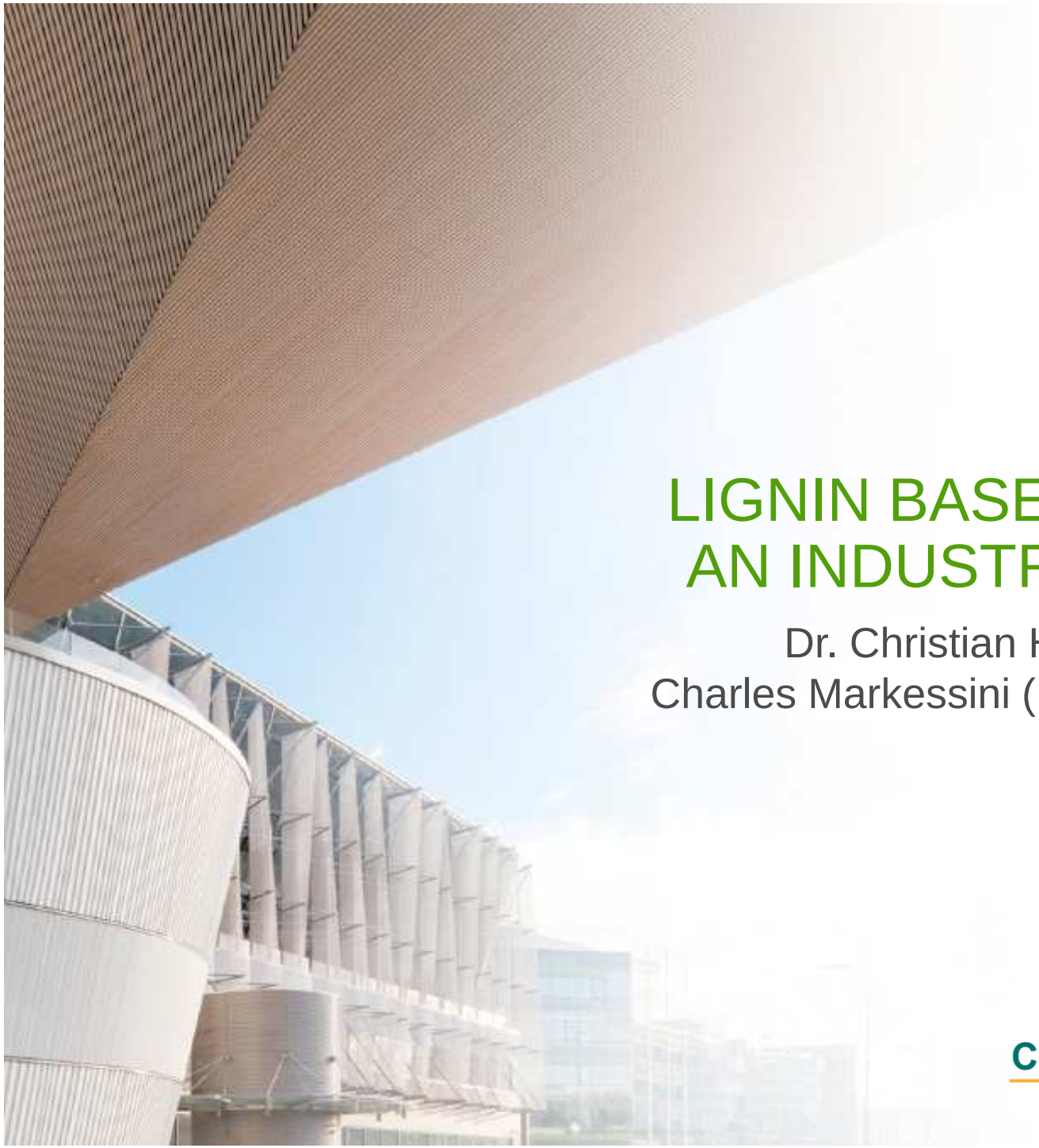


The Biofore Company UPM

# LIGNIN BASED BINDERS - AN INDUSTRIAL REALITY

Dr. Christian Hübsch, UPM GmbH
Charles Markessini (MSc), Chimar Hellas

Chimar Hellas S.A.

