mechanical properties
  - Wood quality





Hardwood research in Göttingen - projects

→ https://www.uni-goettingen.de/en/584672.html

- HoMaba - Wood-based materials in mechanical engineering
- KlimaKleb - Increasing the reliability of bonding and improving the emission behavior of beech glulam
- CEMWOGEO - Cement coating of wood for geotechnical applications
- LVL Mast - Development of material- and construction-optimized transmission pylons
- Laubholz - Innovationsverbund - ZIM-Kooperationsnetzwerk
- Innobond - Development of material-adapted adhesive systems for use in finger-jointed and surface-bonded solid wood products manufactured from both untreated and modified native hardwoods for non-structural components
- Gerlau - Utilisation-oriented investigations of low-value hardwood assortments for the production of innovative products
- Holzschutz-CT - Characterization of penetration and distribution of protection systems in wood by X-ray based Micro Computed Tomography
- Nachwuchsgruppe - Novel applications, markets, and technologies for native hardwood species
- 2TW - Second Generation of ThermoWood
- Fehrensen - Production of marketable, innovative products with improved material properties from native hardwoods through a modification process with fatty acid-modified melamine and dyes
- InnoBuche - Innovative modified beech wood products - Improved material properties in light of increasing beech wood production and high consumer demands to ensure sustainability

Hardwood research in Göttingen – doctoral theses

→ https://www.uni-goettingen.de/de/publications/105140.html

- Bicke S (2019) Dimensionsstabile und pilzresistente Furnierwerkstoffe durch Zellwandmodifizierung mit niedermolekularem Phenol-Formaldehyd. eDiss. Uni Göttingen, 206 S.
- Schlotzhauer P (2019) Strength grading and selected strength properties of European hardwoods eDiss. Uni Göttingen, 149 S.
- Wentzel M (2019) Process optimization of thermal modification of Chilean Eucalyptus nitens plantation wood eDiss. Uni Göttingen, 171 S.
- Fleckenstein M (2018) Technische Lignine als biobasiertes Ausgangsmaterial zur Substitution von erdölbasiertem Phenol in Phenol-Formaldehyd-Harzen. Sierke Verlag, 140 S.
- Lütkemeier B (2018) Kleben von modifiziertem Vollholz – Gestaltung des Grenzbereichs zur Steuerung von Verklebungsmechnismen. Sierke Verlag, 253 S.
- Bastani A (2016) Bondability of modified wood. Cuvillier-Verlag, Göttingen, 138 S.
- Friese F (2014) Entwicklung von Sandwich-Spanplatten aus geringwertigem Buchenholz (*Fagus sylvatica* L.) und Holzsortimenten aus Kurzumtriebsplantagen zur Entlastung des Nadelholzmarktes. Sierke Verlag, 248 S

