



# GREEN-LOOP

## Overview of wood composites production and properties – identification of opportunities and risks

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Online Workshop on "Wood composite material production" – 5 June 2025 –



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## Mission of Fraunhofer Center HTL

- HTL designs energy-efficient heating processes and thus contributes to the sustainable technological progress of society.
- It develops high temperature materials, high temperature components as well as high temperature measuring methods, thereby optimizing thermal processes.
- HTL works with systematic methods on a high scientific-technical level.
- Primary goal is the implementation of its developments in the industry.



## Infrastructure of HTL



Main building in Bayreuth



Fiber pilot plant Bayreuth

- Technical area
  - Bayreuth 3200 m<sup>2</sup>
  - Münchberg 1000 m<sup>2</sup>
  - Würzburg 500 m<sup>2</sup>

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# GREEN-LOOP Consortium




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GREEN-LOOP  
is a member of the  
BIO-MATTERS Cluster



**SUSTAINABLE**  
manufacture systems towards  
novel **BIO-BASED MATERIALS**



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## What's **GREEN-LOOP**?

Wood composite bearings for the tool and appliance sector.



Multifunctional rubber panels for the construction sector.



Bottle closure for the food and beverage sector.



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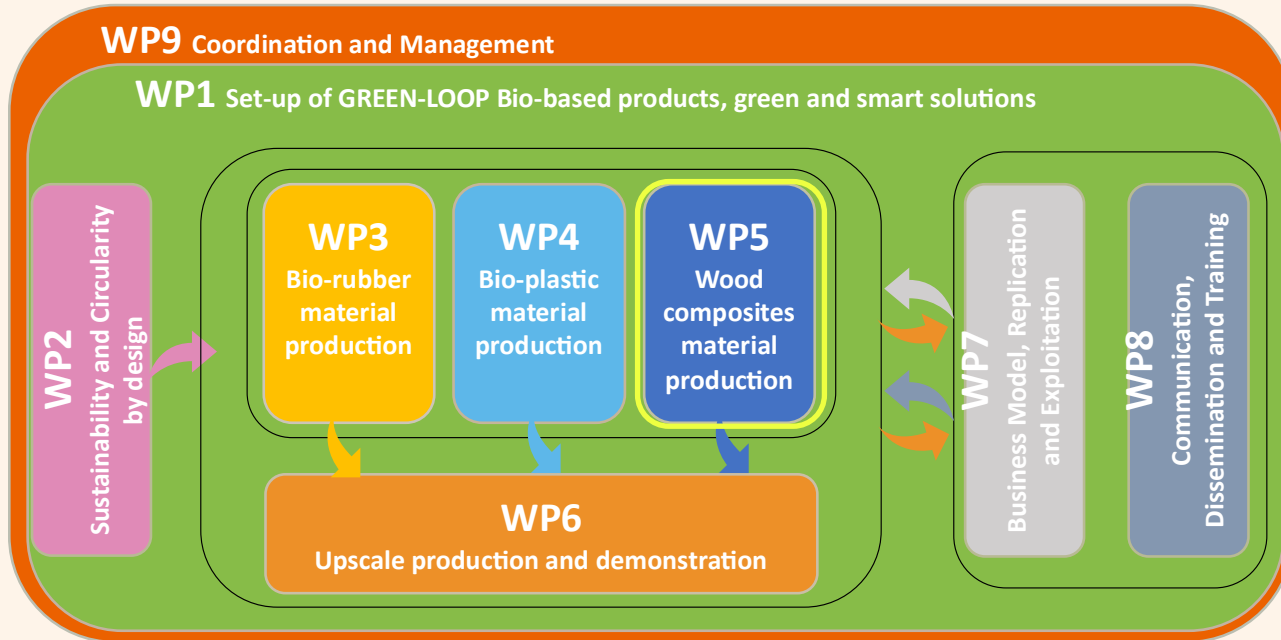


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## Key features (Kick-Off Meeting)