# UPM Today

The Biofore Company UPM

**UPM Biorefining**

- Pulp
- Plantations
- Biofuels
- Sawmills

**UPM Plywood**

- Plywood products

**UPM Paper Asia**

- Fine papers in China
- Label papers globally

Turnover 2013: **EUR 10 billion**

Personnel: **21,000**

Shareowners: **over 90,000**

**UPM Paper ENA**

- Magazine papers in Europe and the USA
- Newsprint and fine papers in Europe


**UPM Raflatac**

- Label materials for product and information labeling

**UPM Biocomposites**

**UPM Biochemicals**

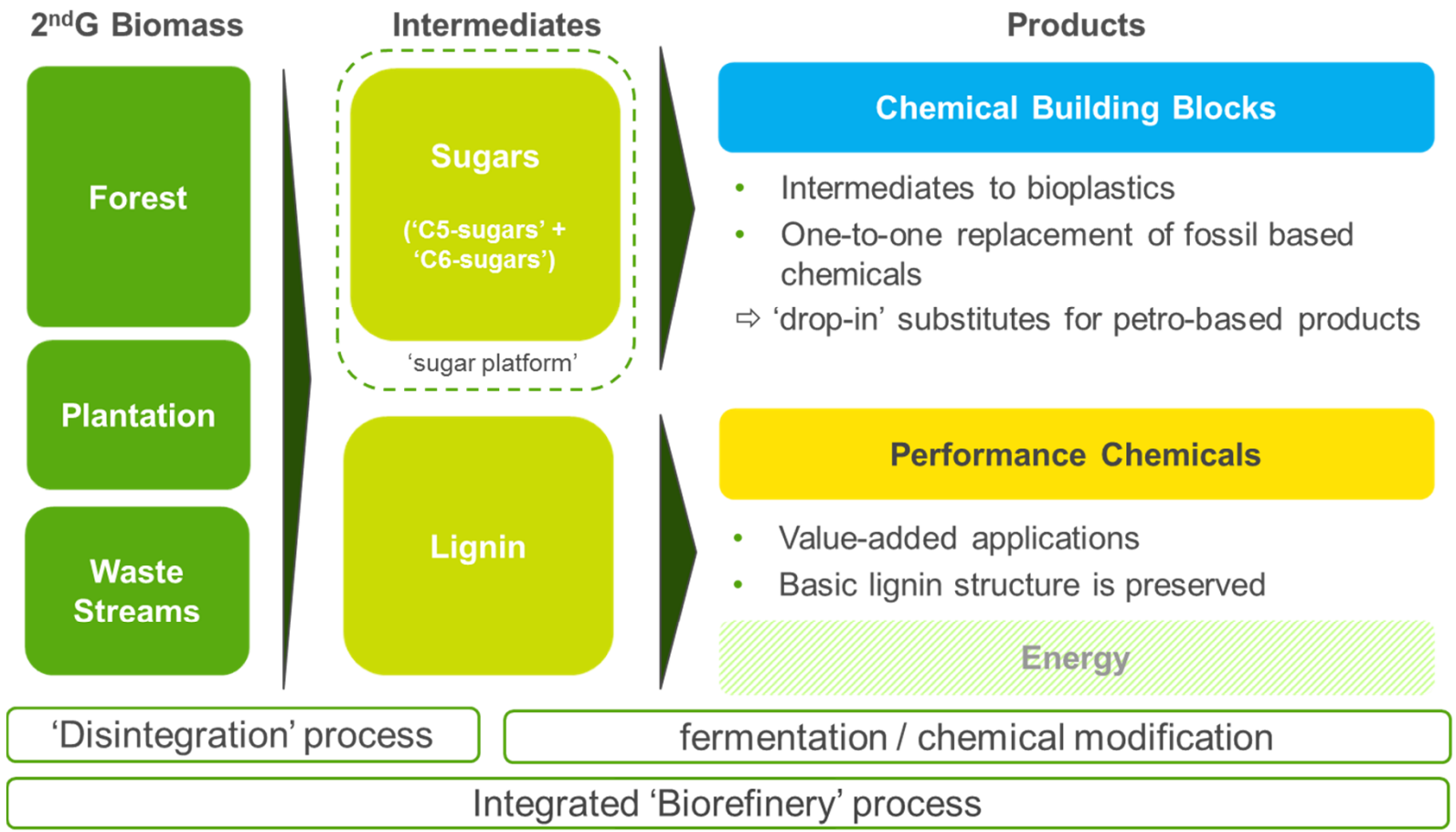
**UPM Energy**

- Hydro-, nuclear- and condensing power (incl. shares in energy companies)
- Electricity production and trading

# UPM Biochemicals Approach –
## Add Value to 2ndG Biomass through Chemical Building Blocks and Performance Chemicals

The Biofore Company UPM

### Partnership in lignin-based resins with Chimar Hellas

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## Lignin

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- Structural material to add strength and to cell walls (20-30% of dry wood matter)
- Origin (e.g. softwood vs. hardwood) and separation process strongly determines properties of technical lignin
- In existing processes the lignin from kraft processes is usually burned for energy production
- Today high quality kraft lignin's can be separated utilizing using industrially proven technology