→ and numerous master & bachelor theses

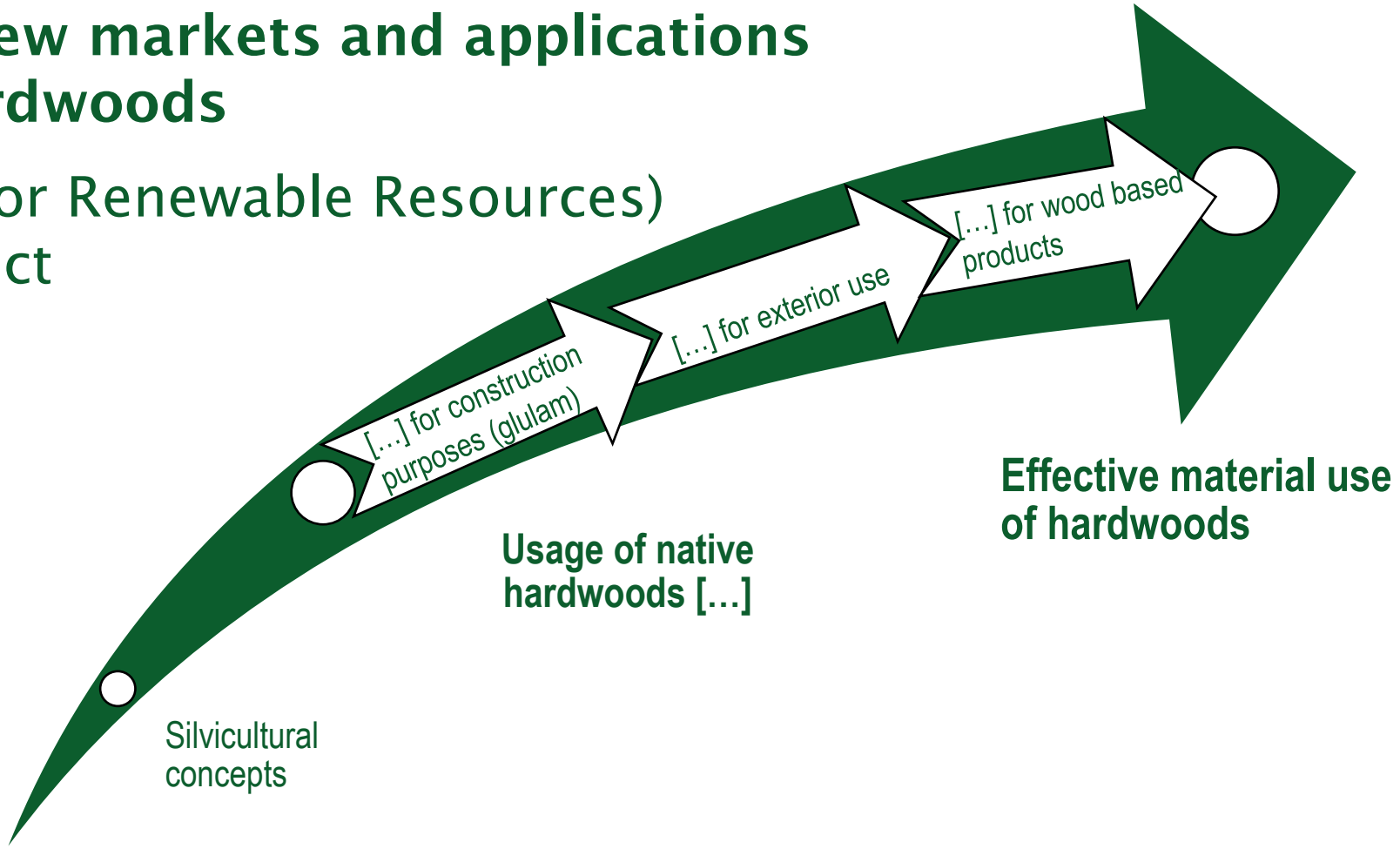
Hardwood research in Göttingen – Main research directions

- Yield analysis
- (strength) grading
- Lamination/ finger-jointing/ glueing
- Durability/ preservation/ wood modification
- Wood composites
- New products

“FNR young research leader programme”: hardwood research project (2012-2017)

Creation of new markets and applications for native hardwoods

FNR (Agency for Renewable Resources) research project



Strength grading: doctoral thesis Philipp Schlotzhauer

- Distribution of strength grading parameters in different species
- Stength grading (optimized after tensile or bending strength)
- Strength testing (strucural timber and glulam)
  - Compression (parallel and perpendicular to grain)
  - Tension (parallel and perpendicular to grain)
  - Bending
- Yield analyses

- Species:
  - Ash (*Fraxinus excelsior*)
  - Birch (*Betula pendula*)
  - Lime (*Tilia spp.*)
  - Maple (*Acer spp.*)
  - Beech (*Fagus sylvatica*)
  - Oak (*Quercus spp.*)

