The Biofore Company UPM

LIGNIN BASED RESINS – RECENT DEVELOPMENTS

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UPM – The Biofore Company

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- Major producer of pulp (~3,6 mio to / a), graphical paper, labels, plywood, and renewable energy
- Emerging businesses in Biofuels, Biochemicals, and Biocomposites
- Headquarter in Helsinki Finland – listed on Helsinki stock exchange
- Sector leader in the Dow Jones Sustainability Index for 5 consecutive years
- Sales 2015: EUR 10.1 billion
- Personnel: 19,600

- 8 years experience with lignin-application development
- focus on lignin-based resins for the wood-products industry

Business Model - LPF

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Target group

- **producers of PF-resins and their customers** who seek to implement innovative and cost-effective resin technology, but do not want to use or do not have corresponding capabilities

Model

- **customized solution provider**, re. each aspect the implementation process

Key activities

- **Understand customers production system and cost-position**, and **translate into a ready-to-implement solution**

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Proprietary Approach For Lignin Activation And Resin Composition

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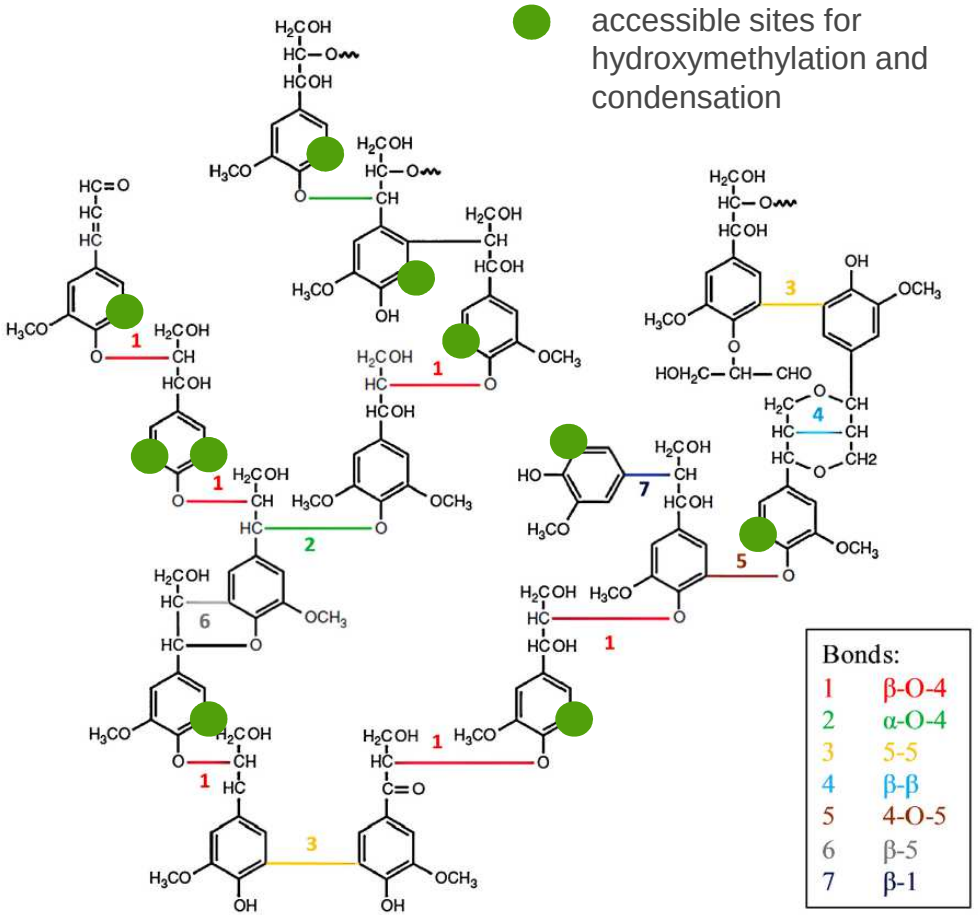
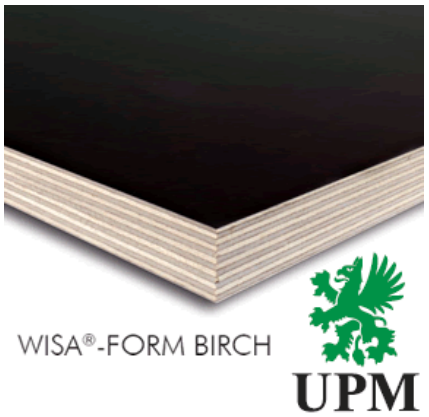


