Nanocellulose: Is it really a good solution for Sustainable Packaging?

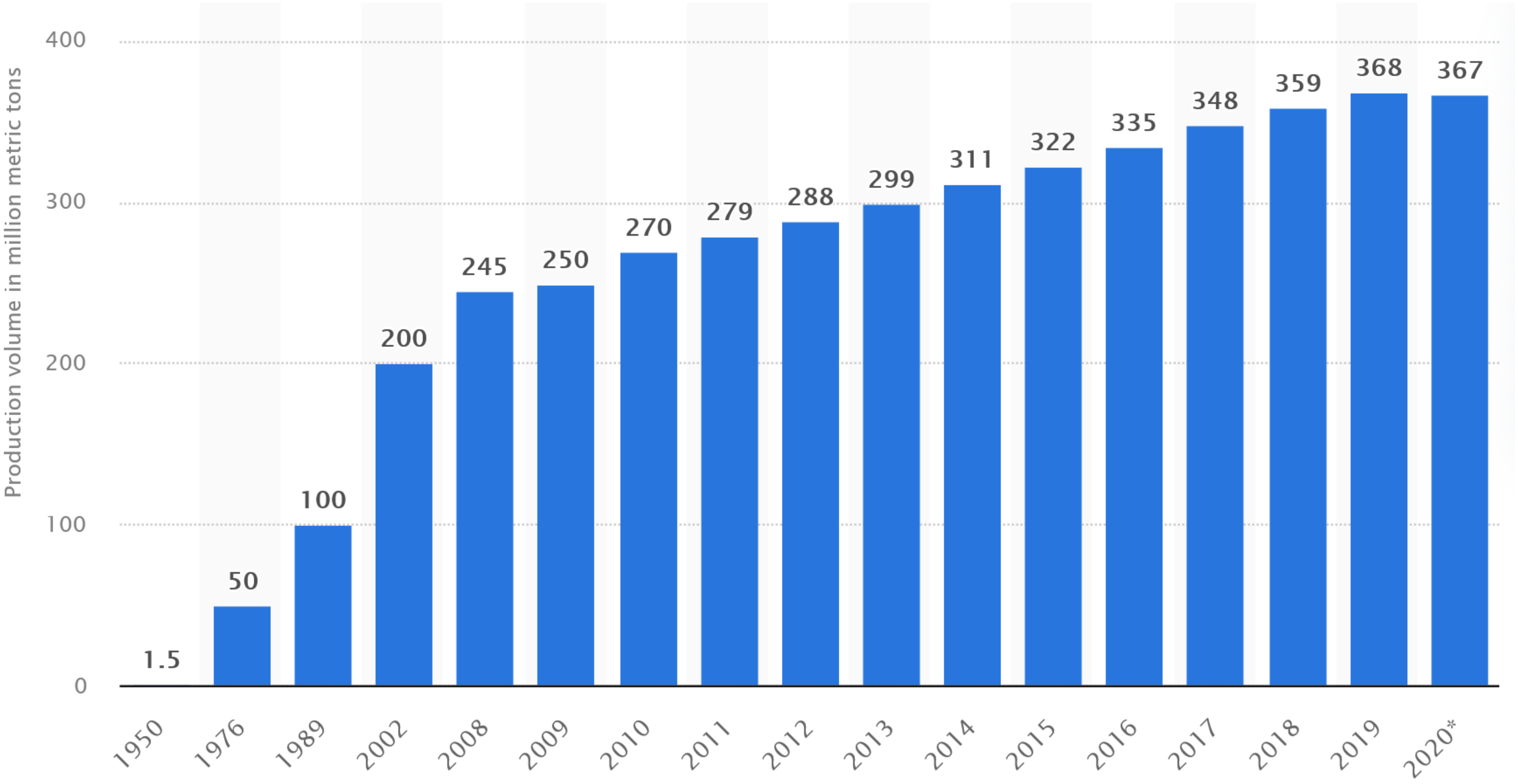
Julien BRAS

University Grenoble Alpes, Grenoble INP – Pagora, LGP2, 38000 Grenoble France
Institut Universitaire de France, 75000 Paris, France

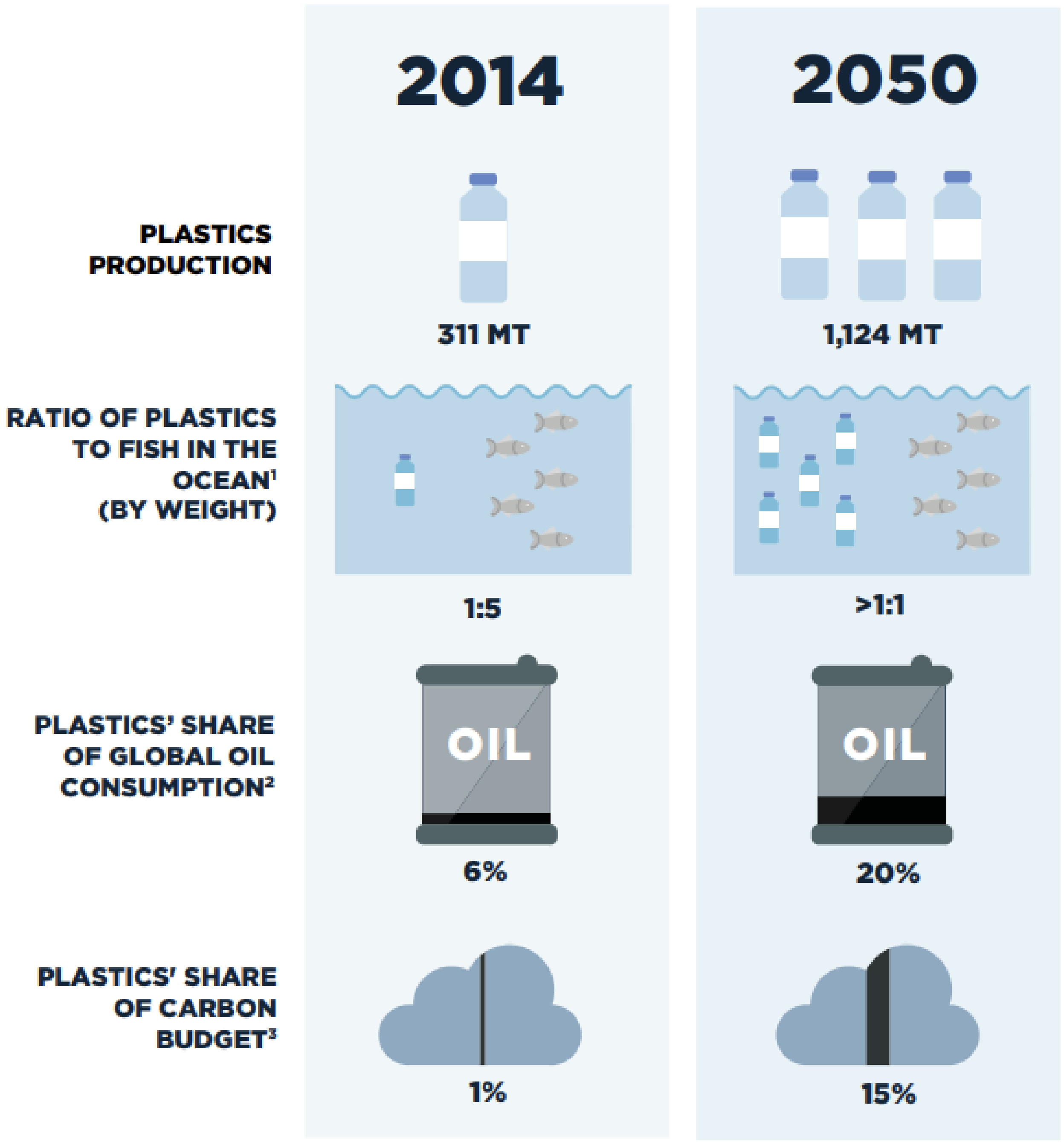
TAPPI NANO DIVISION

Cellulose Valley
BY FONDATION GRENOBLE INP

Annual production of plastics worldwide from 1950 to 2020 (in million metric tons)

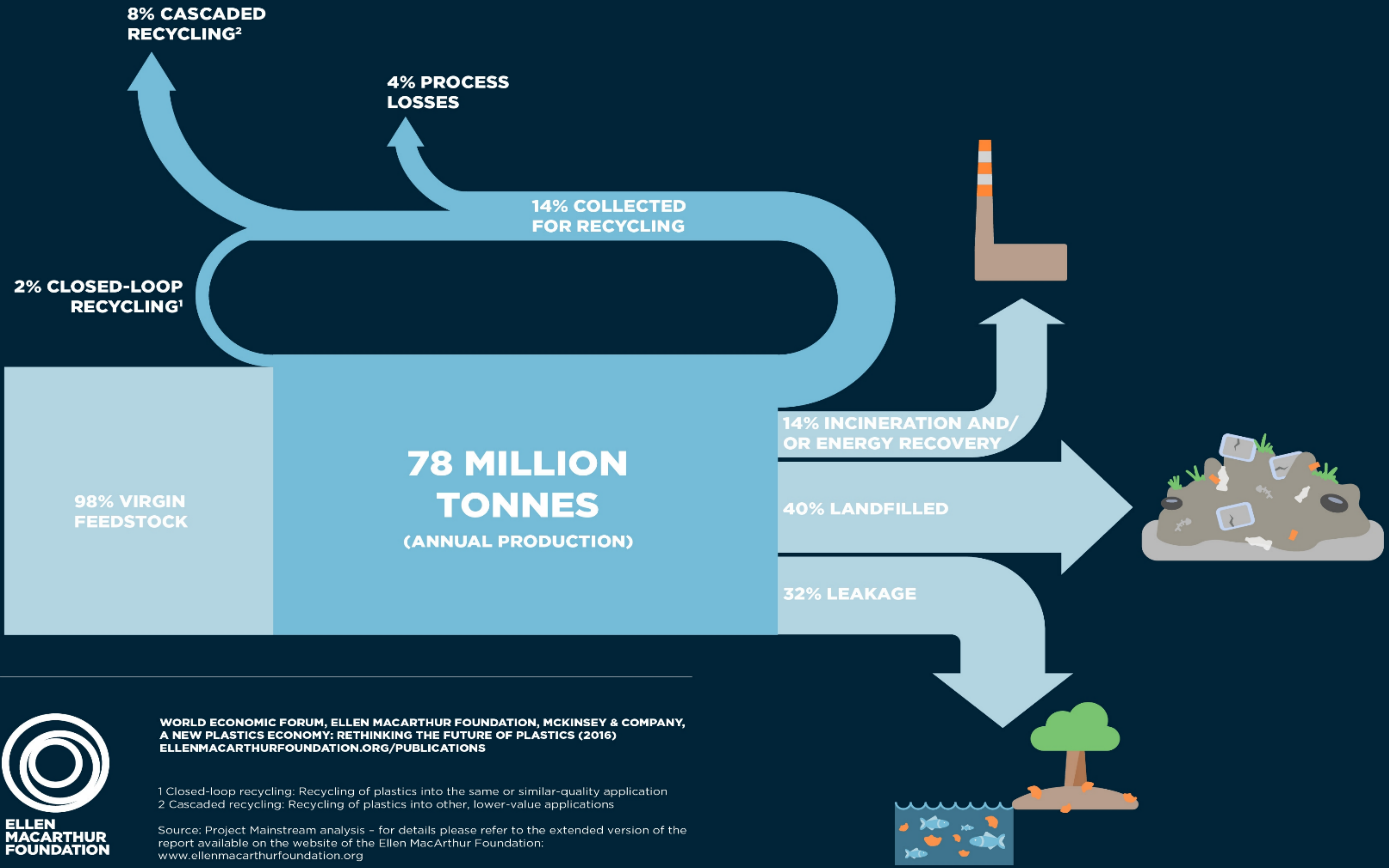


Source: 2021, Statista, https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/



- Ellen MacArthur Foundation, *The New Plastic Economy – Rethinking the future of plastics.* 2014.