Yield analysis birch wood use: doctoral thesis W. Hesselbach

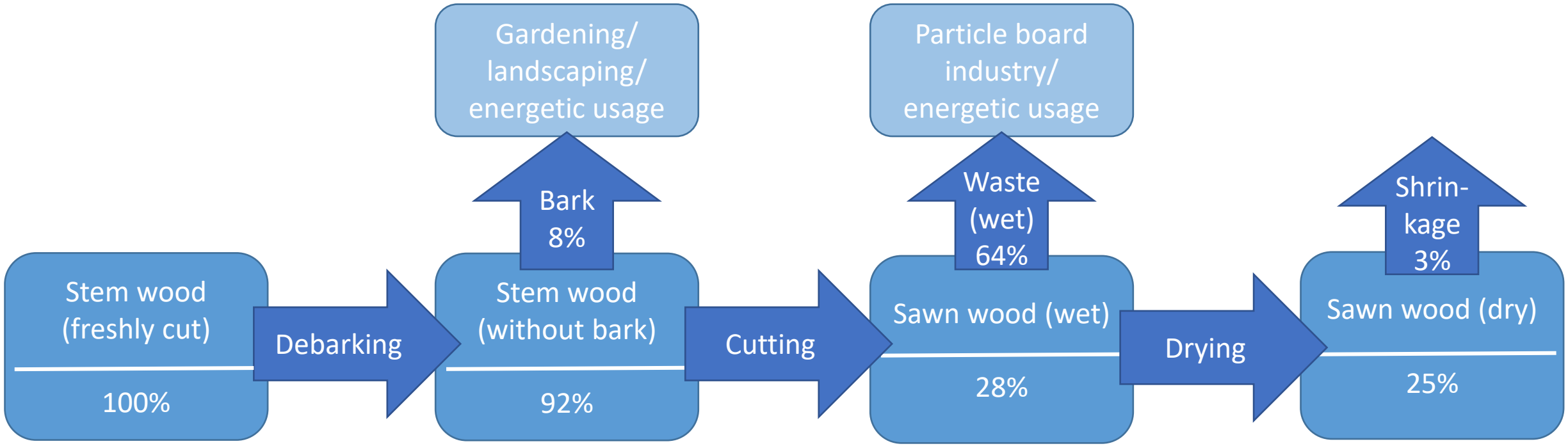


Fig. 12: Scheme of the yield and the by-products.