- Bio-based raw materials: compounds with 50-60 % wood fibres/Particles, 30-40 % biopolymer, 5 % filler
- Recyclability, reusability or refurbishing of the product: > 50 % recyclability of bearings, reduce of maintenance costs
- Advantage over conventional materials: 100 % regenerative resources, eco-friendly, cost efficient, only use water or bio-lubricants
- Use in other sectors: building sector/floor plates, transport sector/rollers

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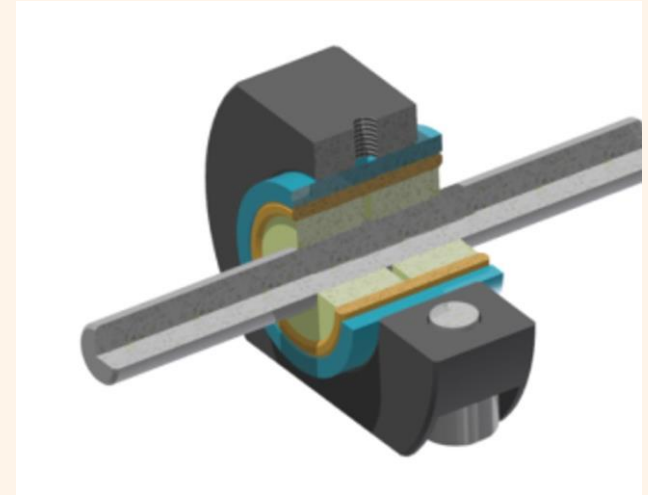
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## Final product (Kick-Off Meeting)

- Wood composite (WC) bearings
- Application in appliance and tool industry (injection unit)
- Demonstration by bio-plastic manufacturing system (Injection)
- Samples such as rings, cylinders, half shells
- Prototype features /design defined by Labrenta (Guala)
- WC Production in small series



Wood Composites as Precision-Engineered Mechanical Components

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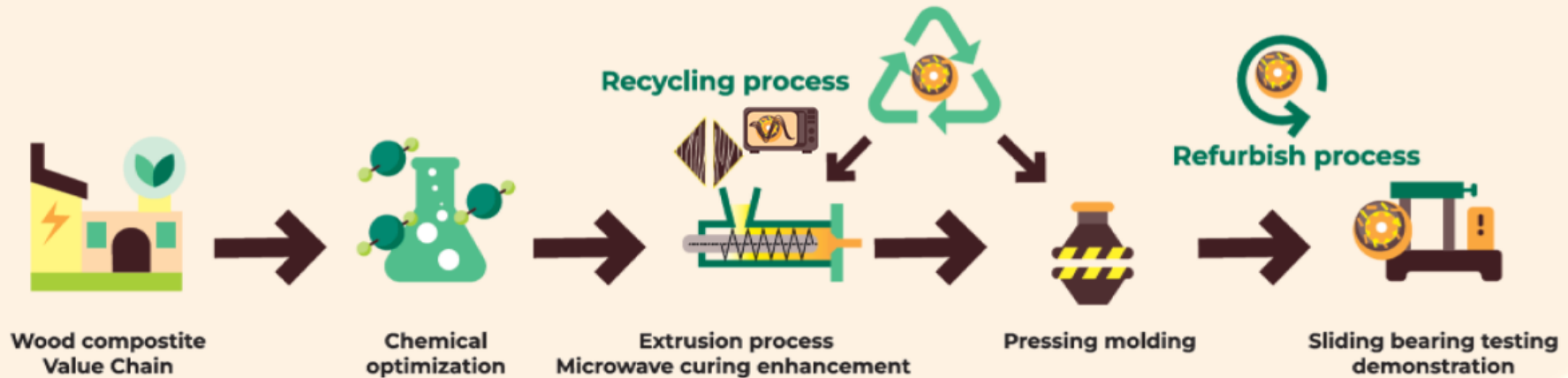
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# Wood composites material production

## Flow Chart



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# Wood Composites: Historical Context & Modern Applications

## Historical Context:

- Plywood dates back to ancient Egypt.
- Particleboard & MDF emerged in the 20th century as cost-effective alternatives.
- WPCs gained popularity in the late 20th century for durability.