TODAY, PLASTIC PACKAGING MATERIAL FLOWS ARE LARGELY LINEAR

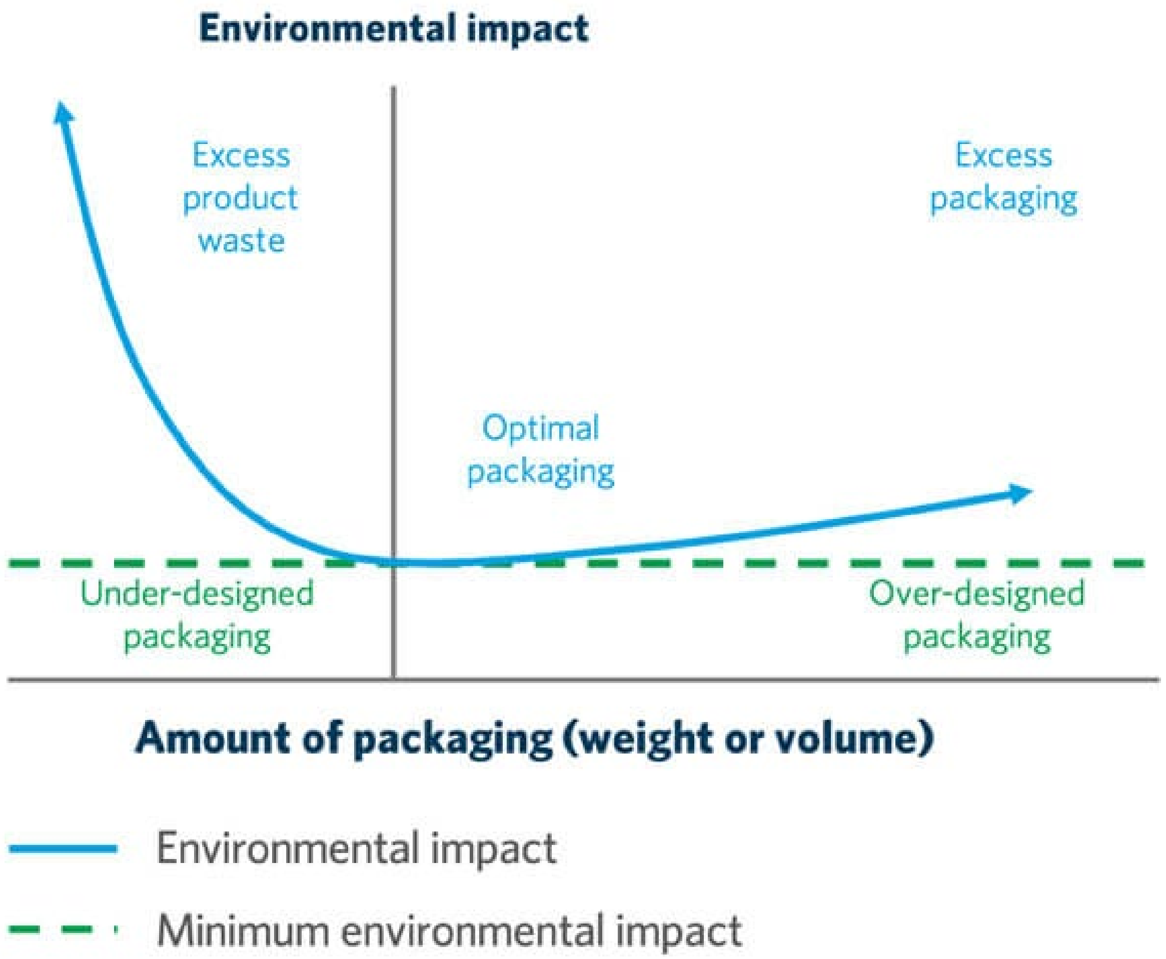


WORLD ECONOMIC FORUM, ELLEN MACARTHUR FOUNDATION, MCKINSEY & COMPANY, A NEW PLASTICS ECONOMY: RETHINKING THE FUTURE OF PLASTICS (2016)
ELLENMACARTHURFOUNDATION.ORG/PUBLICATIONS

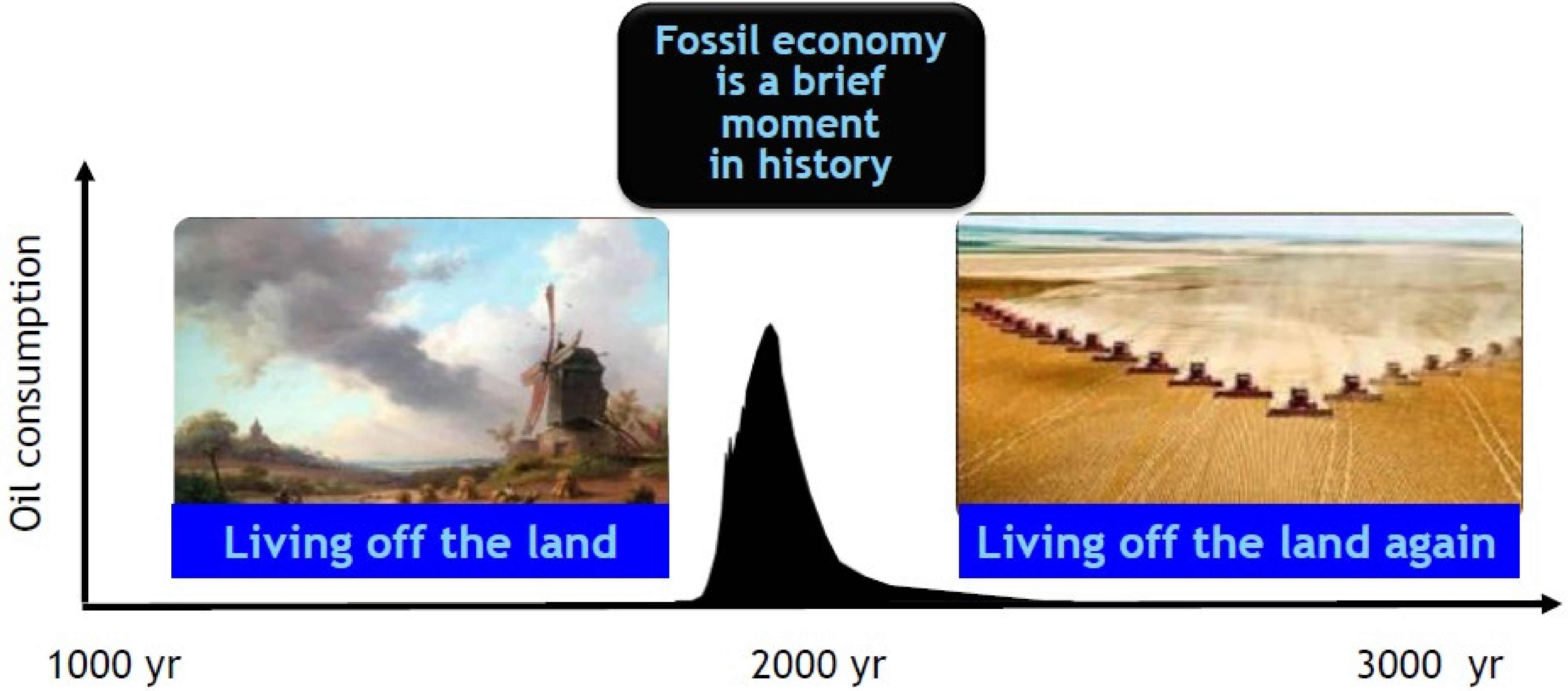
1 Closed-loop recycling: Recycling of plastics into the same or similar-quality application
2 Cascaded recycling: Recycling of plastics into other, lower-value applications

Source: Project Mainstream analysis – for details please refer to the extended version of the report available on the website of the Ellen MacArthur Foundation: www.ellenmacarthurfoundation.org

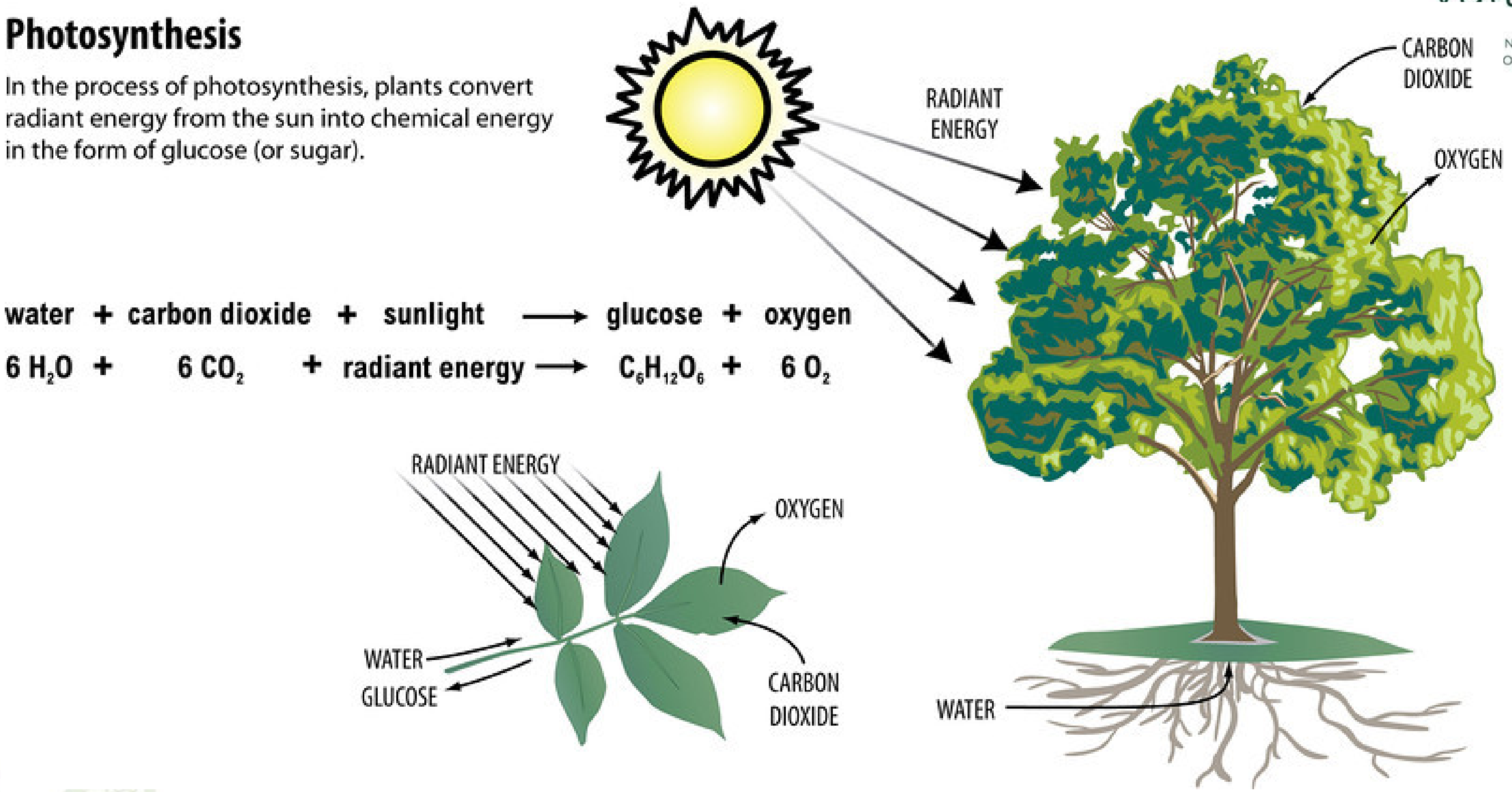
ELLEN MACARTHUR FOUNDATION



Packaging pollutes **BUT**
We need Packaging to limit food waste
and so to limit pollution



