

# 2025 International Conference on Nanotechnology for Renewable Materials

8–11 July 2025 | Girona, Spain

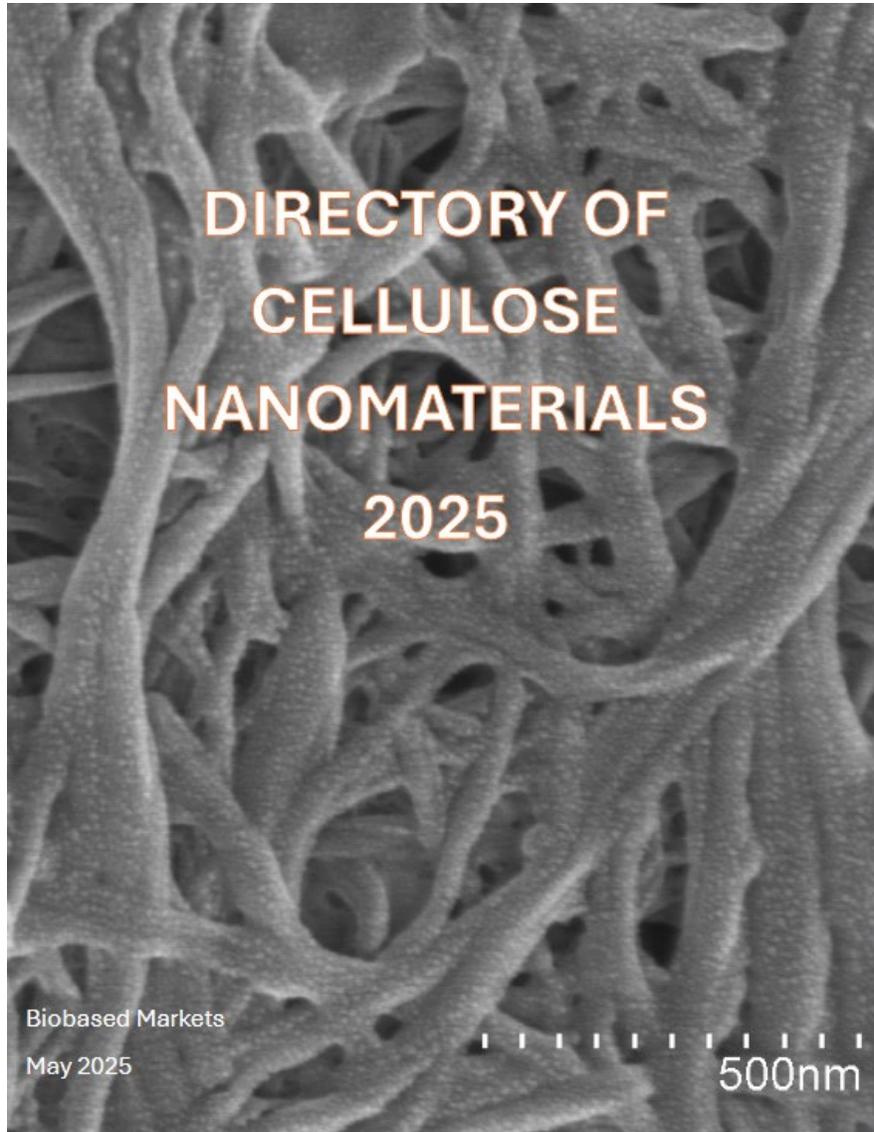
## Valorization of Lignin and Cellulose Nanomaterials: State of the Industry

Presented by  
Jack Miller, Biobased Markets, Market-Intell LLC



# Agenda

- Challenges
  - Cellulose nanomaterial valorization
  - Lignin valorization
  - State of the Industry
- 
- Appendix



## Lignin 2021

A pivotal year

By Jack Miller

**BioBased  
Markets**

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# Key Points

- Valorization equals commercialization.
- Total system economics are critical: energy, capex, opex.
- Commercial challenges can be more significant than technical challenges.
- Collaboration with key customers needed.