## Modern Applications:

-  **Construction** – Flooring, roofing, wall panels.
-  **Furniture** – Cabinets, tables, shelving.
-  **Automotive Industry** – Door panels, dashboards.
-  **Outdoor Uses** – Decking, fencing, park benches.

## Definition:

Wood composites are engineered materials made from wood fibers, particles, or veneers combined with adhesives, resins, or polymers.



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# Comparison with Traditional Materials

## Key Characteristics:

-  More stable than natural wood (resistant to warping & cracking).
-  Can be customized for strength, moisture resistance, and aesthetics.
-  Often made using recycled or reclaimed wood, supporting sustainability.

Property	Wood Composites	Solid Wood	Plastics	Metals
Strength & Durability	Moderate to High	High	Moderate	High
Moisture Resistance	Treated composites are good	Poor	Excellent	Excellent
Workability	Easy to shape, cut	Moderate	Easy	Difficult
Sustainability	Uses recycled materials	Natural but slow-growing	Varies	High energy use in production
Cost	Generally affordable	Expensive	Affordable	Expensive

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# Key Components of Wood Composites

## 1. Key Components of Wood Composites

### •Wood Fibers or Particles:

- Sourced from sawdust, wood chips, or recycled wood.
- Provides structure and natural appearance.

### •Binding Agents (Resins or Adhesives):

- Synthetic (e.g., phenol-formaldehyde, urea-formaldehyde).
- Bio-based (e.g., lignin, starch, bioplastics).

### •Additives for Performance Enhancement:

- **Water Resistance:** Waxes and hydrophobic agents.
- **Fire Retardants:** Borates or other flame-resistant compounds.
- **UV Stabilizers:** Protect against sunlight degradation.
- **Colorants:** Dyes or pigments for aesthetic appeal.

## 2. Typical Composition Ratios (Varies by Type)

Component	Percentage (%)
Wood Fibers/Flour	50–80%
Resins/Binders	10–30%
Additives	5–15%

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# Renewable & Biodegradable Aspects of Wood Composites

## Wood Fibers/Flour

### Renewable Resource:

- Sourced from managed forests and fast-growing species.
- Supports sustainable forestry practices.

### Biodegradability:

- Natural fiber-based composites break down over time.
- Some composites are designed for compostability.

### Lifecycle Impact:

- Lower environmental footprint than non-renewable materials like plastics and metals.