Yield analysis birch wood use: example

Determining the quality

Remain in forest
Minimal diameter (MD): < 7cm

Wood for energy
MD: 7cm

Industrial wood
MD: 10cm
Quality classes:
N, F, K

Trunk wood
MD: 20cm
Quality classes:
A, B, C, D

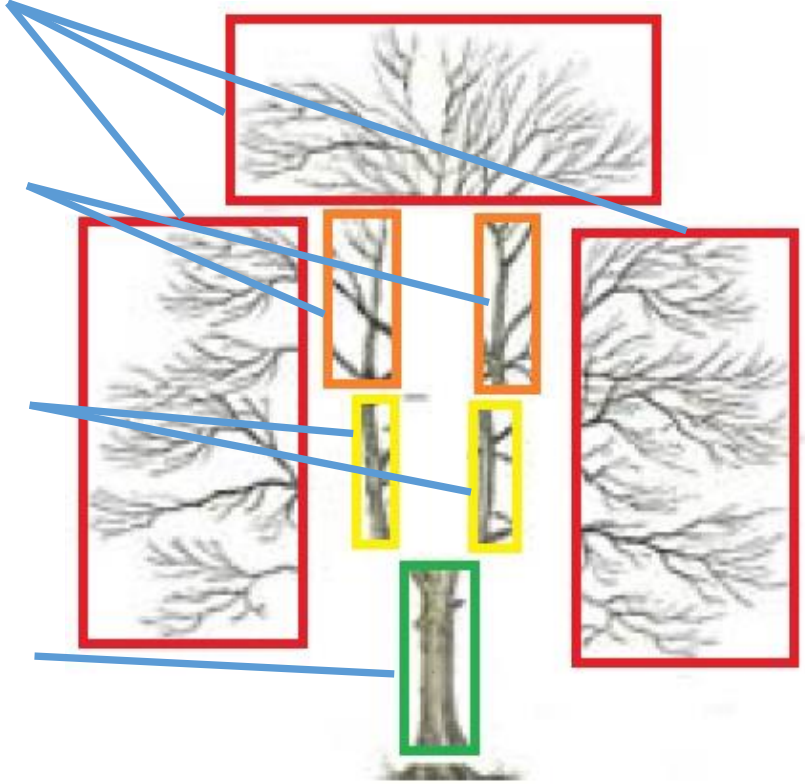
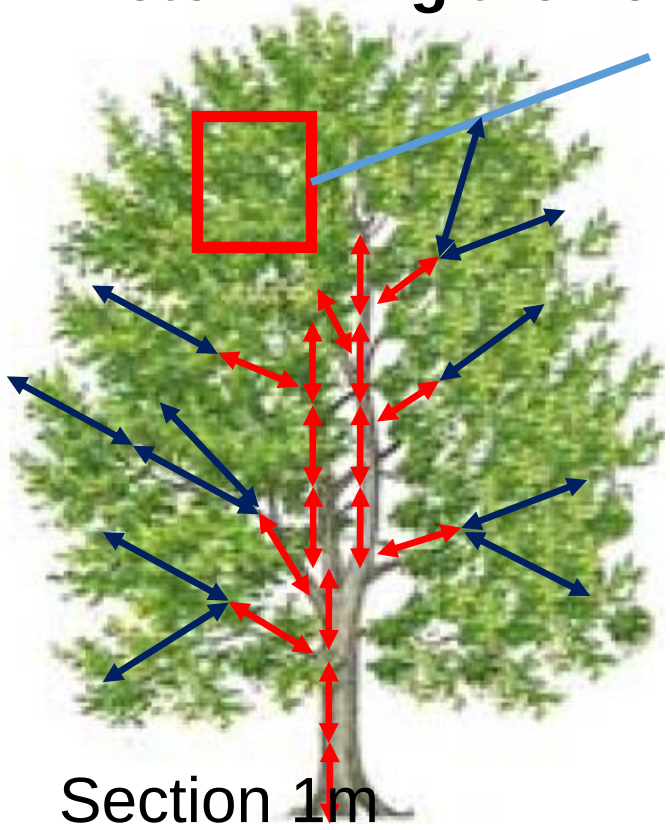


Fig. 5: Determination of the quality-classes after RVR with diameters after results of a conducted survey

Determining the volume

Total length



Collection of representative samples for biomass-determination < 7cm w.b.

1m section

1.5m sectio

Section 1m

Fig. 6: Measurement of the total length and the section diameters to the rough-wood-border of 7cm m.R.

FNR research project „GerLau“ (5 institutes)

Utilization-oriented investigations of low-value hardwood assortments for the production of innovative products

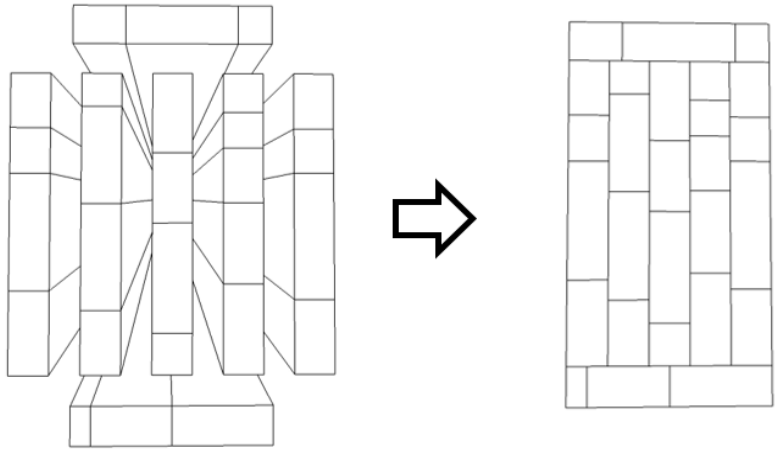
- Round wood potential analysis
- Value chain analysis
- Sawn wood products and insulation material
- particleboards
- Fiberboard technology

FACHAGENTUR NACHWACHSENDE ROHSTOFFE e.V.