# Commercial challenges for new materials

- Need solid value proposition through the supply chain
- Total system economics
- It is not a “drop in” solution
- Market and applications development
- Which material is best for a given application?
- Collaboration
- Lack of multiple sources of supply
- Scale up in production
- Funding challenges: the Valley of Death
- Safety and regulatory issues

# Cellulose Nanomaterials Valorization

- Strength
- Barrier
- Rheology
- Environmental

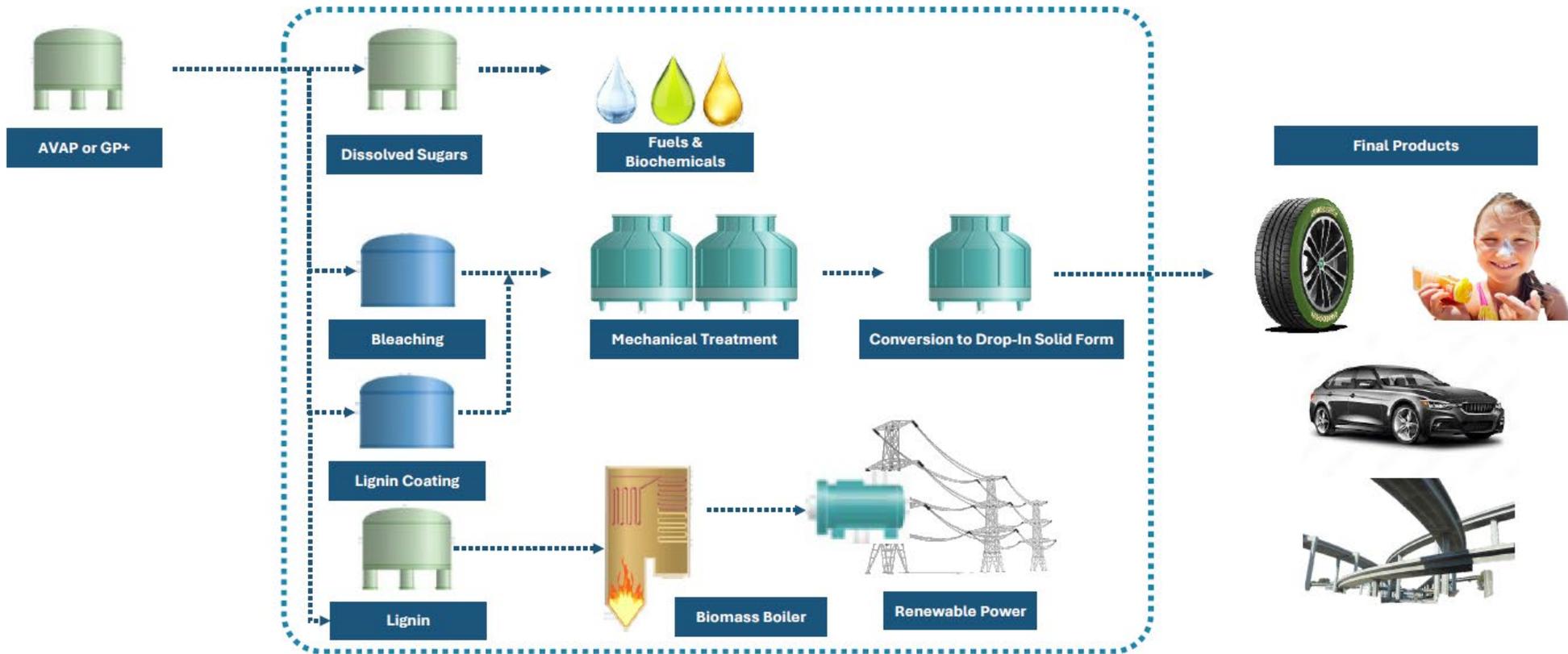
# Cellulose Nanomaterials Economics

- Scale
- Location
- Raw material cost
- Technology
- Drying and redispersion
- Compatibilization

# Commercial Development

- CelluForce
  - Schlumberger: drilling fluids
  - 10 year agreement with multinational cosmetics company
  - Wet spinning of smart textiles
- Sappi
  - Rheology for cosmetics, cement, coatings
  - Barrier for molded fiber and food packaging
- Borregaard
  - Exilva® entangled, fibrillated cellulose fibres for barrier coatings, rheology modifiers, etc.
- Nippon
  - TEMPO
  - CNF reinforced plastic
  - Food and cosmetics
- GranBio
  - Scale-Up of Nanocellulose Dispersion Composite (NDC™) rubber masterbatch with Birla Carbon
- Fibenol
  - Woodcell flagship project: micro-scale specialty cellulose for paper and packaging, energy storage, etc. with DS Smith, Coatex, Skeleton Technologies, RISE, EPFL, others