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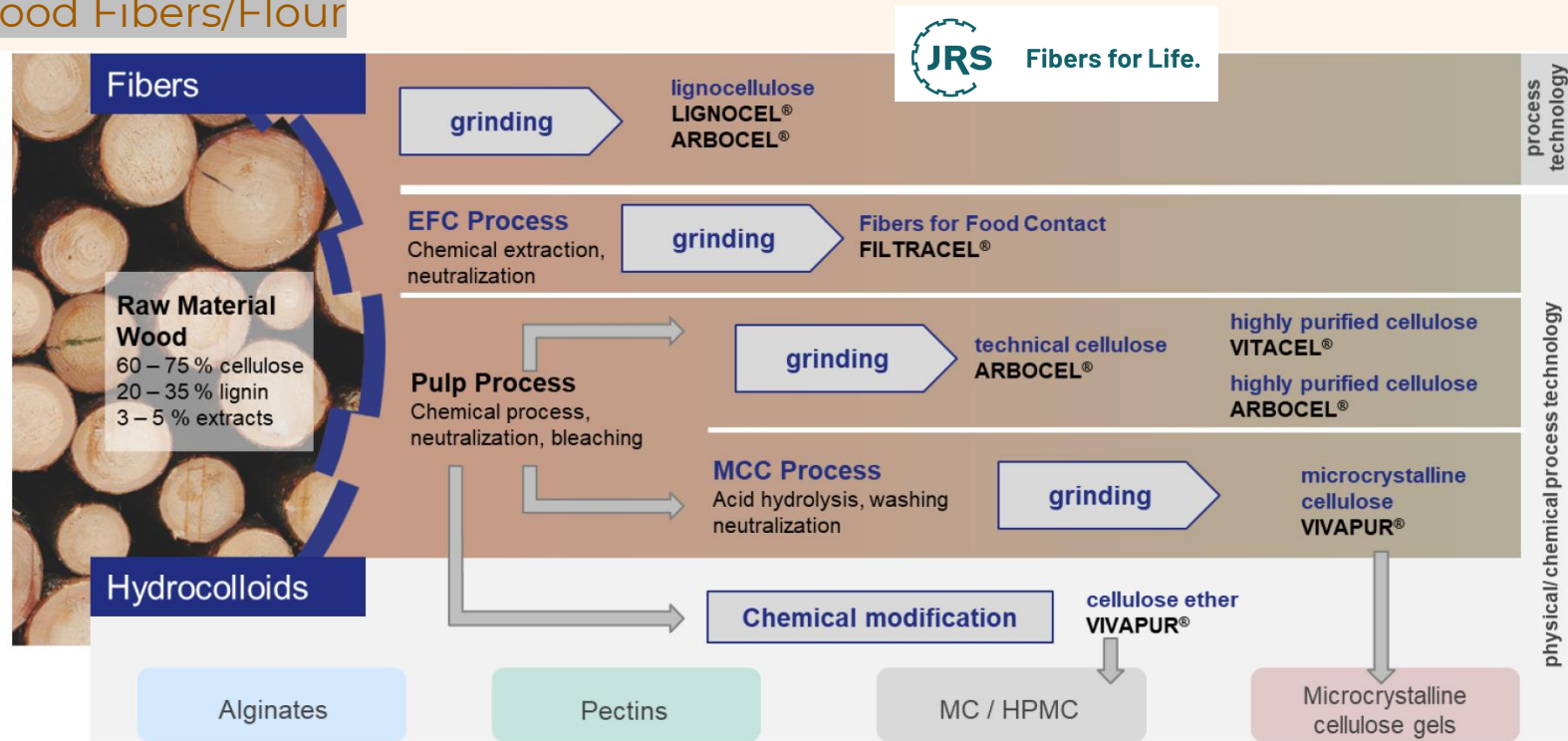
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# Renewable & Biodegradable Aspects of Wood Composites

## Wood Fibers/Flour



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# Renewable & Biodegradable Aspects of Wood Composites

## Wood Fibers/Flour

### ARBOCEL® and LIGNOCEL® cellulose fibers, wood particles and fibers

› Produced from untreated softwood  
sidestreams

#### Application examples:

- › biodegradation tuning (bioplastics)
- › porosity formation (ceramics)
- › crack-stopping properties (rubber)
- › rheology adjustment (glue, ceramics)
- › green strength (brake pads)

### ARBOCEL® product overview

	µm	5 - 13 µm	15 µm	30 µm	60 µm	100 µm	200 µm	300 µm	700 µm	1000 µm	2000 µm
<b>Micrystalline cellulose</b>											
UFC-100	8 - 10	■									
Heweten 101	65				■						
Heweten 12	150						■				
<b>Microcrystalline cellulose spheres</b>											
CS 300	300							■			
Spheres 700	700								■		
<b>Cellulose granules</b>											
EPG 70	300							■			
<b>Native cellulose (Hard wood)</b>											
BE 600-10-TG	18		■								
B 600	60				■						
B 800	130					■					
BC 200	300						■				
BC 1000	700							■	■		
B 400	900									■	
<b>Native cellulose (soft wood)</b>											
FDY - 600	60				■						
FIC 200	300							■			
FIC 500 P	600								■		
FIF 400	2000										■
<b>Off-white cellulose / technical grades</b>											
FD 600-30	45			■							
FD 00	150					■					
PWC-500	500							■			
<b>Grey fibers / technical grades</b>											
ZZC-500	400								■		
ZZ 8-1-G	1000									■	
<b>Wood fibers (soft wood)</b>											
CW 630-PU	30			■							
C 750-FP	70				■						
C 100	100					■					
C 400	250-600								■		
<b>Wood fibers (hard wood)</b>											
HB 120	40-120				■						
HB 300-900	300-800							■	■		
HBK 750-2000 LT	1200-1800									■	