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz

ZIM cooperation project “KlimaKleb”

➢New beech beam (idea)



GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

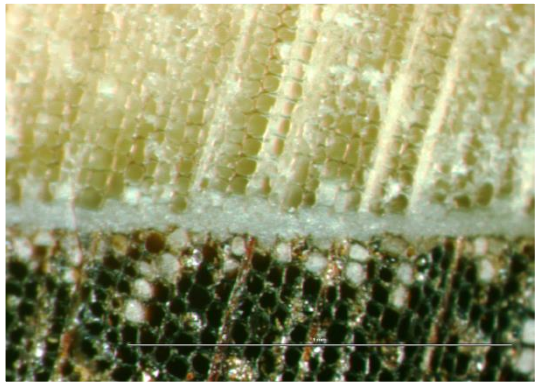
“NOKA”®

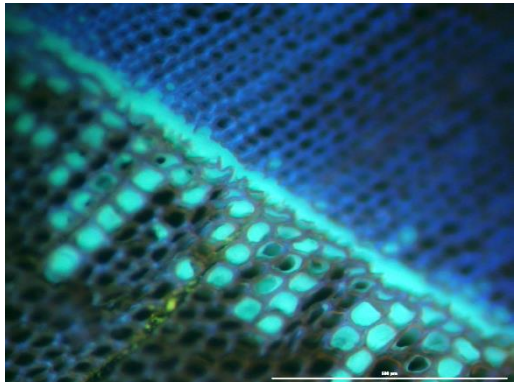
BAUFRITZ
Der Ökohaus-Pionier seit 1896

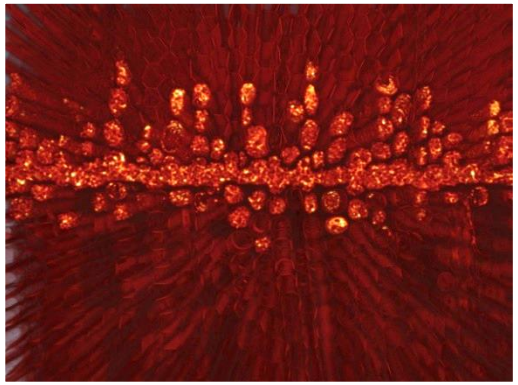
- Research:
  - Surface and finger-joint gluing
  - Humidity change response
  - Emissions
- Goal:
  - Process optimization to lower prices
  - Quality assurance

Hardwood gluing

- Functionalization of wood and wood-based materials with plasma treatment
  - Plasma research group with HAWK
- Discoloration/staining problems in gluing (FNR Innobond)
- Finger jointing (new full scale equipment, doctoral thesis in progress)