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# Current and Future Sources of Lignin – know-how about structure-property relations is crucial

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## Lignosulfonates

- By-product from sulfite pulping process
- Often high content of inorganics and residual carbohydrates
- High molecular weight and sulfonate functionality limit its applications in resins

## Kraft Lignin

- By-product from kraft pulping process
- Commercially accessible via LignoBoost process
- High purity levels and consistent product quality
- High value applications ready to enter to market

## 'Biorefinery Lignin'

- Originating from various different processes, e.g organosolv-type or enzymatic hydrolsis)
- Not commercially accessible today
- Bio-mass type and biorefinery process determine product properties

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# Kraft Lignin is Now Available in Commercial Quantities

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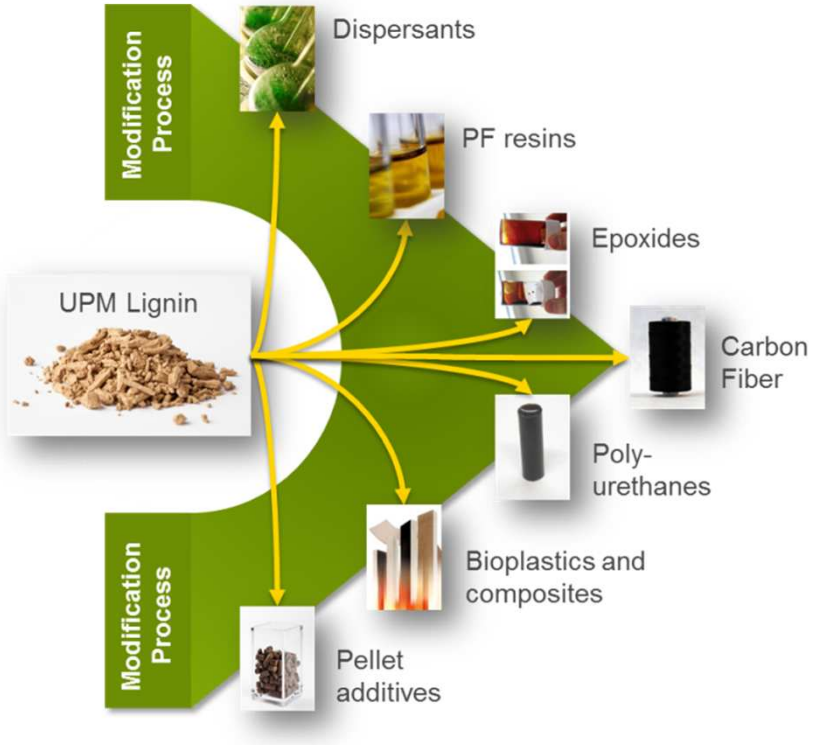
- 2013 the first commercial LignoBoost (Valmet) plant was started up 2013 by Domtar, Plymouth/NC
- As of 1st August 2014, UPM is exclusive distributor of Domtar BioChoice™ in Europe

BIO CHOICE™ A DOMTAR BUSINESS

- Kraft lignin can be used as raw material for various applications
- UPM Biochemicals has developed significant know-how in lignin analytics, structure-property relations, fractionation, purification, modification and applications.