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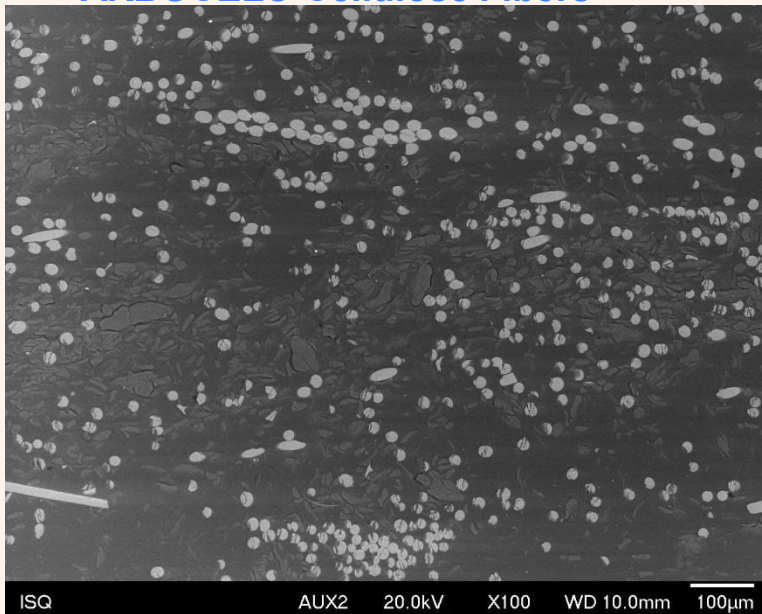


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# Renewable & Biodegradable Aspects of Wood Composites

## Wood Fibers/Flour

### ARBOCEL® Cellulose Fibers



ARBOCEL® B600

### ARBOCEL® Wood Fibers



ARBOCEL® C400



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# Renewable & Biodegradable Aspects of Wood Composites

## Binding Agents: Bio-based polymers

### 1. What are Bioplastics?

There is no standardized definition of a bioplastic

- A bioplastic is a biobased material and/or biodegradable

There are three major categories of bioplastics:

- Biosourced (obtained from renewable resources) and biodegradable materials
- Materials made using fossil fuels (oil) and biodegradable resources
- Biosourced and sustainable materials (non biodegradable)

<b>BIODEGRADABLE</b>	PBAT, PCL, PBSA	PBS, TPS, Starch-based compound, biobased TPE	PLA, PHAs, TPS
<b>NON BIODEGRADABLE</b>	PE, PP, PS, PET, PVC, PUR, PC, ABS, PA, etc.	Biosourced PET, biobased PA 6-10, biobased PC, biobased PUR, biobased TPE, PTT, biobased Copolyesters, Cellulose esters, Hybrids	Biosourced PE, biobased PP, biobased PA-11, biobased PA 10-10
	<b>NON BIOBASED</b>	<b>PARTIALLY BIOBASED</b>	<b>BIOBASED</b>

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# Renewable & Biodegradable Aspects of Wood Composites