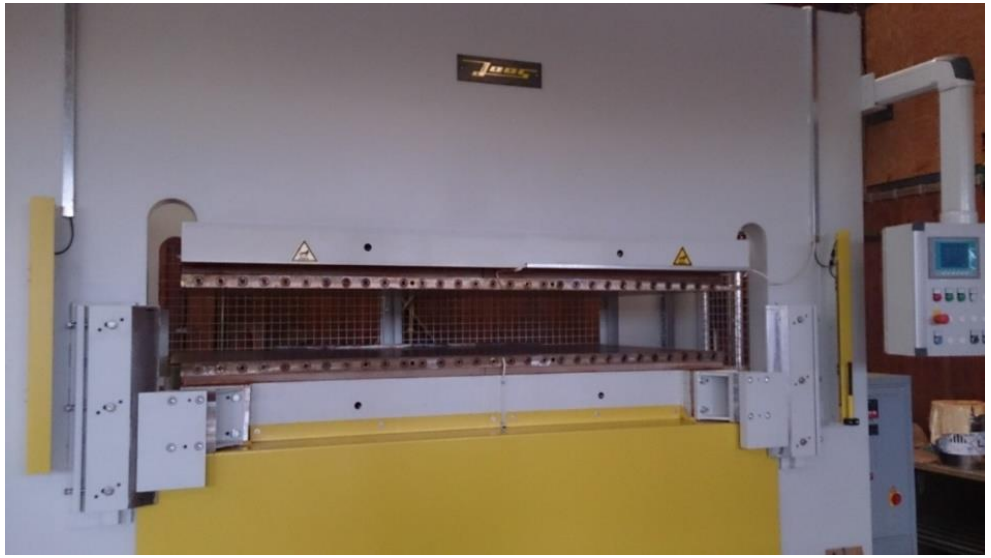
Railway sleepers from beech wood

- New technology to substitute creosote for the protection of railway sleepers, timber bridges and utility poles (projects CreoSub/ ZIM Schwelle)
  - Cooperation with Norway/ UK/ Austria (ÖBB)
  - Cooperation with DB German Railway and impregnation company Fürstenberg

- Focus
  - Impregnation/process optimization
  - New wood preservatives/ combinations
  - Product characterization (sleeper)

Wood-based composites – veneer based

- Special products (cooperation with Blomberger Delignit, Becker, Metsä, Stora, Pollmeier)
  - Beech, birch, poplar, Eucalypt, pine, spruce, etc.
- Plywood and LVL

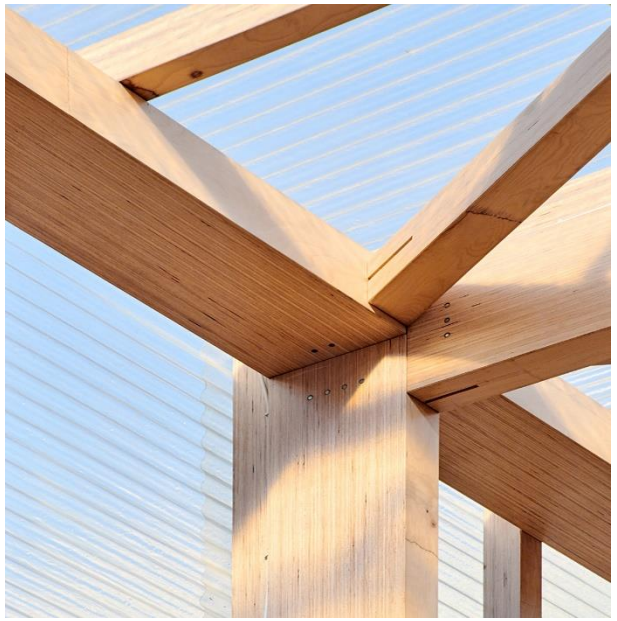


- Wood modification for outdoor use
  - New FNR project with TU Kaiserslautern (Prof. Graf) about acetylated beech LVL

Wood modification of beech veneers/ plywood/ LVL

Pollmeier Massivholz GmbH & Co. KG

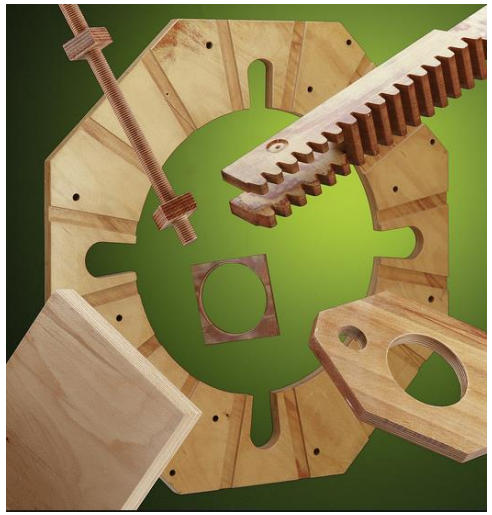
- Laminated veneer lumber → parallel oriented veneers
- BauBuche®