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# The Task: Can Lignin Be Used In PF-based Wood Adhesives?

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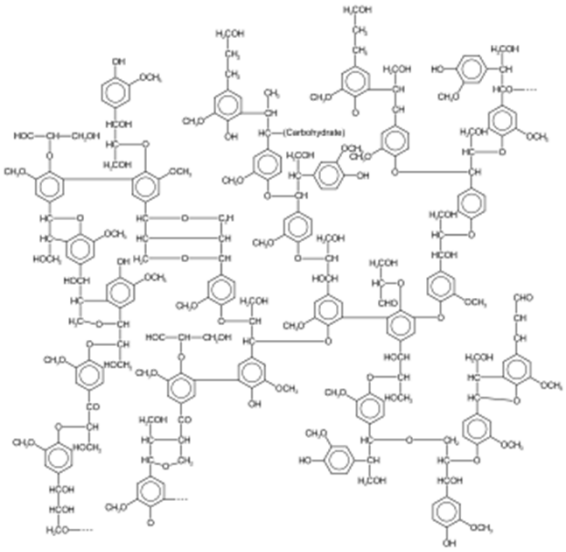
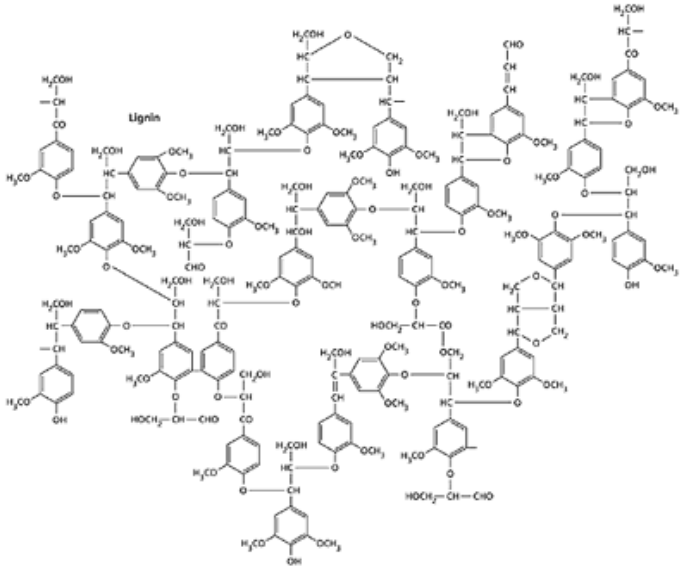
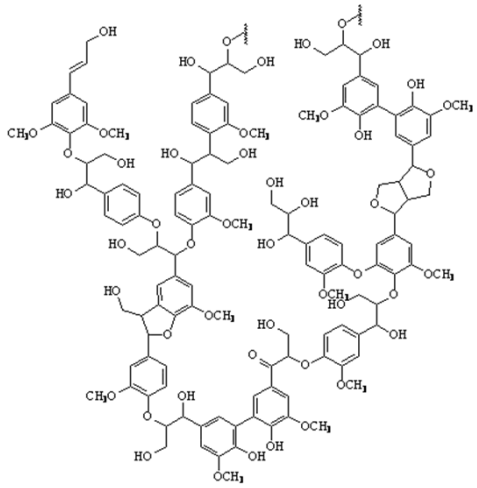
According to literature: yes
In practice: not more than 20% phenol replacement





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## Phenol replacement in plywood adhesives

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Attempt 1: Replace toxic liquid with benign brown powder but the result was rather chewable!!


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# Attempt 2: Chemical treatment of lignin

In theory, breaking down lignin into smaller fragments should increase reactivity.