Structure of softwood-lignin, according to Laurichesse, S.; Avérous, L., *Progress in Polymer Science* **2014,** *39* (7), 1266-1290

Leverage synergies with our colleagues from UPM Plywood



IP-situation

Key patents for lignin activation and and resin composition granted in Finland.

Patents for lignin-activation granted in CAN, US, and EU (allowed).

Further applications pending.

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Chimar Hellas – Binding Innovation

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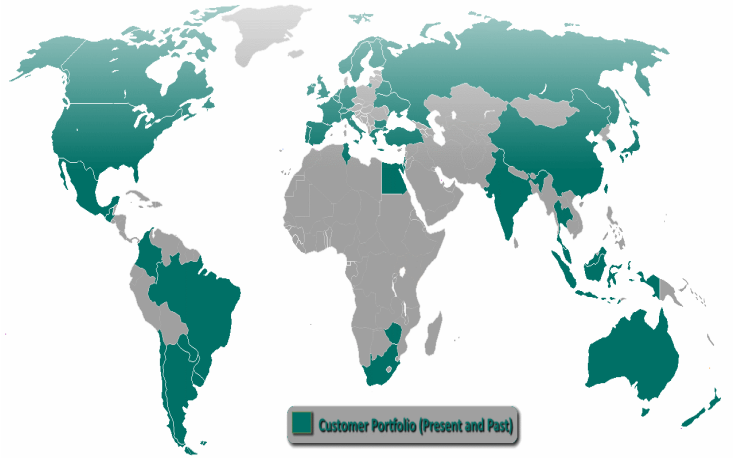
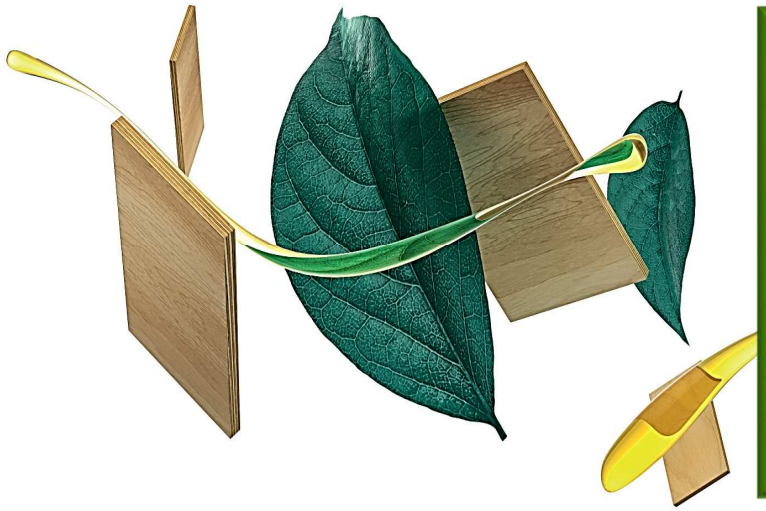
Division	% turnover
Royalties and Tech. support	50%
3rd party R&D	20%
EU Funded Projects	20%
Engineering services	≈5%
Industrial equipment representation	≈5%





Since 1977

40+ countries

>1MT resin per year

TEAM of 28

100+ industrial sites

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Review: September 2014
Successful Full-Scale Trial with 50% Phenol Replacement