# GranBio BioPlus™ Industrial Process



Notes: GP+ BioPlus process typically does not include bleaching

# FiberLean<sup>®</sup> MFC in White Top Liner

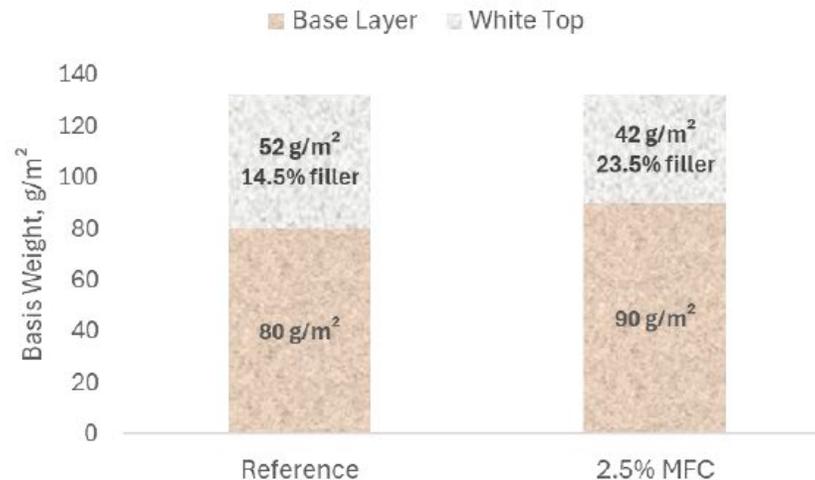
## Case Study – Filler Increase & Lightweighting (White Layer)

### Trial Outcomes:

- 2.5% MFC in white layer.
- +9% filler in the white layer.
- 10 g/m<sup>2</sup> of top layer replaced by brown layer.

### Benefits:

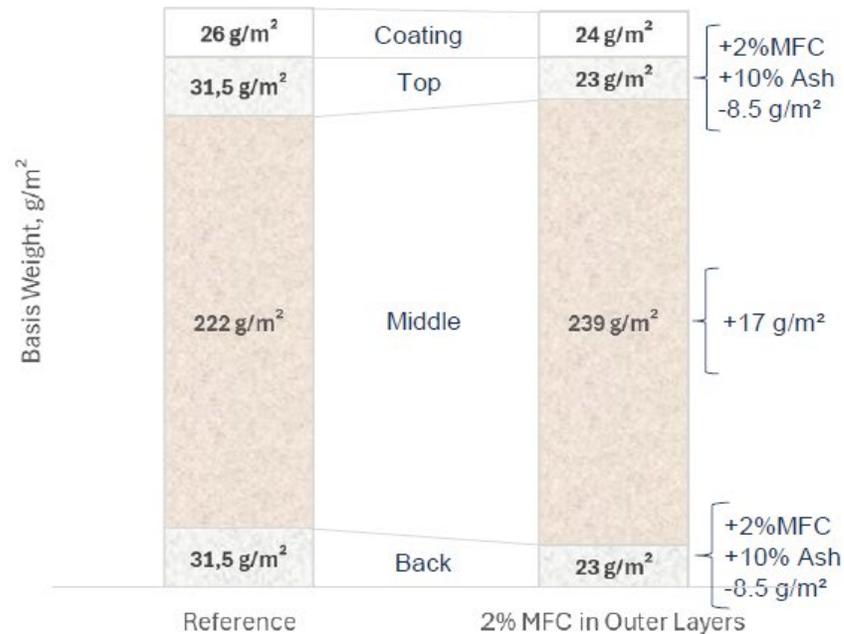
- ✓ 28% reduction of white layer fibre consumption.
- ✓ Same specification at lower cost.
- ✓ Conditions chosen to maintain brightness.
- ✓ Machine speed and runnability maintained.
- ✓ Maintained filler retention.