Fossil economy is a brief moment in history
Oil consumption
Living off the land
Living off the land again
1000 yr
2000 yr
3000 yr



→ BIOMASS = 300-500 Billions tons product every year

Cellulose IS the SUPERSTAR

Cellulose Valley
BY FONDATION GRENOBLE INP



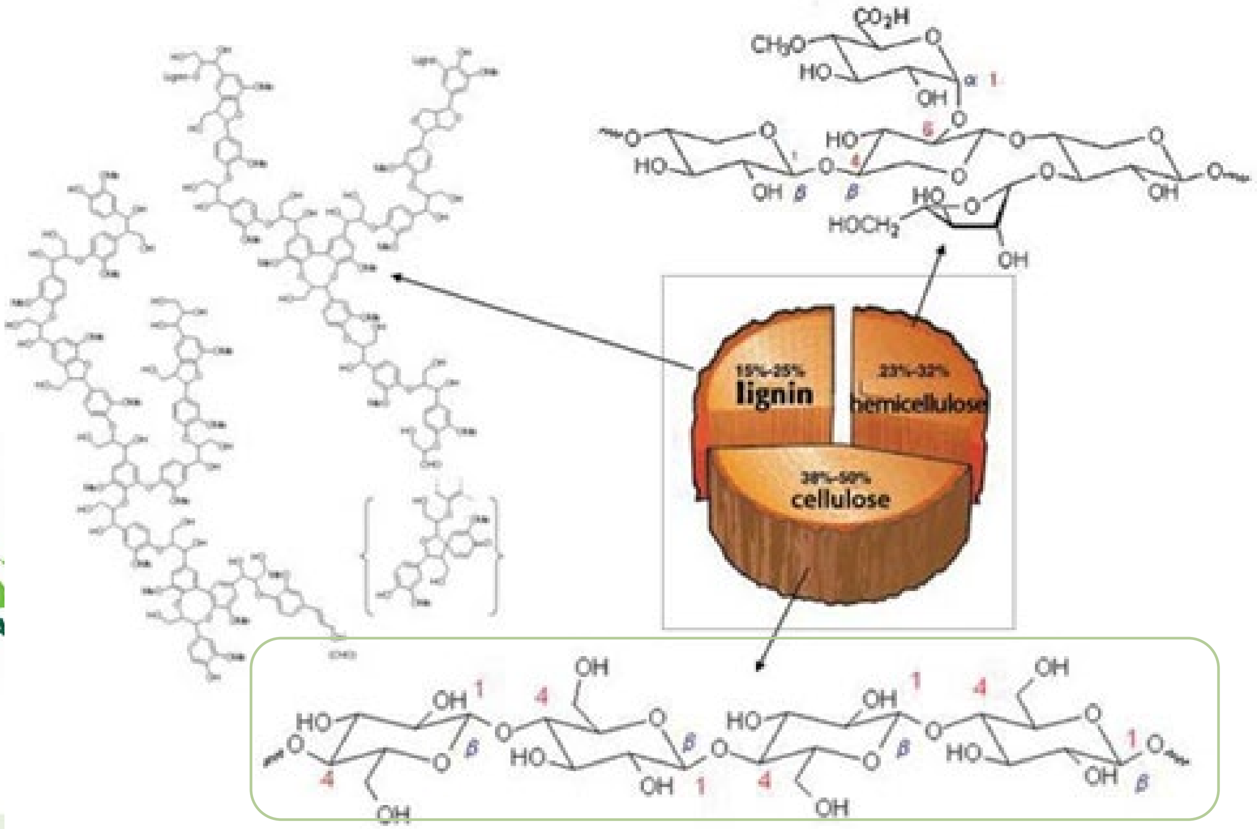


→So many sources everywhere

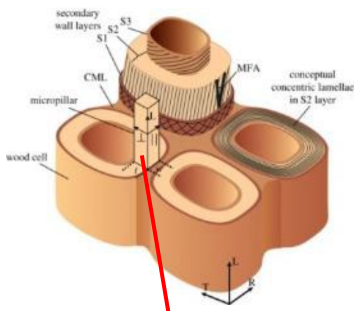
ab. 10-15 t/ha
Dried biomass

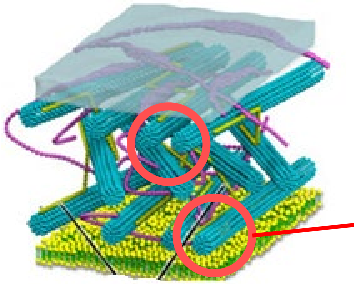
FSC
FORESTS FOR A
FOREVER

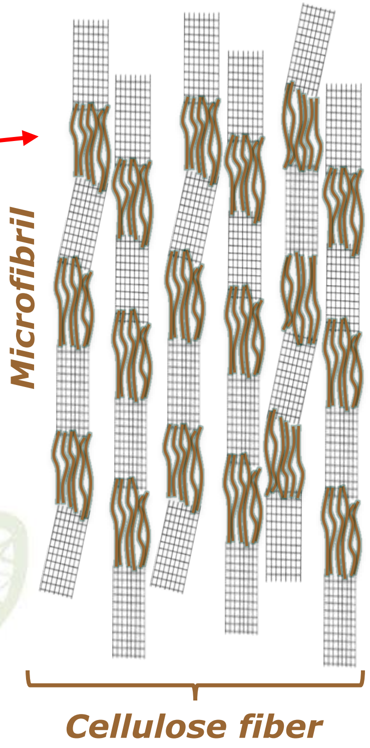
Industry= 300-400 Millions t/y

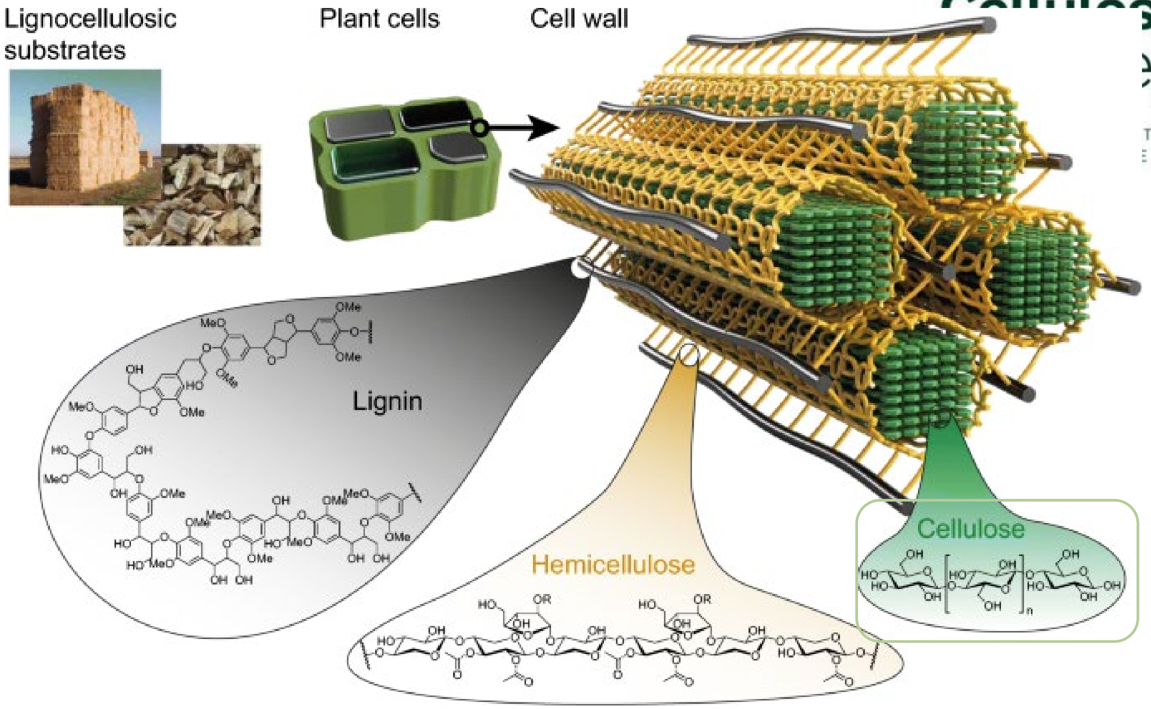


NanoCellulose IS also the SUPERSTAR





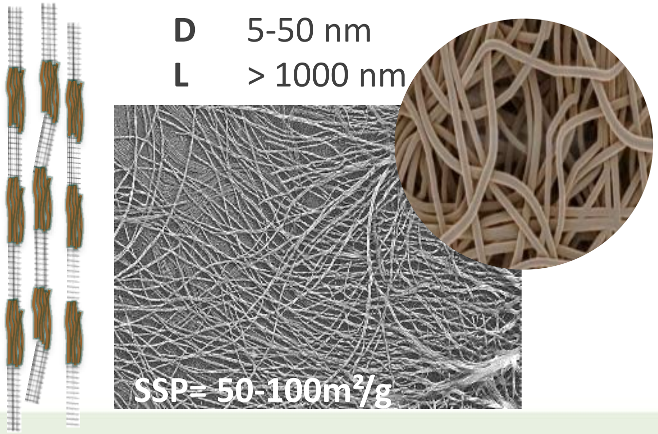




Ab. 50% of wood

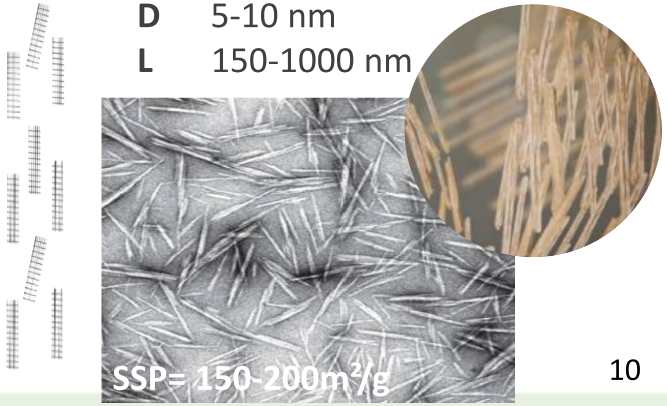
Microfibrillated cellulose (MFC)

D 5-50 nm
L > 1000 nm



Cellulose Nanocrystals (CNC)

D 5-10 nm
L 150-1000 nm



Brethauer, et al . Applied microb. biotech. 2020.