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Product	9-ply 12mm birch plywood
Press factor	0.75min/mm
Press temperature	130^0C
Open time	Up to 30 minutes
Tack	10 / 10
Waiting time	Up to 3 hours
Resin in Glue mix	32.5%
Glue factor	150g/m^2

Results – EN314-1	PF-ref.	LPF
strength a. soaking [Mpa]	**2,2**	**2,1**
wood failure a. soaking [%]	97	98
strength a. boiling [Mpa]	**1,9**	**1,9**
wood failure a. boiling [%]	97	97

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Review:
Still Many Open Questions At That Time

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Is raw material quality stable enough?

Can we get similarly good results on spruce and other wood species?

Can we get LPF-resins to run on curtain coaters?

Can we scale-up resin production to the biggest reactors?

How is compatibility to various hardener systems?

Is there development potential towards higher phenol replacement rates?

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Softwood-Kraft-Lignin
Availability and Quality-consistency

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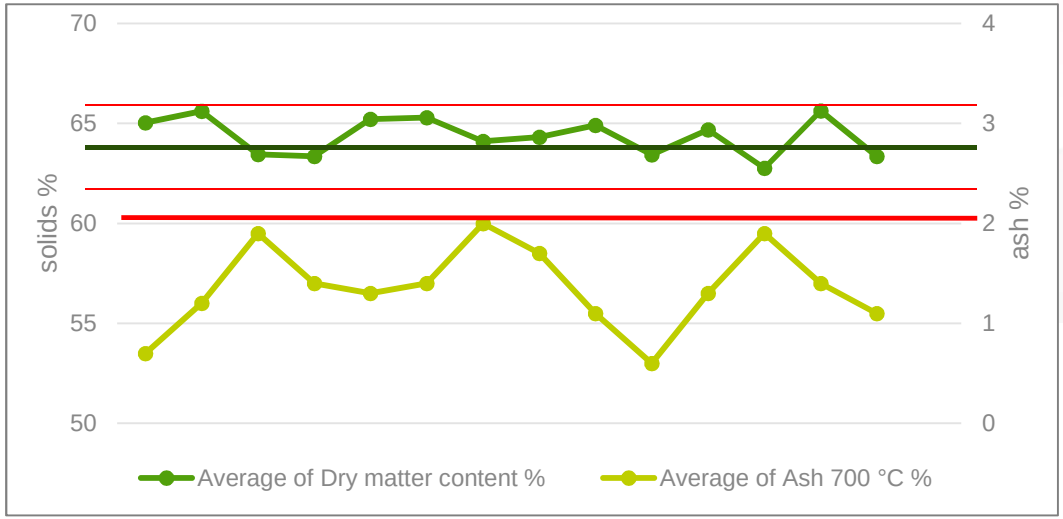
Producer	Design capacity	remark
Domtar / US	25.000 to	since 2014 – our key raw material
Stora Enso / Finland	50.000 to	Supplies dried product (95% dry solids)
West Frazer / CAN	10.500 to	Announced as demo facility / just started

Batch-to-batch fluctuations at Domtar are really small



➔ We have a material we can actually work with!

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Expanding the Range wood species!

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Wood species	Approval
Birch	✔
Spruce	✔
Birch Spruce Combi	✔
Pine	✔
Eucalyptus	✔
Oak	✔
Poplar	✔

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Development of LPF-resins for curtain-coaters

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Pilot-test at Raute:

- LPF 500 (50% phenol replacement) + commercial hardener
- objective: Find formulation that provides a stable curtain with different additives/surfactants
- dosage of the additives 0%, 0.5% and 1%

LPF-resin + hardener without additives

=> curtain breaks from the bottom

1% Additive A – stable curtain

1% Additive B – stable curtain

0,5% Additive C – stable curtain

Conclusion:

- various standard surfactants for PF-curtain resins are well-compatible with LPF-resins

Can We Push It to Higher Phenol Replacement Rates?