## Binding Agents: Bio-based polymers

MATERIALS	ORIGIN / END OF LIFE	RESOURCES	PROPERTIES	APPLICATIONS
<b>Equivalents to oil-based versions (BioPET, BioPE, BioPA, BioPP, etc.)</b>	20 to ≈ 100 % biobased, not biodegradable nor compostable	Sugar cane, molasses, vegetable oils	Equivalent to standard polymers, remain recyclable and not biodegradable, easy to process	All kind of applications
<b>PLA</b>	≈100% biobased and 100% biodegradable and compostable	Corn starch, sugar cane, sugar beet, etc.	Transparent, rigid, low thermal resistance, low barrier properties	Food and cosmetic packaging, consumer goods, fibres, 3D printing
<b>PHAs</b>	≈100% biobased and 100% biodegradable and compostable	Corn starch, sugar cane, sugar beet, other biomasses	Opaque to translucent, rigid to very soft, good thermal resistance and barrier properties	Consumer goods, agriculture, packagings, water treatment
<b>Biopolyesters</b>	Partially biobased and 100% biodegradable and compostable	Corn starch, sugar cane, sugar beet, etc.	Opaque to translucent, rigid to very soft, good thermal resistance, low barrier properties	Bags, agriculture, packagings, consumer goods
<b>Cellulose based</b>	Mainly biobased and could be biodegradable and compostable	Wood pulp Transparent, rigid, low thermal resistance, low barrier properties	Transparent, rigid, good thermal resistance and barrier properties	Packagings, consumer goods, cosmetic and luxury
<b>Biobased elastomers</b>	Mainly partially biobased	Biobased polyols (vegetable oils, sugars, etc.)	Very soft, low hardness, good mechanical properties	Consumer goods, construction, automotive, sport and leisure
<b>Starch based</b>	Partially biobased and could be biodegradable and compostable	Starch (corn, potatoes, tapioca, etc.)	Soft, sensitive to moisture, controlled biodegradation	Bags, agriculture, packagings, consumer goods
<b>Biocomposites</b>	Partially biobased and could be biodegradable and compostable	Natural fibers with standard or biopolymers	Rigid, good mechanical properties, natural aspect	Consumer goods, automotive, construction

# Renewable & Biodegradable Aspects of Wood Composites

## Additives

### Plasticizers:

- › To improve dispersion of filler material in matrix and prevent aggregation of filler material together
- › Increase ductility
- › Polyethylene glycol (PEG), glycerol and tributyl citrate (TBC)
- › Proportion of plasticizer also important
- › Dispersion of filler material is directly proportional to mechanical properties
- › Fiber surface treatment is important

### Surface treatment:

- › Physical treatments
  - Stretching, Calendaring
  - Hydrothermal treatment
  - Plasma processing system
  - Thermo treatment
- › Chemical treatments
  - Alkali treatment (NaOH)
  - Benzoylation (NaOH + Benzoyl chloride and peroxide)
  - Bleaching (NaOH + Hydrogen peroxide)
  - Acetylation treatment (esterification)
  - Silane treatment (Coupling agent)



# Renewable & Biodegradable Aspects of Wood Composites

## Biocomposites by Stora Enso

Made from almost 100% bio-based materials, contains natural fibers

Grade	Wood Content	Tensile Strength <i>ISO 527-2/50</i>	Tensile Modulus <i>ISO 527-2/2</i>	Tensile E@B <i>ISO 527-2/50</i>	Flex Modulus <i>ISO 178</i>	Carbon footprint <i>ISO 14067</i>	Carbon footprint Eco-grades <i>ISO 14067</i>
<b>Pure</b>							
Pure S30	30 %	35 MPa	3600 MPa	2,2 %	3200 MPa	0,84 Kg/CO2	-0,92 Kg/CO2
Pure S40	40 %	43 MPa	4500 MPa	2,2 %	4200 MPa	0,5 Kg/CO2	-1,06 Kg/CO2
Pure S50	50 %	49 MPa	5700 MPa	1,8 %	5300 MPa	0,13 Kg/CO2	-1,22 Kg/CO2
Pure L40	40 %	37 MPa	4600 MPa	1,6 %	4300 MPa	0,5 Kg/CO2	-1,06 Kg/CO2
Pure L50	50 %	44 MPa	5500 MPa	1,6 %	5300 MPa	0,13 Kg/CO2	-1,22 Kg/CO2
<b>Plus</b>							
Plus S40 Impact D	40 %	50 MPa	4600 MPa	3,5 %	4400 MPa	0,75 Kg/CO2	-0,81 Kg/CO2
Plus S30 Flex K	30 %	27 MPa	1900 MPa	8,0 %	1900 MPa	0,84 Kg/CO2	-0,42 Kg/CO2
Plus S40 Flex K	40 %	31 MPa	2300 MPa	7,0 %	2300 MPa	0,5 Kg/CO2	-0,55 Kg/CO2
3D S50 Flex K	50 %	30 MPa	2700 MPa	7,0 %	2800 MPa	0,13 Kg/CO2	-0,67 Kg/CO2
<b>Prime</b>							
Prime C20 High GK	20 %	60 MPa	2600 MPa	12,0 %	2300 MPa	2,09 Kg/CO2	0,39 Kg/CO2
Prime S30 High GG	30 %	50 MPa	2800 MPa	9,5 %	2600 MPa	1,33 Kg/CO2	-0,28 Kg/CO2
Prime S40 Impact I	40 %	64 MPa	4600 MPa	6,0 %	4300 MPa	1,26 Kg/CO2	-0,30 Kg/CO2