Nanocellulose:
Is it really a good solution for Sustainable Packaging?

↓

What means **sustainable packaging ?**

Sustainable design check list

- Choose the most suitable packaging material for each product
- Use recycled or biobased plastic
- Choose the right packaging size & functionalities
- Ensure product protection to minimise waste
- Ensure hygiene and food safety
- Ensure reusability or recyclability
- Make LCA calculations to ensure your packaging is truly sustainable
- Communicate your sustainability message on your packaging
- Inform the used raw materials and communicate recycling instructions on the packaging

Source: Amerplast 2023

Source: ecoart 2023

Nanocellulose:
Is it really a good solution for Sustainable Packaging?

↓

PRELIMINARY ASUMPTION:

Sustainable production of Nanocellulose

Low carbon footprint and low price

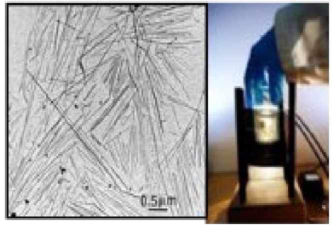
My group research topics

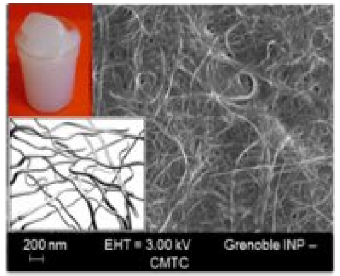
Cellulose Valley
BY FONDATION GRENOBLE INP

BIOMASS — NANO-CELLULOSE — MATERIALS — APPLICATIONS

T1: Nanocellulose preparation **process optimization**

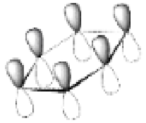
(Deconstruction)

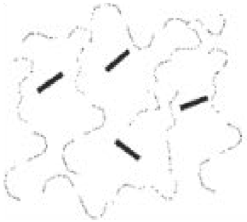




T2: Nanocellulose surface **functionnalization**

(activation)

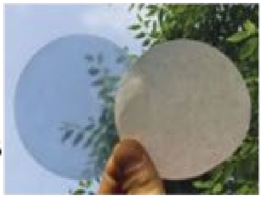




T3: Material preparation **processes**

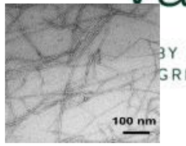
for high performance (nano)cellulose materials

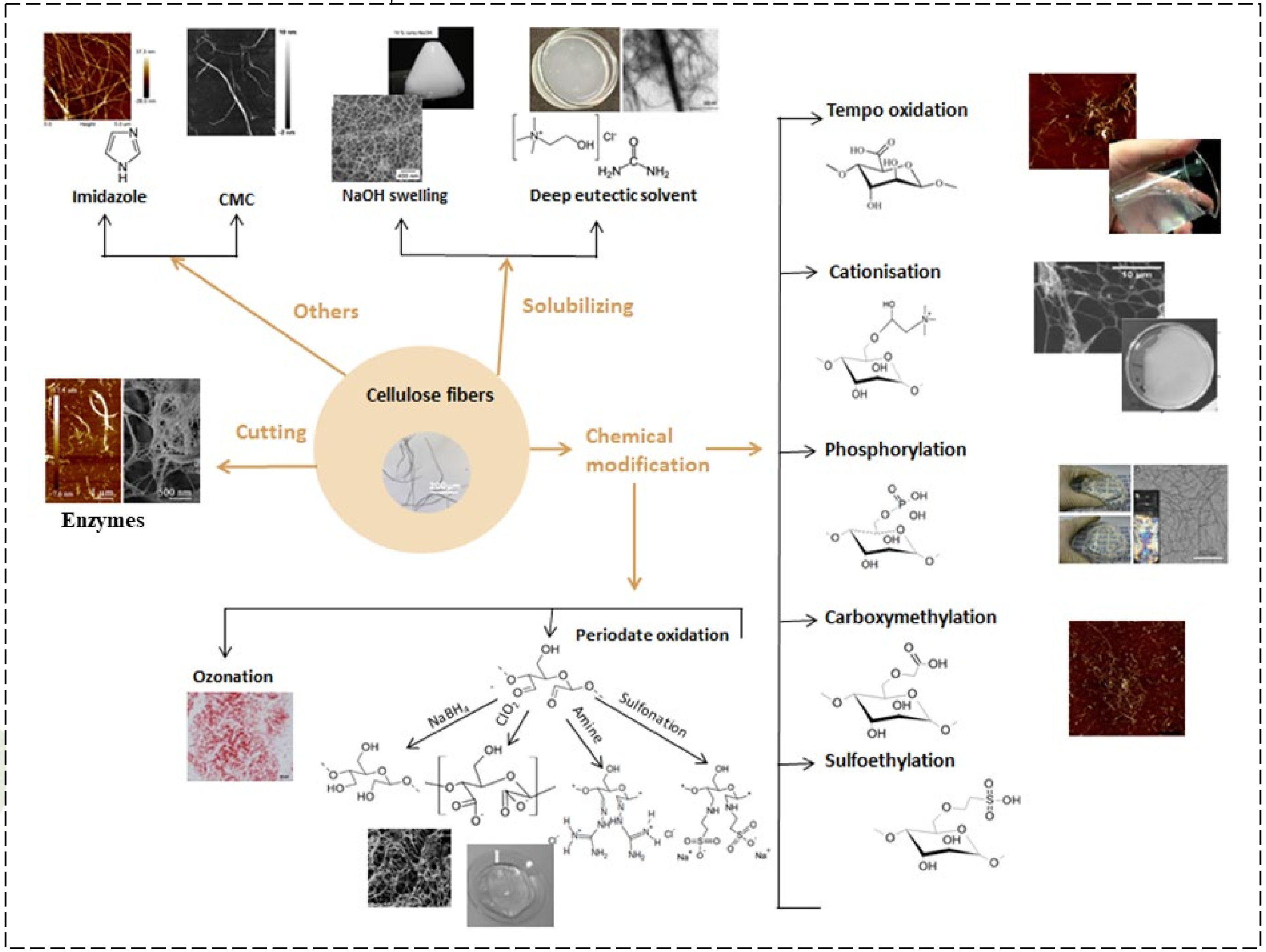
(reconstruction)



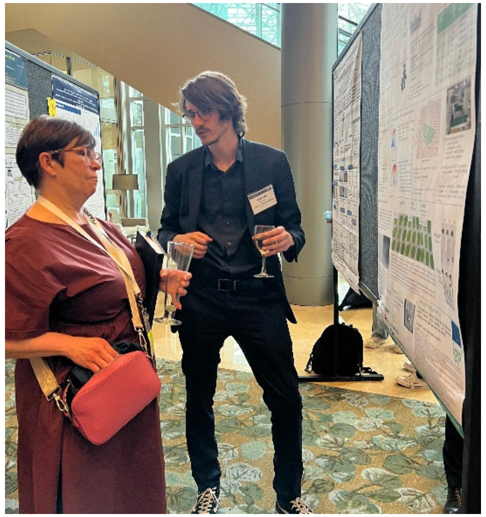
Nanocellulose & Sustainable production

Cellulose fibers → Chemical/enzymatic pretreatment → Mechanical treatment → Cellulose nanofibrils (CNF)





Mechanochemistry

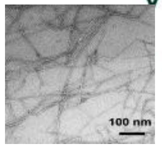


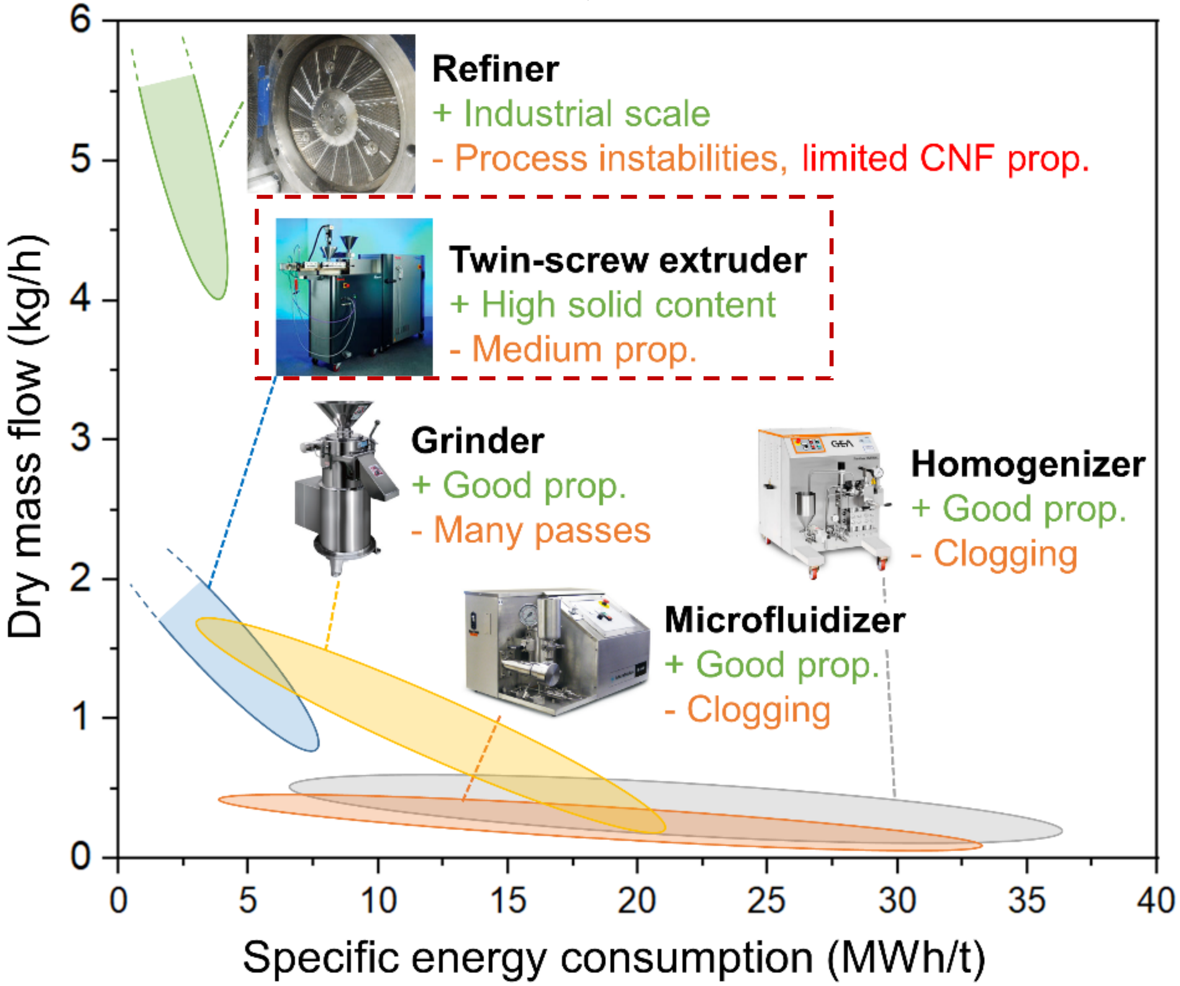
R2R phosphorylation

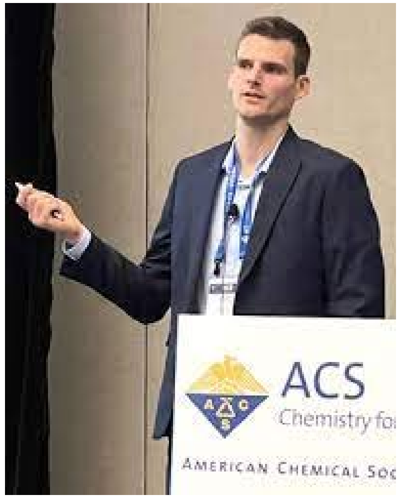
F Rol, MN Belgacem, A Gandini, J Bras, Recent advances in surface-modified cellulose nanofibrils, Progress in Polymer Science (2019), 88, 241-264