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Yes, we can! Some tweaks required (done meanwhile).

9-ply birch plywood – 2mm veneers

		Soaking		Boiling	
LPF750		WF%	Strength N/mm2	WF%	Strength N/mm2
PFL-750, commercial hardener from Prefere Resins	**avr**	**57**	**2,6**		
	surface A	69	3,0		
	middle	41	2,0	40	1,7
	surface C	63	2,9		
Standard-PF-reference + commercial hardener	**avr**	**78**	**3,0**		
	surface A	69	3,2		
	middle	89	2,5	64	2,1
	surface C	76	3,3		

- ➔ clear indication that LPF-resin was undercured in the middle glue line
- ➔ can be compensated either through slight reformulation or adaptation of the pressing-regime
- ➔ fast dry-out of the resin as one challenge!

Formaldehyde emmission of panels with LPF-resin according to EN717

Average emmission	Average moisture
0,091 mg/m2/h	12,48%

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Further Reactivity Increase For Short Press Cycles and Low Press T

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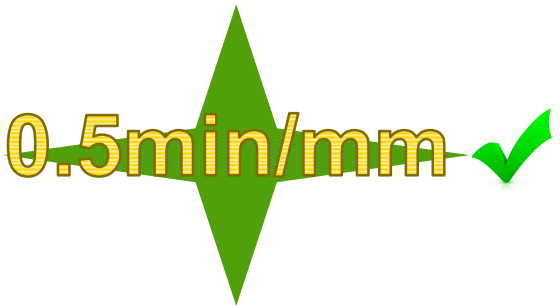
Reactivity A.K.A. The BIG Challenge!!

Voice of the customer: our process is at low temperature (110ºC)
and we want to press fast and of course no cost increase!

It is well known from the literature that the phenolic resins are catalyzed by alkali metals and alkali earths, selection of the right combination is critical

pH
Alkalinity
Resin Molar Ratio
Linear vs. Crosslinked molecules (crosslink density)
Resin cooking and synthesis parameters have an effect on reactivity

Version	Gel time (100ºC)
Original	56’
Modified	45’



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Additional Findings

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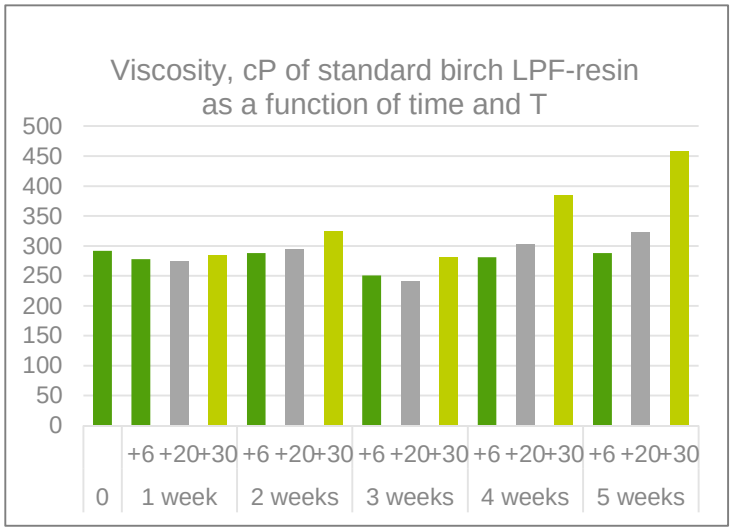
- Scaleability of resin production to large reactors
- Compatibility to various types of hardeners / extenders
- Continuos runability on large lines
- Lignin-handling
- Storage stability