source: FIBERLean

# FiberLean<sup>®</sup> MFC in FBB (top layer)

Case Study – Filler Increase & Lightweighting & Improved Coating Hold-out



## Trial Outcomes:

### In both outer layers

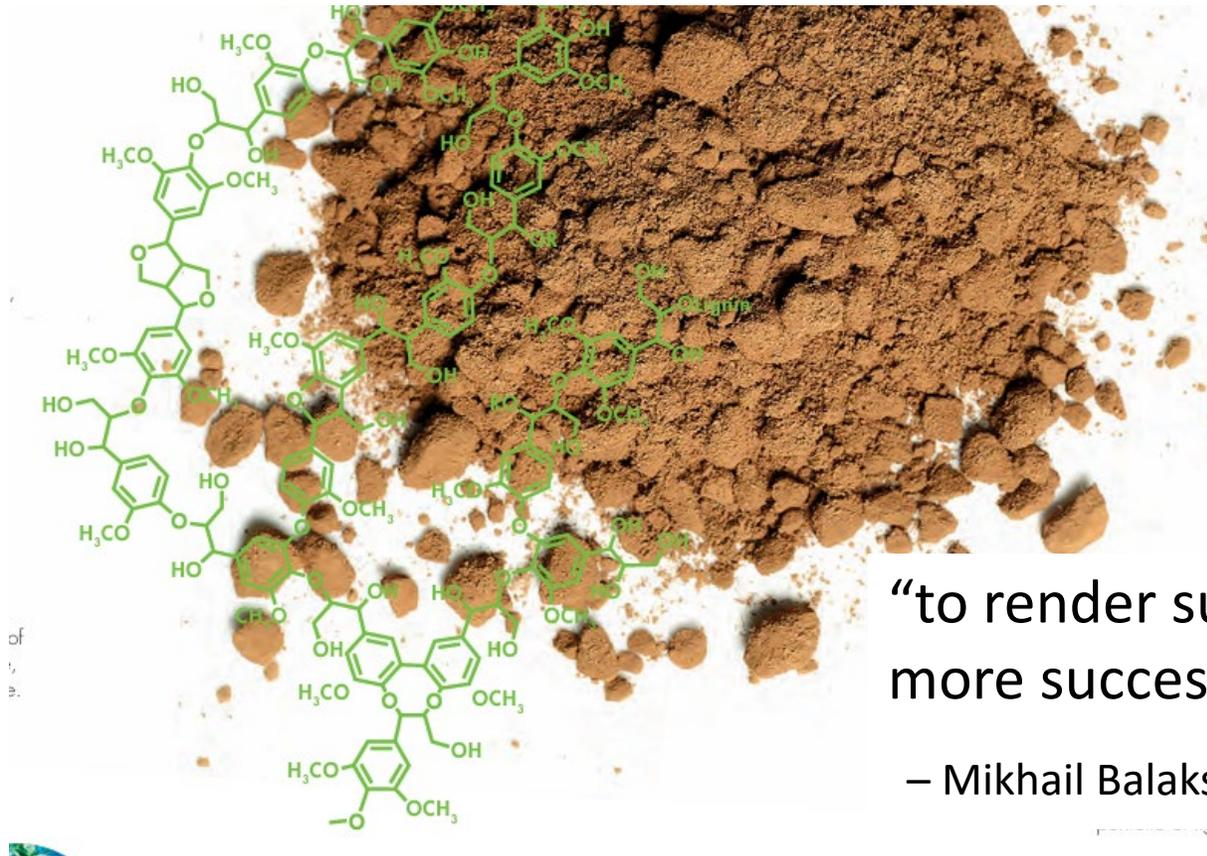
- +2% MFC in both outer layers
- +10% filler (0 to 10%)
- -8.5 g/m<sup>2</sup> reduction

## Benefits:

- ✓ 34% reduction of chemical pulp.
- ✓ Specification maintained at a reduced cost.
- ✓ Process parameters unchanged.
- ✓ 50% ply bond starch reduction.
- ✓ 1 pph pre-coat latex reduction.
- ✓ 2 g/m<sup>2</sup> coat weight reduction.