Nanocellulose & Sustainable production

Cellulose fibers → Chemical/enzymatic pretreatment → Mechanical treatment → Cellulose nanofibrils (CNF)







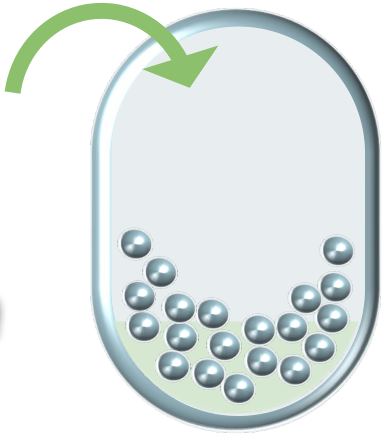
Twin screw extrusion

G Banvillet, Bras J.,et al, Cellulose nanofibril production by the combined use of four mechanical fibrillation processes with different destructuration effects, Cellulose, 1-24, (2023)

Nanocellulose & Sustainable production

Fibres addition

Cotton cellulosic fibers
Consistency (65 wt%)



Mechanical treatment

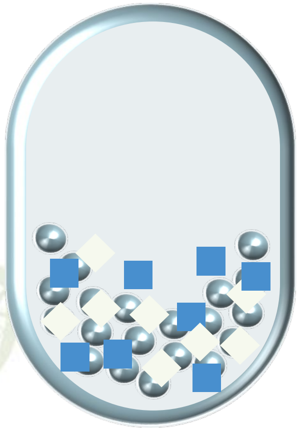
Ball milling

30 Hz – 1 h 30 min

Ambient temperature

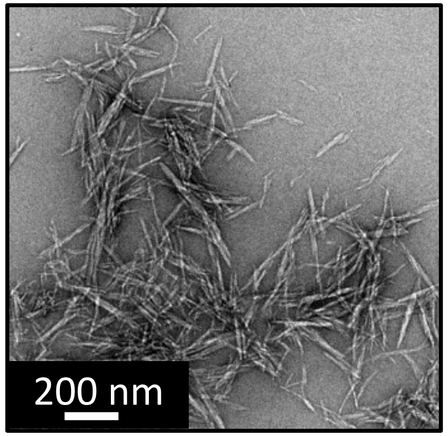
NADES obtention

30 Hz - 15 seconds



ChCl OAD

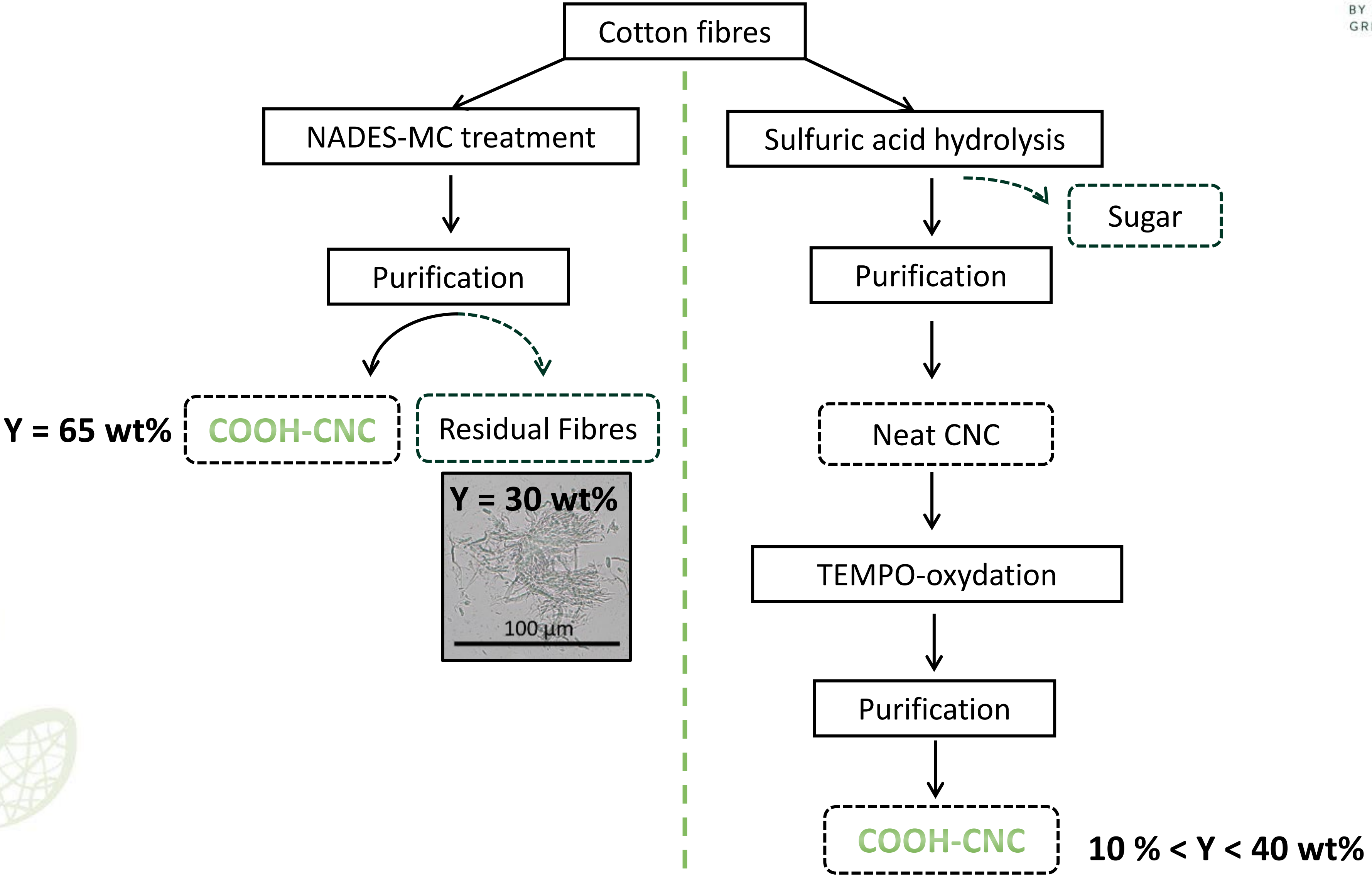
Anionic CNC with High yield



L Douard, MN Belgacem, Bras J, Extraction of Carboxylated Nanocellulose by Combining Mechanochemistry and NADES, ACS Sustainable Chemistry & Engineering 10 (39), 13017-13025, (2022)

Nanocellulose & Sustainable production

- ❑ Proposed process
- ❑ Classical process



Bras, Douard, Belgacem, Patent submitted in March 2022, FR2202544

Nanocellulose & Sustainable production

- Need more public Life Cycle Assesment

Impact Category	Unit	Enzymatic Treatments & Homogenisation (ENZHO)		TEMPO-Oxidation and Homogenisation (TOHO)		TEMPO-Oxidation and Ultrasonication (TOSO)	
		Virgin Materials (Hardwood Kraft Pulp)	Recycled Materials (Industrial Waste Sludge)	Virgin Materials (Cotton linters)	Recycled Materials (Industrial Waste Sludge)	Virgin Materials (Cotton Linters)	Recycled Materials (Industrial Waste Sludge)
Climate change	kg CO_2 eq	1.86×10^{-1}	1.77×10^{-1}	6.32×10^{-1}	6.78×10^{-1}	8.80×10^{-1}	7.84×10^{-1}

Figure 4. Relative environmental performances of the six CNFs based on the results of the characterisation step. The highest impact per each category is given 100% of the impact.

Gallo Stampino, Paola et al. “Comparative Life Cycle Assessment of Cellulose Nanofibres Production Routes from Virgin and Recycled Raw Materials.” Molecules 26 (2021).

Nanocellulose & Sustainable production

- ❑ Need more public Life Cycle Assesment

Step of the LCA	Strategies for Reduction of Energy Demand	Strategies for the Development of Low-Carbon Materials
Extraction of raw materials	1. Usage of fruit and vegetable wastes reduces energy consumption [83].	1. Usage of fruit and vegetable wastes reduces environmental impacts [83].
Cellulose products manufacturing	1. Using better insulation and heat recovery during the process. 2. Burning some by-products for using the generated energy [87]. 3. Reducing solvent consumption can decrease energy consumption for the reaction indirectly. 4. Reducing the reaction time can decrease power consumption [99].	1. Recovery of excessive solvents, especially in pretreatment reaction processes for reducing the environmental impact. 2. Using by-products as inputs for other processes, specifically in large-scale processes [85]. 3. Reusing of water used in the production of cellulose products, especially in the washing stage, for other processes [86].

Foroughi, Firoozeh et al. "A Review on the Life Cycle Assessment of Cellulose: From Properties to the Potential of Making It a Low Carbon Material." Materials 14 (2021)

Nanocellulose:
Is it really a good solution for Sustainable Packaging?

↓

PRELIMINARY ASUMPTION:

Sustainable production of Nanocellulose
Low carbon footprint and low price

↓

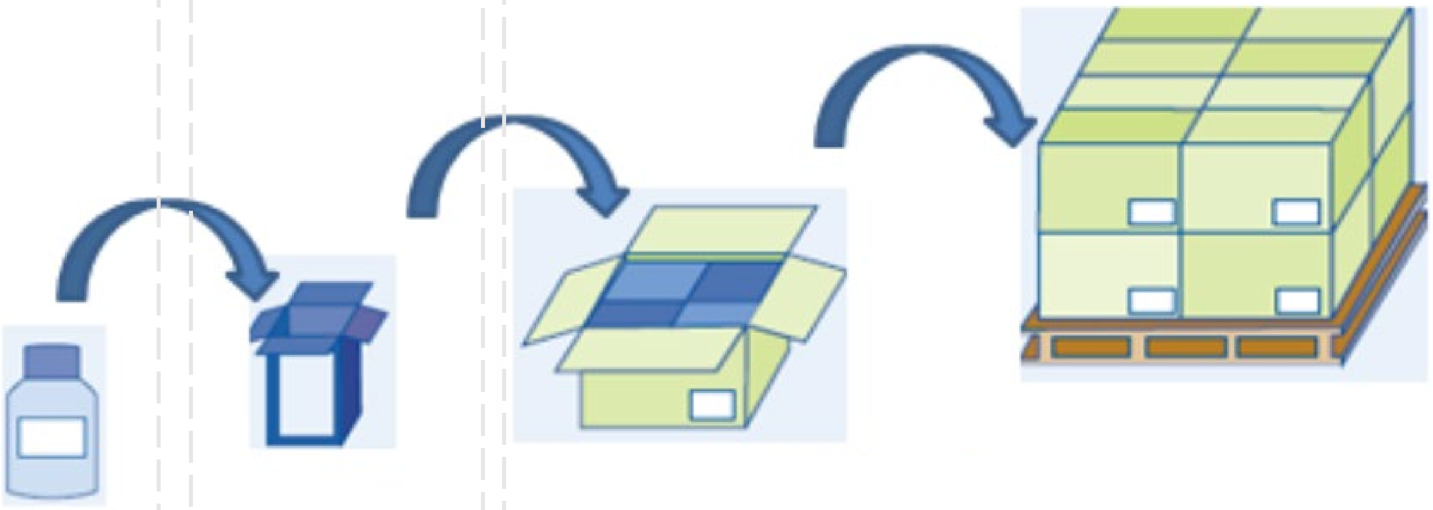
IN WHICH PACKAGING APPLICATIONS ?