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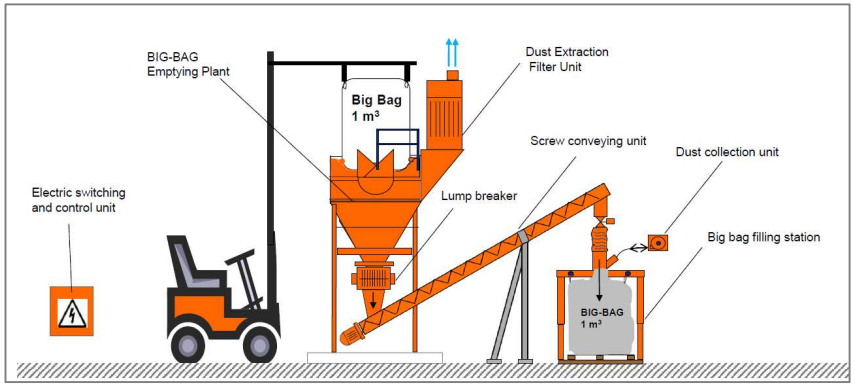

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Lignin-based Phenolic Resins For Production of High Pressure Laminates (HPL)

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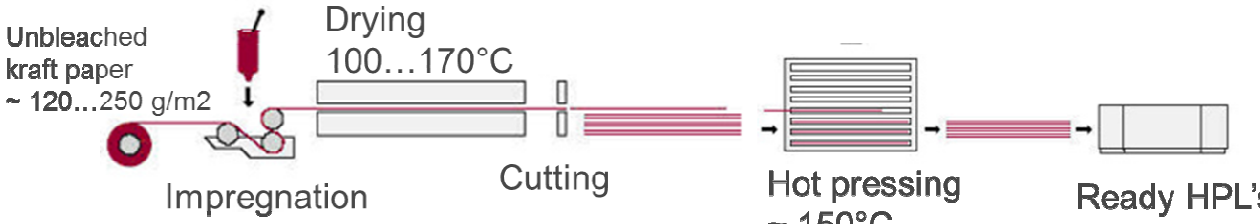
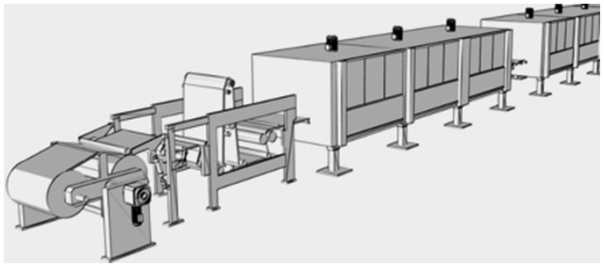
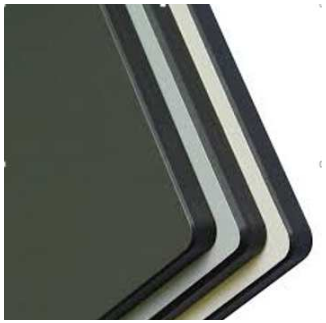


PF = phenol formaldehyde
LPF = lignin phenol formaldehyde





- Very demanding application, due to complexity of the production process, the quality-requirements for the final product, and the polymeric nature of softwood-lignin
  ➔ surface quality typically good; good penetration and flow as the most critical parameters regarding moisture resistance
- Resins with 30% phenol replacement validated at full-scale; 50% replacement validated at lab/pilot scale in both, thin laminates and compact boards

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Outlook

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Expansion into OSB and LVL is underway



Further increase phenol replacement rate, up to 100% phenol-free resins

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Conclusions – Take Aways

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Lignin-based phenolic resins meanwhile are fully proven on a broad variety of industrial lines and veneer types

Lignin raw material quality is stable and on a very high level

Further improvements, especially regarding reactivity, robustness, shelf-life could be realized

LPF-resins for high-pressure laminates (both thin and compact) have been successfully qualified on full scale – strong pull from the industry to improve renewable content of the product

Besides plywood, OSB and LVL are under intensive development; the door is wide open towards cost-effective, high-performance, phenol-free resins.

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