Source: FiberLean

# Lignin



“to render sugar/biofuel biorefineries economically more successful, the main focus should be on lignin”

– Mikhail Balakshin, Aalto University

Image courtesy of UPM

# Lignin Valorization

- What could we make with lignin?
- Well, what does it do in a tree?
  - UV Protection
  - Waterproofing
  - Rigidity/strength
  - Glueing/adhesion
  - Disease protection

Prof. Claire Halpin, University of Dundee, Introduction at Marcus Wallenberg Prize Symposium, November 2024

# Lignin Economics

- Scale
- Raw material cost
- Cost of alternative energy
- Technology
- Kraft mill chemical balance
- Valorization of all side streams

# Lignin valorization

Lignin Applications Potential Value			
(000 tonnes)			
	Current	Potential	Value/ tonne
Graphene	<1	n/a	\$20,000+
Energy storage	<10	700	\$3,000+
Activated carbon	<10	15,000	\$2,500
Sustainable Aviation Fuel	<10	850	\$2,400
Vanillin	30	300	\$2,000
Carbon fiber	<10	250	\$1,500
Phenolic resins/phenol derivatives	40	5,000	\$1,200
BTX	<10	200,000	\$500
Cement/concrete additives	400	4,000	\$500
Biofuels	30	>200,000	\$500
Bitumen, asphalt	10	25,000	<\$500
Misc dispersants and binders	400	1,000	various
All other	200	n/a	various
<b>Total</b>	<b>1,100</b>	<b>&gt;400,000</b>	

Sources: Biobased Markets; Borregaard Business Model, Businesses & Strategy, presentation, July 2020; Miller J. Lignin: Technology, Applications and Markets, RISI, 2017; Heikkilä M. MetGen, Collaboration to Drive Innovation, Presentation at IFBC, June 2019; Balakshin M. et al., ChemSusChem 10.1002/cssc.202002553; Jiang, Xiao; de Assis, Camilla. Lignin Fractionation from Laboratory to Commercialization: Chemistry, Scalability and Techno-economic analysis. Green chemistry, submitted August 31, 2020.

# Lignin valorization

- VTT: LigniOx oxidation for plasticizers and dispersants
- VTT: LigniSmart thermal conversion for carbonized materials
- UPM BioPiva™: resins for OSB, plywood, laminates; polymer blends
- UPM Leuna: lignin-based renewable functional fillers
- Vertoro : Goldilocks hydrogenation
- Stora Enso Lineo®: Lignode® batteries; NeoLigno® binders
- Suzano Ecolig®: rubber, resins, thermoplastic, cosmetics, construction, etc.
- Fibenol Lignova™: resins, PU foams, composites
- Praj Industries: bitumen
- MetGen: depolymerization, debottlenecking biorefineries
- Lignin Industries Renol: industrial packaging, polymer compounds, ABS

# VTT High-value lignin applications

## Surface active agents

- **LigniOx technology** for production of
  - concrete and gypsum plasticizers
  - versatile dispersants for paints and coatings



## Carbonised materials

- Thermal conversion to produce lignin-based carbon materials
  - Energy storage applications
  - Water and air purification
- **LigniSmart technology**



## Functional additives

- Fire retardants
- Antioxidants
- UV screen
- Antimicrobial compounds
- **Lignin nanoparticle formation**



## ANALYTICS

### LIGNIN

Kraft

Soda

Organosolv

Hydrolysis residue

Novel lignins

## SCALE-UP PILOTING



## Phenolic resins for wood products

- **Solvent fractionation** for increasing homogeneity
- **CatLignin** technology for reactive lignin production
- **Biotechnical activation**