Orientations

REDUCE

Social responsibility
Change of the consumption habits

Understand the packaging



Primary packaging

Secondary packaging containing several primary packagings

Tertiary packaging: transportation and logistic purposes (pallet, boxes, stretchable film…)

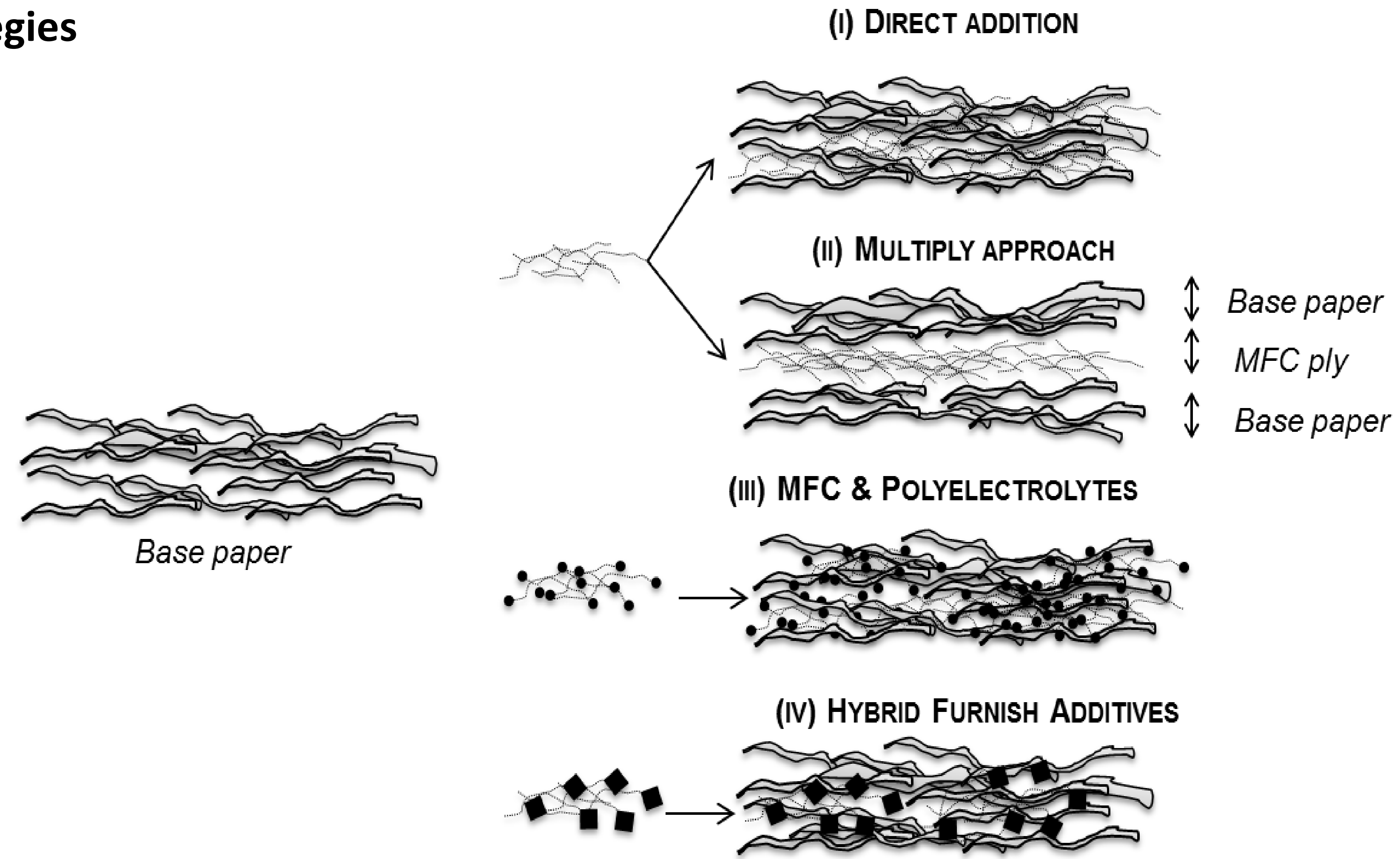
=> Development of Barrier shift concept (in progress)

PACKAGED FOOD CONCENTRATE WITH BARRIER PROPERTIES PROVIDED BY AN EDIBLE PACKAGING, Niederreiter, Bras et al, WO2022043072

BARRIER PACKAGING MATERIAL COMPRISING A CARDBOARD-BASED MOISTURE SCAVENGER, Wyser, Giardiello et Bras, WO2022135986

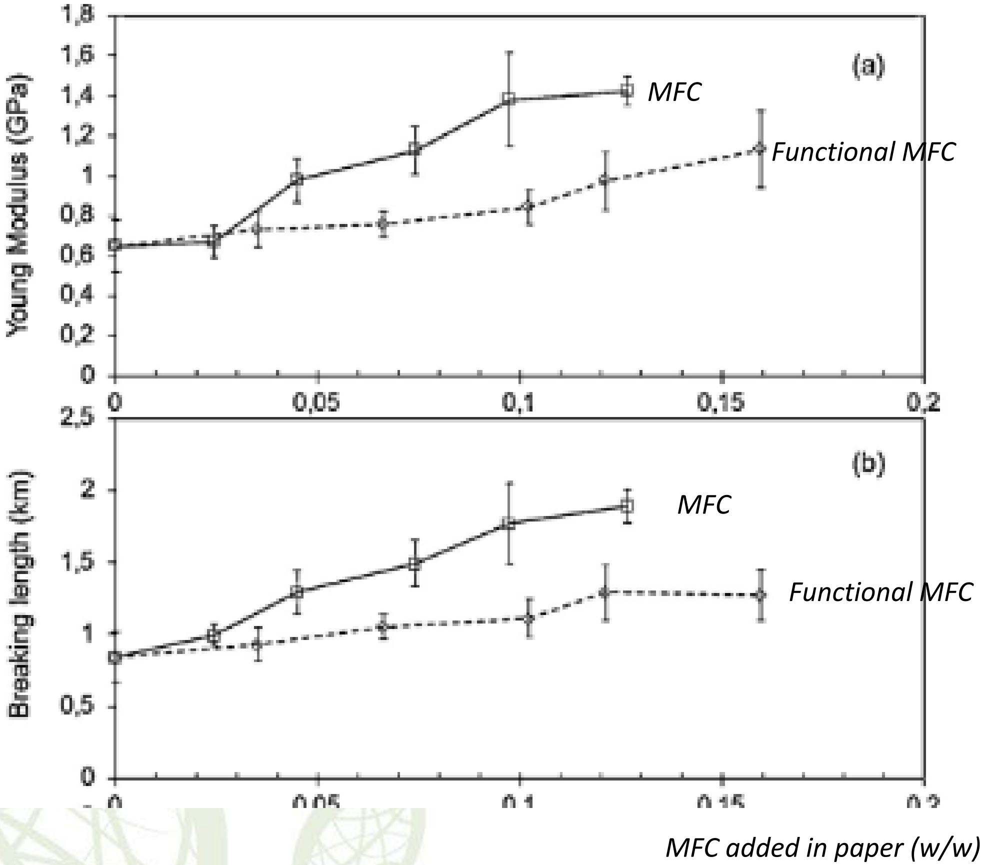
Nanocellulose to reduce weight

Several strategies

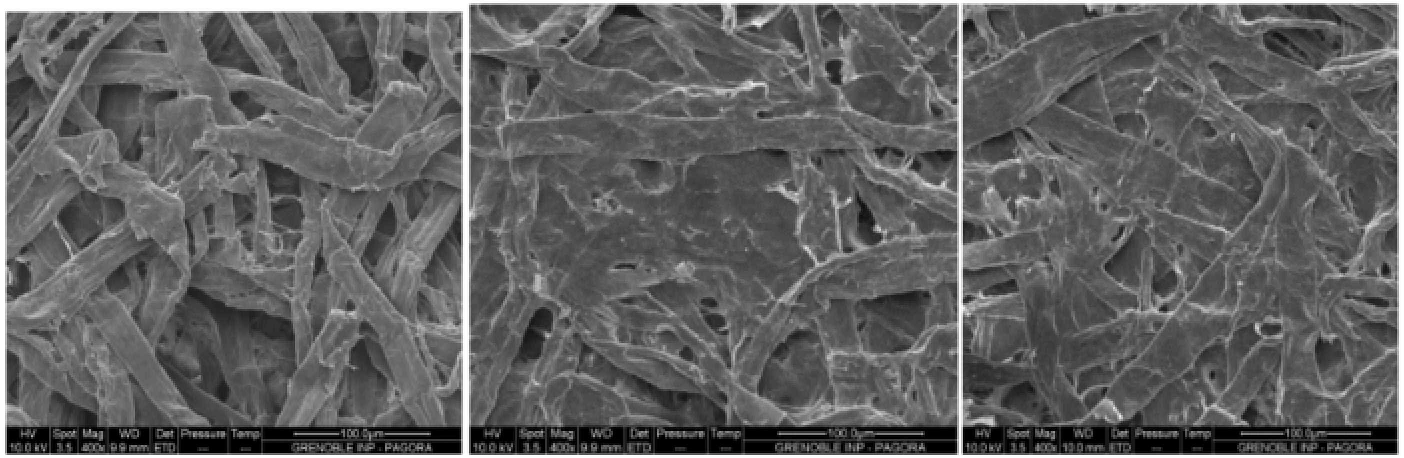


Bardet R.., Bras J., MFC in Paper, 2014, Handbook of Green Materials, K.Oksman,

Nanocellulose to reduce weight



Missoum K., Bras J., et al, Industrial Crops and Products 48 (2013) 98–105,



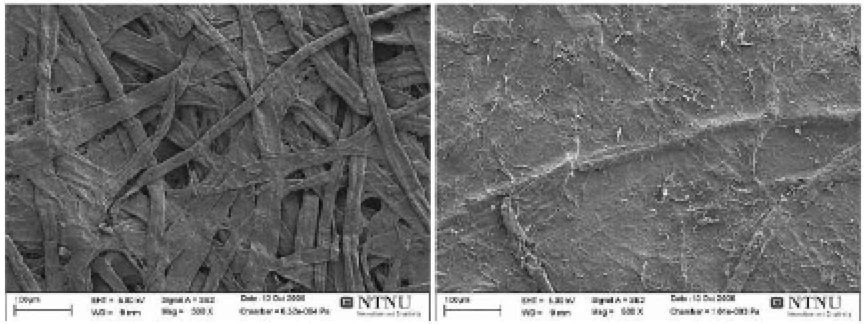
Effect of addition of MFC and TEMPO-MFC on the mechanical properties of paper sheets prepared from unbeaten bagasse.