Wood modification with phenolic resins

Deutsche Holzveredelung Schmeing GmbH & Co. KG

- Synthetic resin densified wood
- dehonit® leading in compressed laminated wood



Wood modification of beech with phenolic resins

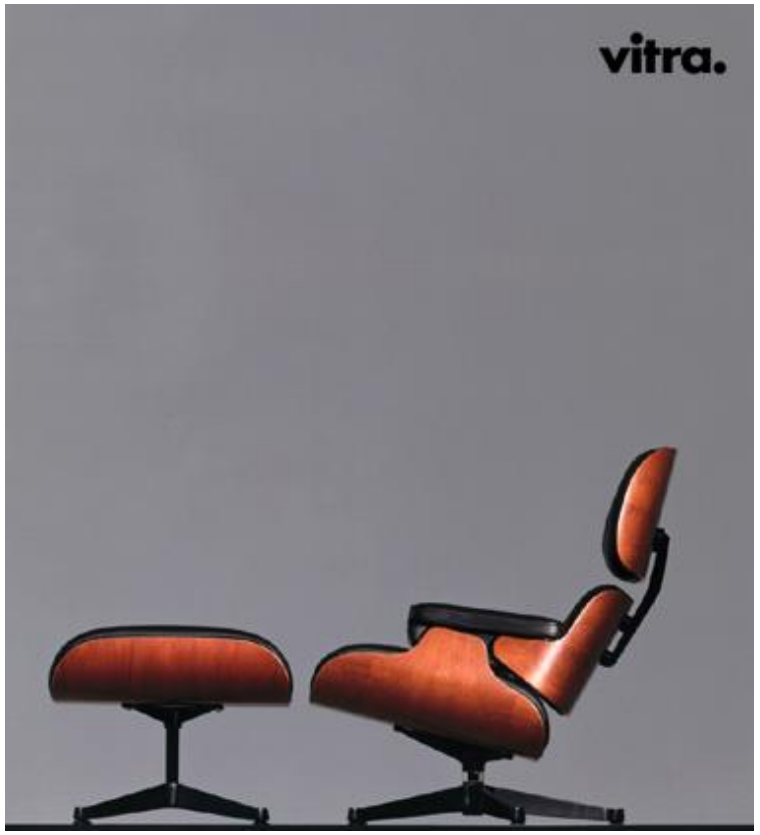
Delignit AG/ Blomberger Holzindustrie GmbH → Delignit®

- Trailerfloor
- Protection systems
- Synthetic resin densified wood

Wood modification of beech moulded wood for outside use

Becker Brakel - Fritz Becker GmbH & Co. KG





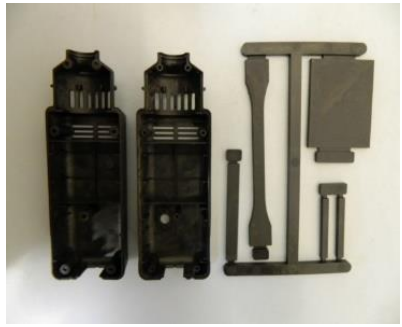





Wood-Polymer Composites (WPC)

Thermoplastics (matrix) mixed with wood particles/fibers

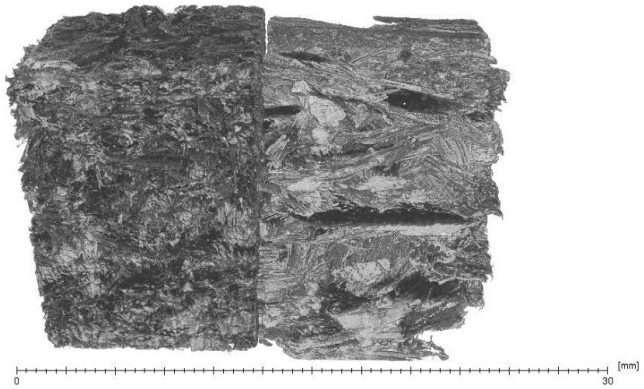
- Low value hardwoods
- Short rotation plantations
- Residual timber



Wood-based composites

Particle and fiberboards / insulation material

- Low density wood-based composites from short-rotation plantations (Kiri, Pappel)
- Utilization of residual timber
  - Adaption of gluing
  - Process development



Conclusions: What do we know?