storaenso

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**!!! Stora Enso produces no more biocomposites as to 2023 !!!**



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# Renewable & Biodegradable Aspects of Wood Composites

Biocomposites by Tecnar



The Tecnar GmbH is an innovative company that develops and produces its own bioplastics and biocomposites based on renewable raw materials.

## Product overview: ARBOBLEND®

- › ARBOBLEND® combines a great number of material types and a wide range of property profiles.
- › The materials on offer are up to 100% bio-based.
- › Depending on the formula, ARBOBLEND® materials contain biopolymers such as polyhydroxyalkanoates (PHA), polycaprolactone (PCL), polyester (e.g. bio-PET), starch, polylactic acid (PLA), bio-polyolefins (bio-PE), bio-polyamides (bio-PA), lignin, natural resins, natural waxes, natural oils, natural fatty acids, cellulose, organic additives and natural reinforcing fibres.
- › ARBOBLEND® materials are designed to be biodegradable or resistant depending on the intended application. Biodegradability is a property that offers an additional benefit in applications such as urns, plant aids, mulch films and many other uses.

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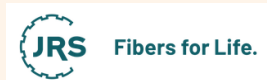
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# Manufacturing Process of Wood Composites

→ Biopolymer Mix



→ Wood Fibers  
size < 1 mm



→ Fillers (Fibers)/  
additives



Batch 1	Batch 2	Batch 3
12 Materials	7 Materials	12 Materials
Biopolymer Mix 1	Biopolymer Mix 2	Biopolymer Mix 2
+ Graphite	+ Wood Fibres	+ Wood Fibres
	+ Recycled Glass Fibres	+ Recycled Glass Fibres
	+ Lignin	+ Lignin



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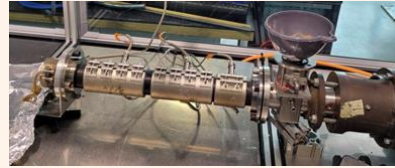
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# Manufacturing Process of Wood Composites

Compounding  
with Eirich Mixer



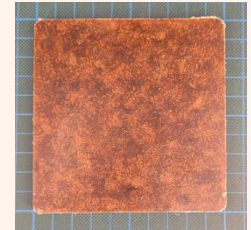
Extrusion



Extrudate  
cutting



Test plate  
moulding (100 x  
100 x 5 mm)



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# Manufacturing Process of Wood Composites



MW-system and sensor integration into extruder system for WC extrusion



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# Manufacturing Process of Wood Composites

## ➤ Microwave barrel adaptation/manufacturing



Metallic barrel – not suitable for MW



Fiber glass composite barrel – suitable for MW



New fiber glass composite barrel – manufacturing



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# Manufacturing Process of Wood Composites



- Successful WC manufacturing with the MW help
- Tribological testing and validation