## Fuels and chemicals

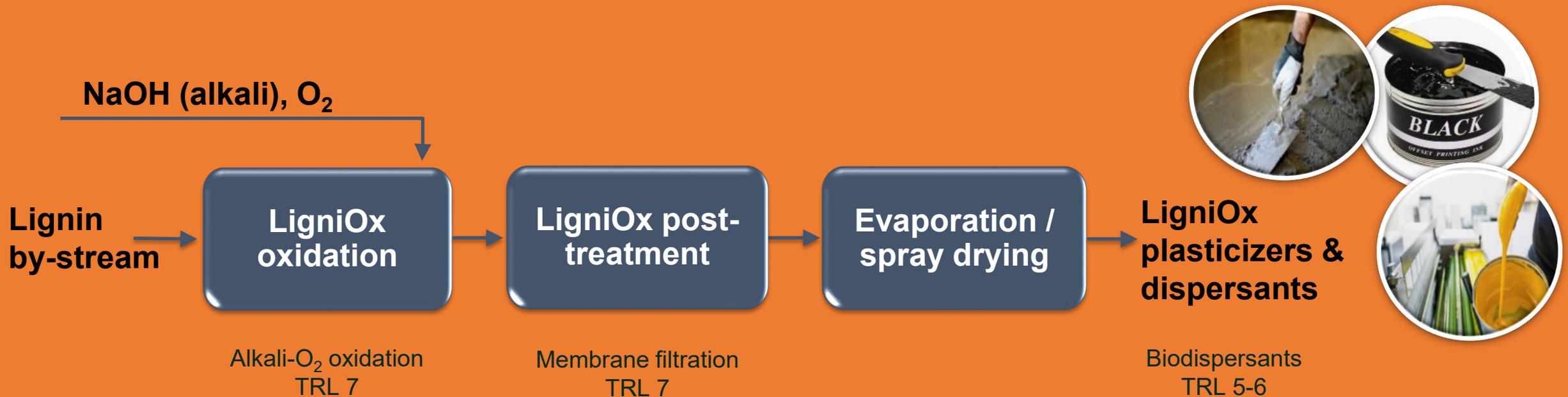
- Degradation by **HTL, Pyrolysis, Solvolysis**
- Lignin aromatics



## Thermoplastics

- Composites
- Hot melt adhesives
- Coatings
- **Internal and external plasticization**