- Characteristics determined (in labs, mostly little, error-free specimens)
  → mostly not worse or even better than softwoods
- Overall wood characteristics:
  - Strength values correlate with density (poplar … oak)
  - Outside use without wood protection difficult (low natural durability)

- Low yields due to log characteristics (curves, taper, ovality, etc.)
- Adapted sawing technology necessary

- Production of high quality (glued) products possible, but :
  optimization/development is necessary in order to reduce costs of end products and ensure constant high quality

Conclusions: What do we know? → What do we have to do?

- Creation of special markets with special:
  - “low-value” products for special applications like low value beech wood as bottom plates for building multistory houses (low bending strength, but high perpendicular to grain compression strength)
  - Railway sleepers
  - Veneer based products → LVL
  - New products?
- Promoting standardization of hardwood products (products standards, ETAs, glue standards, etc.)
- Development of species-specific strength grading (optimized after bending strength of structural timber, compression strength perp. to grain of bottom plates, tension strength of glulam lamellas, etc.)
- Gathering knowledge (in Germany FNR workshops and “Laubholz-Innovationsverbund”, in Switzerland BAFU, EU-projects, projects in France)

Perspectives of hardwood research

Conclusions

Conclusions: what we know

- Hardwood species represent a main share of Europe's forest resources and their importance in forestry will increase due to climate change. Large-scale adaptation of forests will foster more hardwoods.
- Hardwoods are underexploited in the field of construction and wood products. Taking in account the high resilience of hardwoods to climate change, they are a very good alternative to softwoods in many sectors.
- High-density hardwoods have interesting strength properties and are suitable for production of engineered wood products.
  - Quality assurance of the raw material is essential to achieve the highest product properties.
  - The bonding of hardwood is possible with standard wood adhesives; however the presence of extractives and the specific wood anatomy should be carefully evaluated.

Conclusions: what we know

- Low-density hardwood can be used to produce wood-based composites and wood-polymer composites.
- Hardwood can be modified with minerals or environmentally friendly agents, which enable a wide range of exterior applications, e.g. facades, bridges, railway sleepers, utility poles, etc.
- Side-stream products of the hardwood processing contain interesting molecules that can be extracted and valorized in different sectors.
  → Extraction and refinery technologies = new business opportunities for the hardwood sawmill industry.

Conclusions: what we know

- Material characteristics have been determined
  (lab research: mostly based on small & error-free specimens)
  → mostly not worse, but often even better than softwoods
- Overall wood characteristics
  - Strength values correlate with density (wide range from poplar … oak)
  - Exterior use without wood protection difficult (low natural durability)
- Low yields due to log characteristics (curves, taper, ovality, etc.)
- Adapted sawing technology necessary
- Production of high quality (glued) products possible, but:
  optimization/development is necessary in order to reduce costs of
  end products and ensure constant high quality

Conclusions: what we need to do !

1. Creation of markets for special material characteristics :
   - "Low-value" products for special applications, e.g. low value beech wood as bottom plates for multi-storey houses (low bending strength, but high perpendicular strength to gain compression strength)
   - Durable products for exterior use, e.g. railway sleepers
   - Veneer based products, e.g. LVL
   - *New products?*
2. Species-specific strength grading to optimize material performance: bending (structural timber), compression (bottom plates), tension (glulam lamellas), etc.
3. Promote standardization of hardwood products (products, ETAs, glues, etc.)
4. Gathering and exchange knowledge, build up hardwoods research community

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