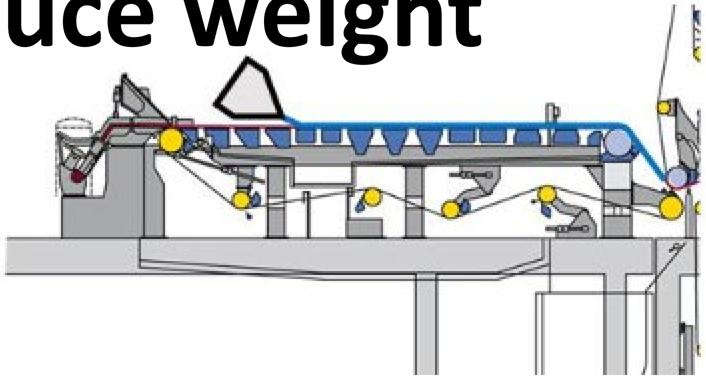
Sample	Breaking length (km)	Wet breaking length (km)
Unbeaten bagasse	2.97 (0.15)	0.078 (0.009)
Beaten bagasse (B)	4.83 (0.49)	0.16 (0.02)
B + 2.5% MFC	3.61 (0.18)	0.13 (0.01)
B + 2.5% TMFC	3.49 (0.36)	0.12 (0.01)
B + 5% MFC	4.63 (0.68)	0.14 (0.01)
B + 5% TMFC	4.51 (0.23)	0.18 (0.03)
B + 10% MFC	4.9 (0.41)	0.17 (0.02)
B + 10% TMFC	4.87 (0.29)	0.29 (0.05)
B + 20% MFC	4.23 (0.29)	0.18 (0.02)
B + 20% TMFC	4.22 (0.59)	0.42 (0.05)

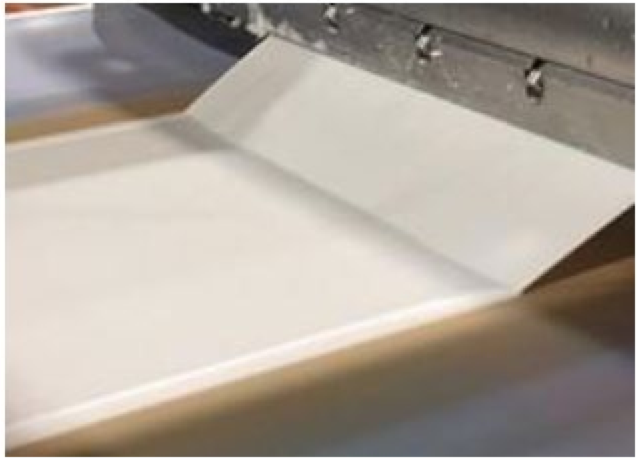
Values between brackets are the standard deviation.

Hassan M.., Bras J., et al, Industrial Crops and Products 64 (2015) 9–15,

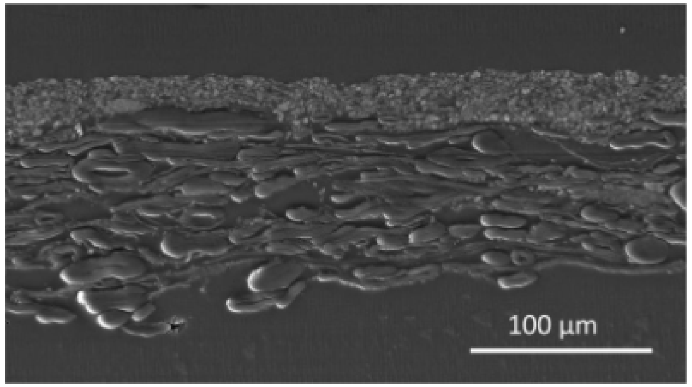
Nanocellulose to reduce weight

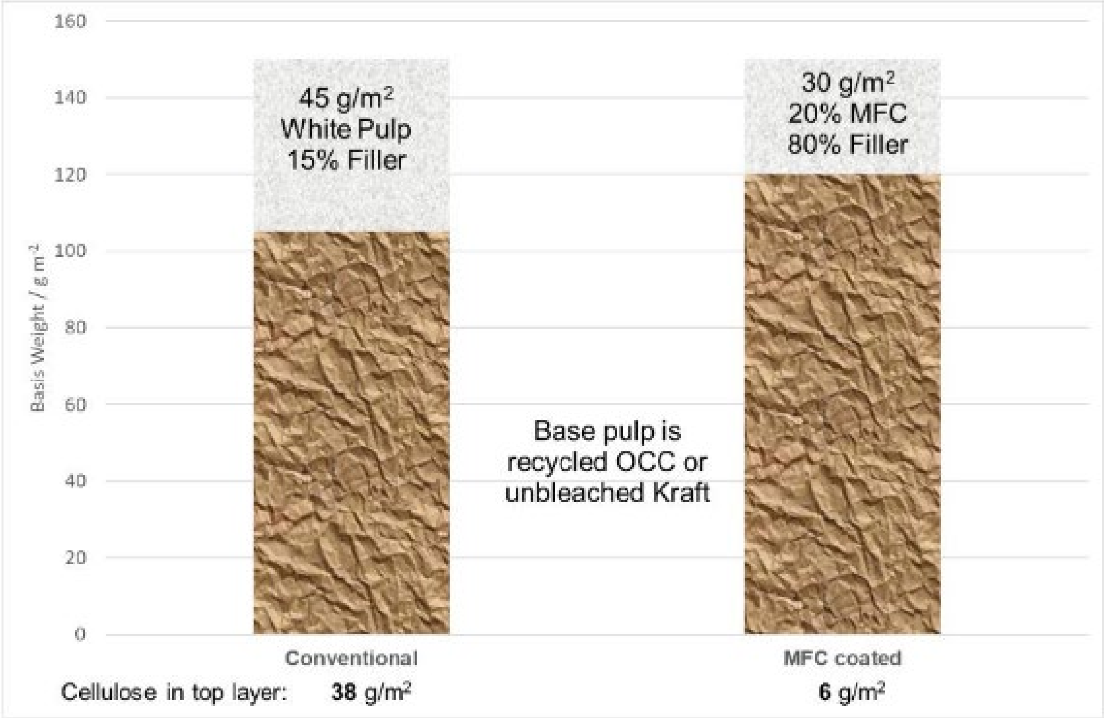


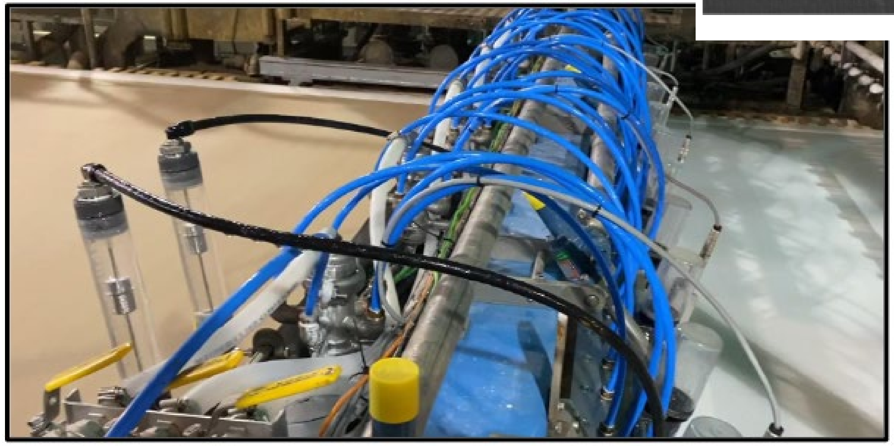




- MFC suspension is applied at the wet end of a papermachine, just after the 'wet line'
- Dewatering is achievable with existing elements – vacuum boxes, presses and dryers