# VTT LigniOx technology

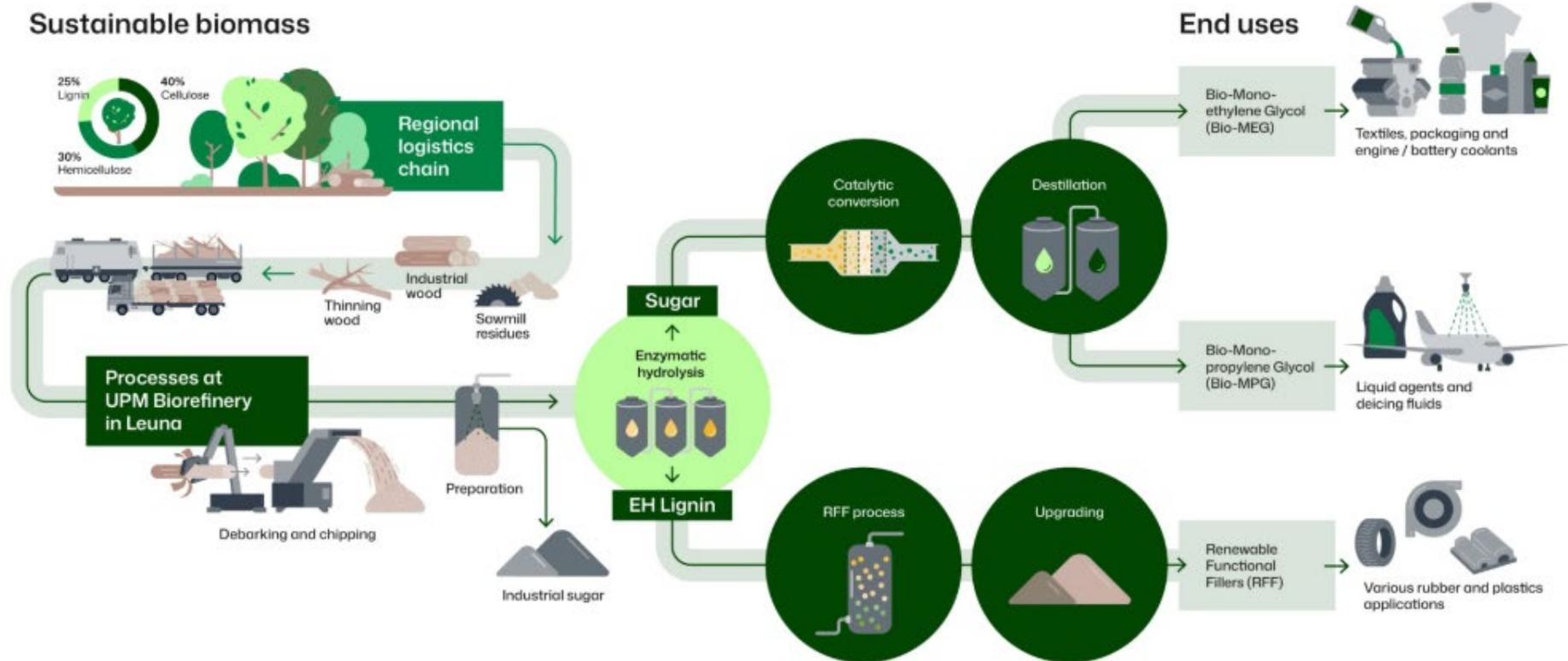


- [LigniOx Process Concept to Produce Lignin Dispersants at a Kraft Pulp Mill and an Organosolv Biorefinery - VTT's Research Information Portal](#)
- [LigniOx™ lignin recovery](#)
- [LigniOx | Circular Bio-based Europe Joint Undertaking \(CBE JU\)](#)
- [BA5404 Lignin and sidestream valorization - VTT's Research Information Portal](#)
- [VTT Technology 409: NWBC 2022 - The 10th Nordic Wood Biorefinery Conference](#)

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# UPM Leuna



Source: UPM

# Energy storage

- Lithium-ion
  - 10 to 20 grams of graphite per amp hour
  - 700 billion watt hours 2022
  - 1 million tonnes graphite in 2022
  - 7 million tonnes graphite in 2030
- Sodium-ion:
  - Stora Enso Lignode<sup>®</sup> and Altris
  - 20 Ah, 3V

Source:

<https://poweringautos.com/how-much-graphite-in-a-lithium-ion-battery/>  
[Lithium-ion battery demand forecast for 2030 | McKinsey](#)  
[Graphite Market Forecast: Top Trends for Graphite in 2025 | INN /](#)

# Lignosulfonates

- Market and applications well established
- Market is mature and declining as sulfite mills are in decline

# State of the Industry

- Old business model
  - Pulp and paper mills produce pulp and paper; lignin is burned for fuel
  - Biorefineries produce ethanol; lignin is burned for fuel
- New business model
  - Pulp and paper mills produce pulp, paper, lignin, biochemicals, specialty cellulose, nanocellulose
  - Biorefineries produce ethanol, lignin, biochemicals, specialty cellulose, nanocellulose

# Cellulose nanomaterials

- Overall capacity '18 to '23 CAGR 16%.
- Large recent increases at Suzano (20 ktpy MFC), Sappi (6 ktpy MFC), and Performance Biofilaments (7 ktpy CF)
- Also: Fibenol, NBG, Norske Skog, ITENE, Re-Fresh Global, Weidmann, ANPOLY, Sugino
- “Mills Captive” continues to dominate with ~70% of the market, but growth in this mature market will slow
- In general, production grows slightly faster than capacity as demand growth leads capacity growth
- Mature markets will see slower growth '23-'30 than '18-23; emerging markets will see faster growth

# Lignin

- Lignosulfonate remains ~90% of the market, but is mature and declining due to decline of sulfite pulping.
- The future is kraft lignin and biorefinery lignin.
- Known kraft lignin capacity grew at about 3% from 2015-23.
- Shutdowns at Sunila, Charleston and West Fraser created a shortfall in supply, but Södra in 2027 will replace much of what was lost.
- Biorefinery lignin will get a significant increase with startup of UPM Leuna this year.

# Conclusions

- Development of markets and applications for new materials is time consuming.
- Commercial challenges can be greater than technical challenges.
- New applications and markets are emerging every day as are new technologies for production as well as valorization.
- I believe the future is bright!