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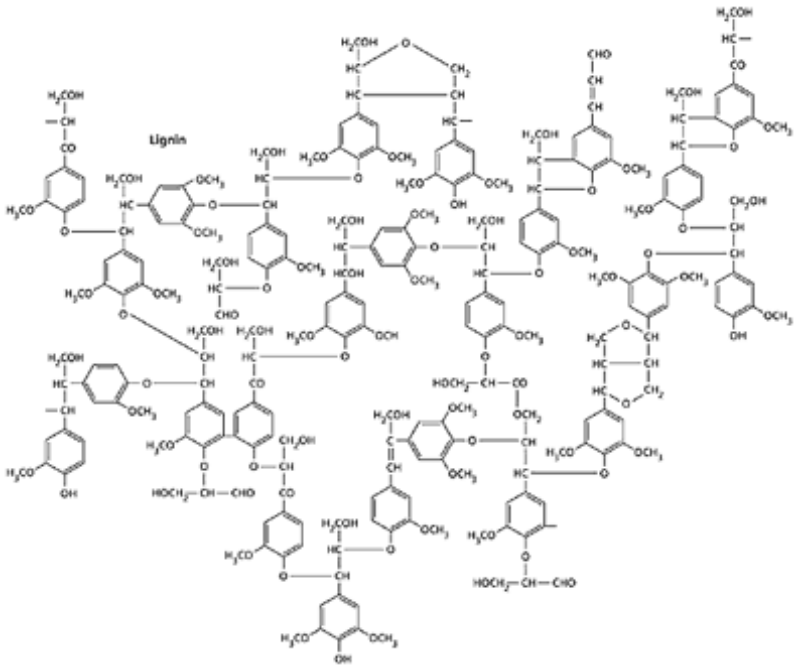
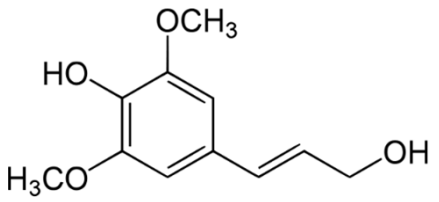
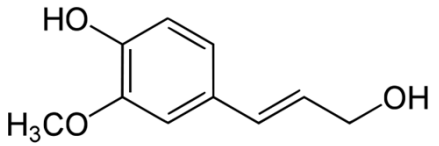


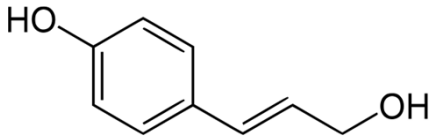

"IDEAL"




p-Coumaryl Alcohol




Coniferyl Alcohol




Sinapyl Alcohol

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## Properties of resins from chemically treated lignin

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ADVANTAGES:

- Viscosity increase was observed in alkaline environment thus:
  - A reaction takes place!
  - A “resin” is produced!
- 5-ply Birch plywood produced was classified as class 3 (Exterior Uncovered) according to EN 314-2:1993

DISADVANTAGES:

- Low reactivity (Gel time 100$^{o}$C: 100min.)
- Viscosity tripled in a week at 20$^{o}$C
- Plywood produced but low tack and wood failure was zero

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# Attempt 3: Partial replacement of phenol by activated lignin (50%)

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- A PFL adhesive was formulated with acceptable properties and performance!

| Application | Plywood |
|---|---|
| Phenol substitution level | 50% |
| Solids, % | 43.4 |
| Viscosity 25$^0$C, mPa•s | 290 |
| pH 25$^0$C | 12.6 |

| Product | 9-ply 12mm birch plywood |
|---|---|
| Press factor | 0.75min/mm |
| Press temperature | 130$^0$C |
| 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$^2$ |

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# Mechanical Testing

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| Pre-treatment, EN 314-1:2004 | Soaking 5.1.1 | Cooking 5.1.3 |
|---|---|---|
| Press Factor, min/mm | 0.75 | |
| Top glue line | | |
| Fv, N/mm$^2$ | 2.06 | 1.84 |
| %W | 96 | 96 |
| Middle glue line | | |
| Fv, N/mm$^2$ | 2.03 | 1.68 |
| %W | 95 | 98 |
| Bottom glue line | | |
| Fv, N/mm$^2$ | 2.26 | 1.92 |
| %W | 99 | 99 |