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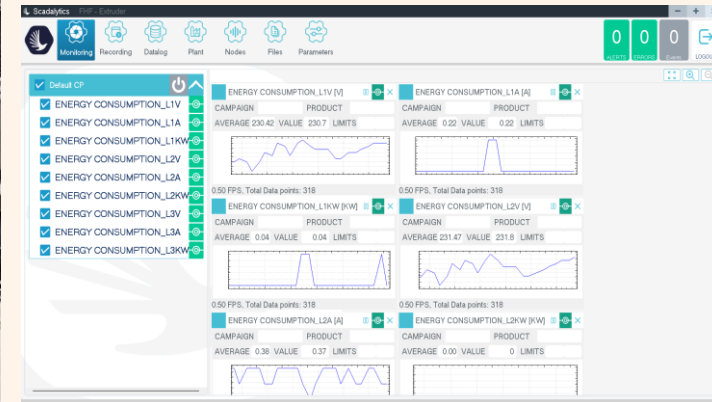
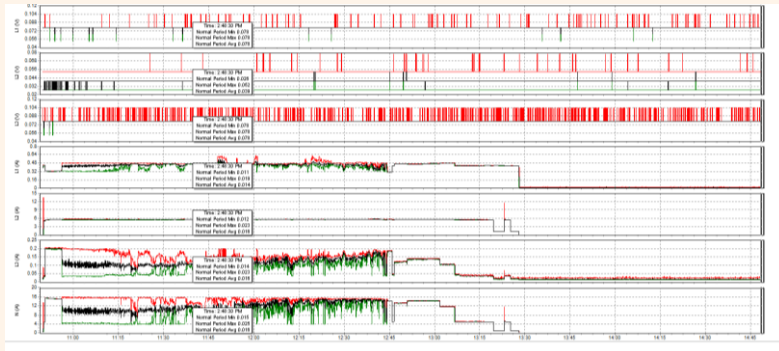
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# Manufacturing Process of Wood Composites

- Online monitoring of energy consumption (IRIS)
- Preliminary results:
- Conventional heating extrusion: 3,2 kWh
- Microwave heating prototype: 3,0 kWh



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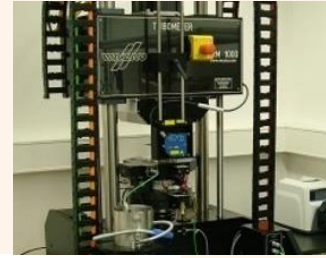
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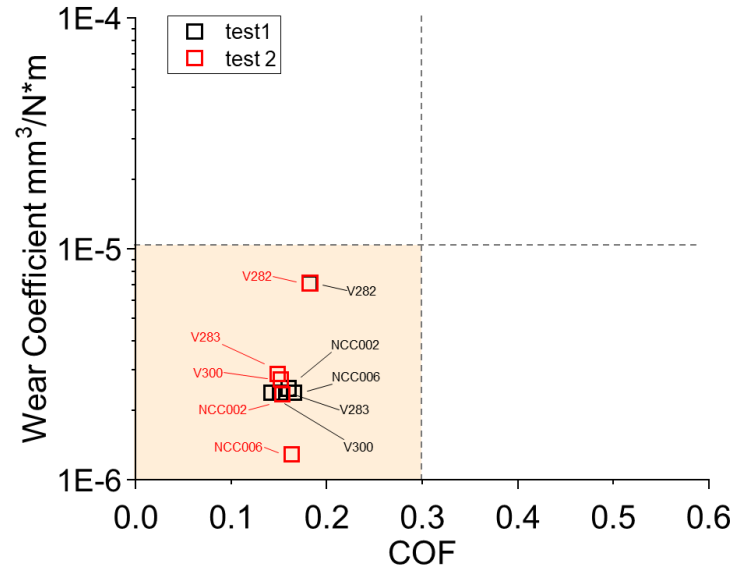
# Tribological testing and validation



*Overview of friction and wear results of*

- *Material panels from NCC (NC\*)*
- *Material produced with MW assistance (V300)*

**→** *Very good wear properties reproduced and confirmed*



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# Summary and Outlook

-  Very low friction coefficients achieved with Wood composites.
-  Good wear resistance of WC, comparable with various PA4.6 benchmark materials.
-  MW-system and sensor integration into extruder system to reduce energy consumption.
-  Manufacturing net-shape WC bearing prototypes and their testing in industrial environments (TRL6).

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## Q&A / discussion

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