# Thank you

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# Appendix

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# Cellulose Nanomaterials: CNC

CNC Capacity 2025 (tonnes per year, dry basis)		
Producer	Process	Capacity
CelluForce, Canada	sulfuric acid hydrolysis	300
Anomera, Canada	carboxylated	170
GranBio, U.S.	SO <sub>2</sub> fractionation	130
Navitas, Slovenia	proprietary	50
Fibenol, Estonia	reactive extrusion	40
Forest Products Lab, U.S.	sulfuric acid hydrolysis	3
Blue Goose Biorefineries, Canada	metal catalyzed oxidation	2
Innotech Alberta	sulfuric acid hydrolysis	<1
Cellulose Lab, Canada	various	<1
ANPOLY, Inc., Korea	sulfuric acid hydrolysis	n/a
FPInnovations, Canada	sulfuric acid hydrolysis	pilot
Hangzhou Yeuha Technology Co., China	proprietary	pilot
Nordic Bioproducts Group	from MCC	pilot
Tianjin Haojia Cellulose Co. Ltd., China	modified and unmodified	pilot

Source: 2025 Directory of Cellulose Nanomaterials

# Microbrillated Cellulose (MFC)

<b>MFC Capacity 2025</b> (tonnes per year, dry basis)		
<b>Producer</b>	<b>Process</b>	<b>Capacity</b>
Suzano, Brazil	mechanical	20,000
FiberLean Technologies, UK	mechanical	13,000
Sappi Biotech, Global	proprietary	6,220
Borregaard, Norway	proprietary	1,000
Woodspin, Finland	mechanical	1,000
Norske Skog, Norway	mechanical	526
Klabin, Brazil	mechanical	350
RISE, transportable container factory	enzymatic pretreatment	200
Daicel, Japan	high pressure homogenizer	200
Weidmann Fiber Technology, Switzerland	mechanical	150
CTP/FCBA, France	enzymatic pretreatment	25
RISE, Sweden	enzymatic pretreatment	25
Stora Enso, Finland	n/a	N/A
Empa, Switzerland	enzymatic pretreatment	pilot
InoFib, France	chemical pretreatment	pilot
ITENE, Spain	mechanical	pilot
KCL, Finland	n/a	pilot
Re-Fresh Global, Germany	enzymatic treatment	pilot
Tianjin Haojia Cellulose, China	modified: TEMPO, other	pilot
UPM, Finland	n/a	pilot

Source: 2025 Directory of Cellulose Nanomaterials

# Cellulose Nanofibrils

CNF Capacity 2025 (tonnes per year, dry basis)		
Producer	Process	Capacity
Sappi Biotech, Global	proprietary	650
Nippon Paper, Japan	TEMPO, carboxylated	560
University of Maine, U.S.	mechanical	260
GranBio, U.S.	SO <sub>2</sub> fractionation	130
CelluComp, UK	chemical pretreatment	100
Oji Paper, Japan	phosphate esterification	40
Sugino Machine, Japan	oblique collision	39
Chuetsu Pulp and Paper, Japan	aqueous counter collision	30
Seiko PMC, Japan	modified hydrophobic	24
Cellulose Lab, Canada	TEMPO, other	18
ANPOLY, Korea	TEMPO	10
Tianjin Haojia Cellulose Co., Ltd, China	TEMPO, carboxylated	3
Dai-ichi Kogyo (DKS), Japan	TEMPO	1
U.S. Forest Products Lab, U.S.	TEMPO, mechanical	<1
NANOCEL, Spain	enzymatic, chemical, mechanical	<1
Marusumi Paper Co., Ltd., Japan	chemical	n/a
Toagosei Co., Ltd., Japan	Sodium hypochlorite oxidation	n/a
ITENE, Spain	mechanical	pilot
Nordic Bioproducts Group	from MCC	pilot
Re-Fresh Global, Germany	enzymatic treatment	pilot
VTT, Finland	chemical, enzymatic, mechanical	pilot

Source: 2025 Directory of Cellulose Nanomaterials

# Cellulose Filaments

Cellulose Filaments Capacity 2025 (tonnes per year, dry basis)		
Producer	Process	Capacity
Performance BioFilaments, Canada	mechanical	7,000
Kruger, Canada	mechanical	6,000
Tianjin Haojia Cellulose, China	n/a	n/a

Source: 2025 Directory of Cellulose Nanomaterials