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## Pilot trial in South America
## 50% Phenol Replacement

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| veneers | Eliotti Pine |
|---|---|
| Daily production, $m^3$ | 250 |
| % Resin solids in glue mix | 28.0% |
| Glue factor, liquid $g/m^2$ | 180 |
| Maximum assembly time, min | 50 |
| Thickness to test, mm | 18 |
| No. of veneers | 5 |
| Veneer thickness, mm | 1.9 |
| Pressing temperature, ℃ | 130 |
| Press factor, min/mm | 0.78 |

| auto-clave | | cyclic test | |
|---|---|---|---|
| Fv, $N/mm^2$ | %W | Fv, $N/mm^2$ | %W |
| 1.31 | 82 | 1.18 | 82 |

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# Applications beyond wood products
# Industrial example: mineral wool @20% phenol replacement

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| ID | Sample ID | thickness [mm] | density [kg/m$^3$] | | tensile strength [kPa] | | compressive strength [kPa] | | point load [N] | |
|---|---|---|---|---|---|---|---|---|---|---|
| PF resin | 2.1.9 | 50 | 153.9 | 153 | | | 68.9 | 65.0 | 809 | 701 |
| | 2.1.10 | | 153.5 | | 24.2 | 26.6 | 67.1 | | 655 | |
| | 2.1.11 | | 151.2 | | 33.3 | | 67.1 | | 840 | |
| | 2.1.12 | | 150.5 | | 23.5 | | 63.0 | | 550 | |
| | 2.1.13 | | 153.4 | | 25.4 | | 57.1 | | 674 | |
| | 2.1.14 | | 156.3 | | | | 66.8 | | 678 | |
| PFL resin | 2.2.15 | 50 | 143.9 | 147 | | | 64.2 | 65.3 | 692 | 717 |
| | 2.2.16 | | 149.8 | | 39.9 | 27.1 | 69.7 | | 738 | |
| | 2.2.17 | | 145.8 | | 22.5 | | 66.1 | | 724 | |
| | 2.2.18 | | 143.0 | | 23.1 | | 63.5 | | 681 | |
| | 2.2.19 | | 145.8 | | 22.9 | | 61.3 | | 746 | |
| | 2.2.20 | | 152.1 | | | | 67.2 | | 720 | |

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# Applications beyond wood products
# Lab example: HPL

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Neither blisters nor delamination were observed!

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## Conclusions

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- A method for activation/modification of lignin has been developed
- The activated/modified lignin shows:
  - Reactivity towards formaldehyde
  - A clear potential to substitute significant quantities of phenol in various applications
- At an industrial scale lignin has substituted:
  - 50% of phenol in two separate plywood mills
  - 20% of phenol in one mineral wool plant
- At a lab / pilot scale:
  - 50% phenol substitution in HPL
  - 75% in plywood

# Initial Portfolio

The Biofore Company UPM

## UPM BioPiva™ 238

Alkali activated aqueous solution of Kraft lignin for alkaline phenolic resins. Ideally suited for phenolic resins for plywood, OSB and particleboard.

(products for other applications are available upon request)

## Domtar BioChoice™

purified softwood kraft lignin

# Lignin-Based Binders – an industrial reality

The Biofore Company UPM

Based on 100% bio-based, purified, lignin product, available in industrial quantities.

'Lead' resin formulations and formulation support available to resin producers and applicators for a fast growing range of applications.

Excellent performance - stringent quality control and our proprietary technology allow for reliable and effective binder formulation.

Depending on the application, 75% replacement of phenol and a significant reduction in formaldehyde used for producing resins are possible in resole-type PF resins, without compromising performance.

Reduced dependency on fossil raw materials - lignin-based products can help to increase security of supply while enabling a smooth transition to renewable raw material.

Cost savings - based on their outstanding performance, UPM's lignin based solutions can help realize cost savings in a variety of applications.

Chimar Hellas S.A.

# Thank You!

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