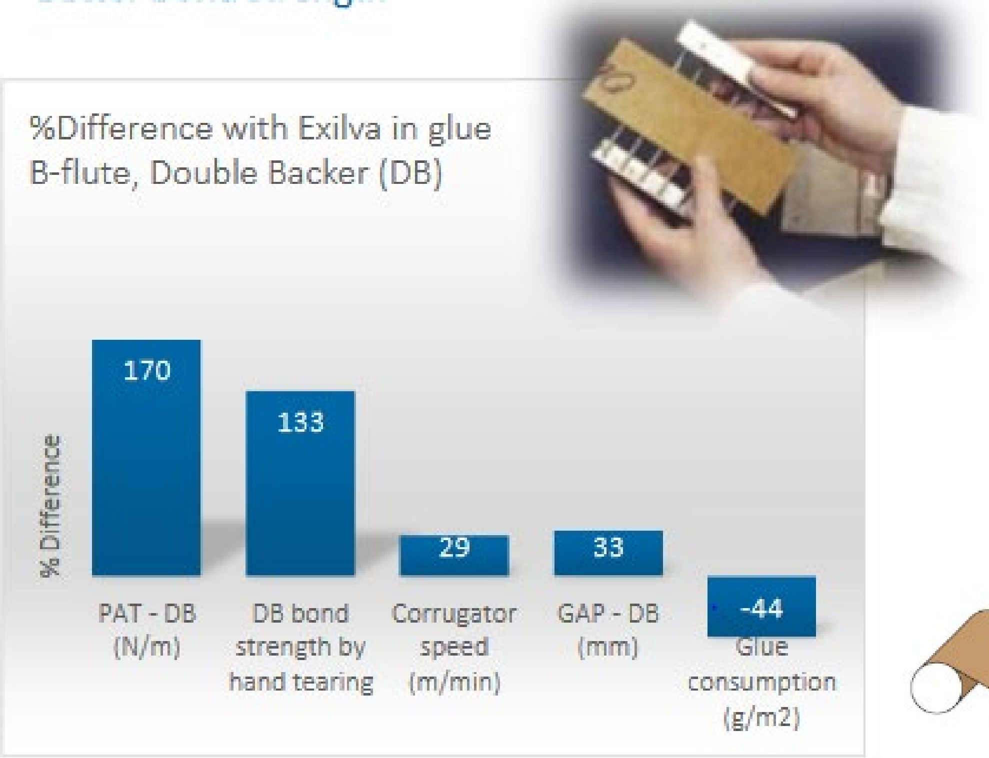


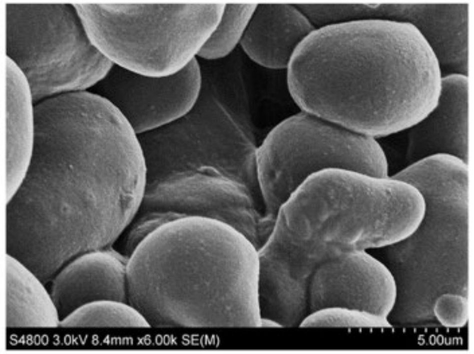


J. Philipps, 2022, PFI Rise Nanocellulose seminar

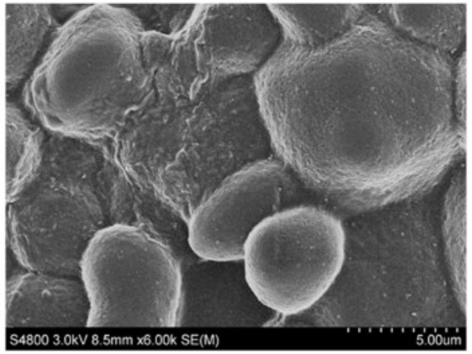
Nanocellulose to reduce weight

- Better bond strength

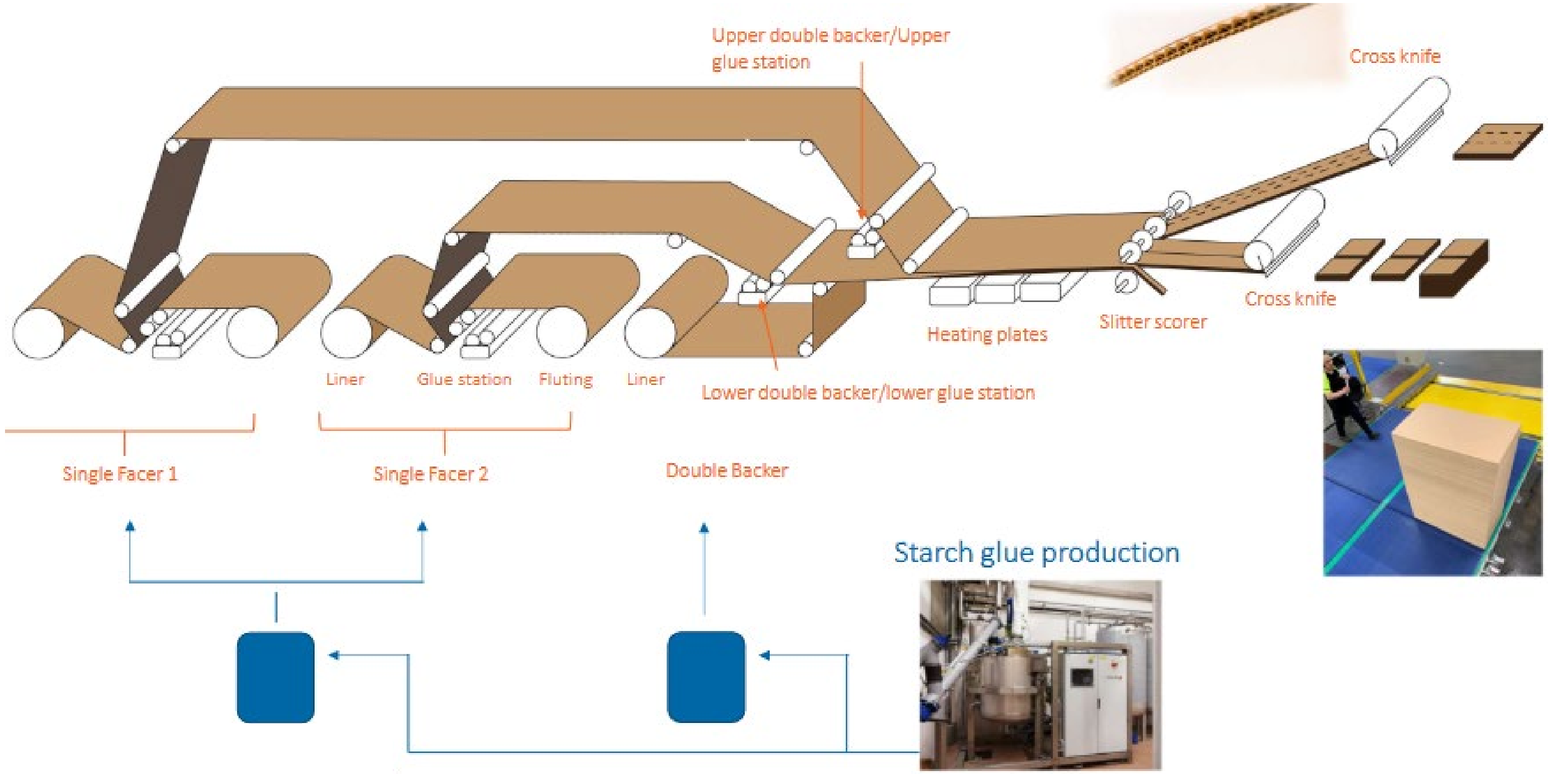




Starch adhesive without Exilva



Starch adhesive with Exilva



Orientations

☑

REDUCE	REUSE
	
Social responsibility Change of the consumption habits	Refill and Reuse

Bulk products

Cellulose Valley
BY FONDATION GRENOBLE INP

Eliminate Single Use Packagings

CIRCULAR DELIVERY

- Refill container delivered to consumer
- Collaboration with LOOP/ TerraCycle

REFILL SYSTEMS

- Water system to refill consumers container
- Piloted in US, France and Switzerland

SINGLE-DOSE DISPENSERS

- Dosing system for powdered beverages
- Rolled out in 39 markets globally

IN-STORE DISPENSERS

- Bulk dosing system for petcare and soluble coffee
- Piloted in Switzerland

Source: Nestle Press release, Sept 2020

Bulk products

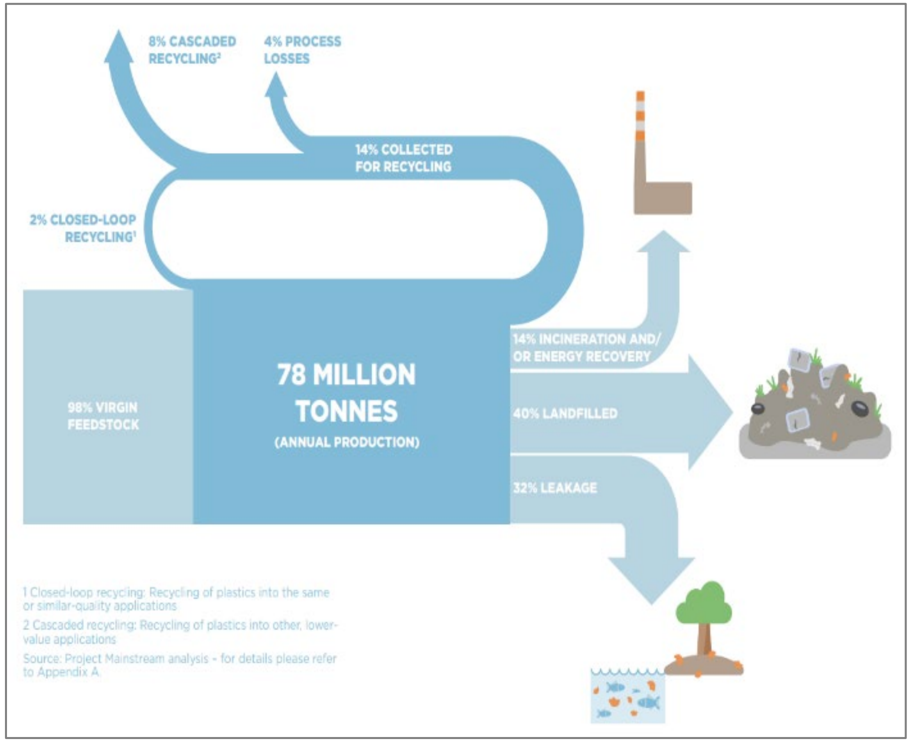
Cellulose Valley
BY FONDATION GRENOBLE INP

=> Development of Cellulose Nacre concept (in progress)

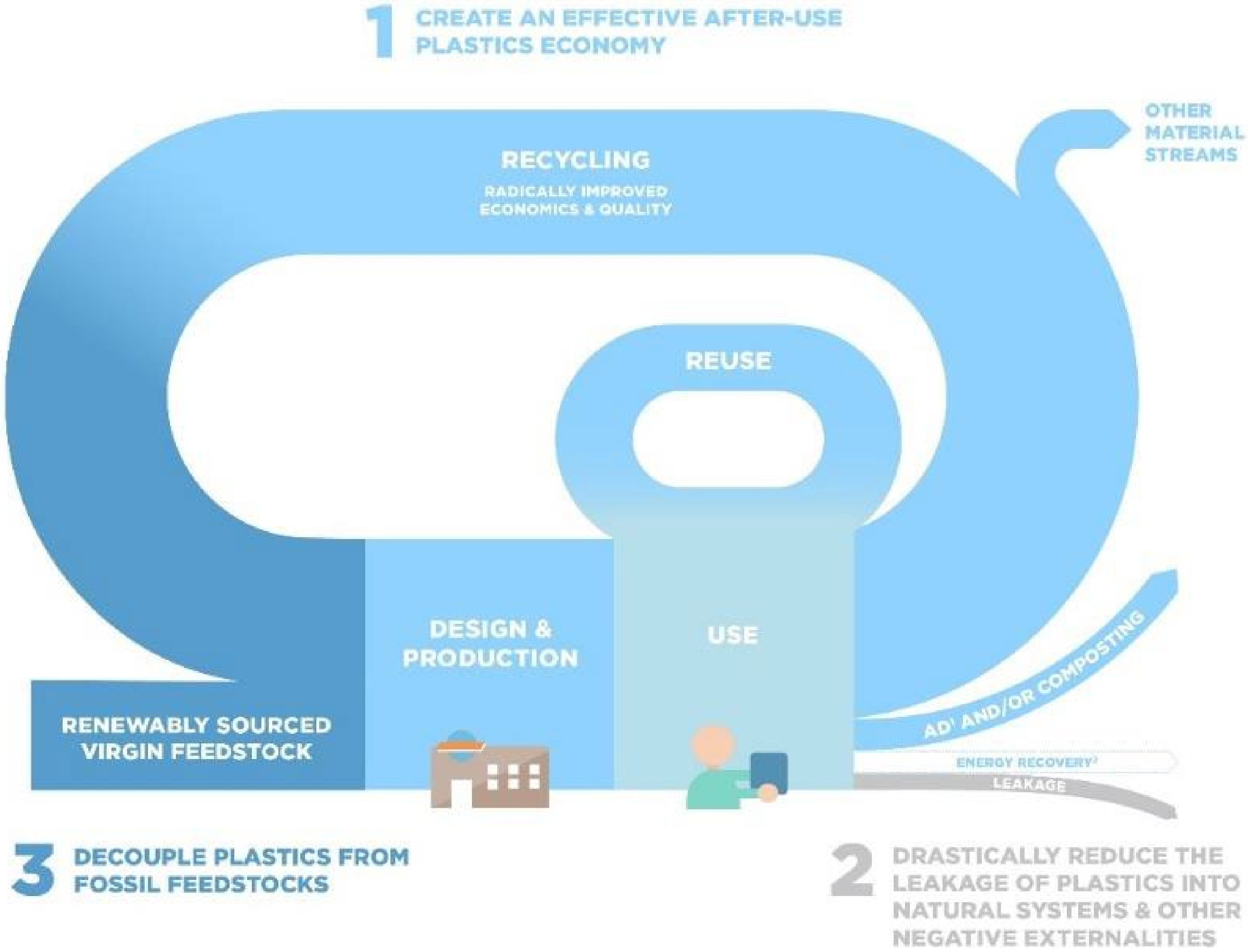
Orientations

REDUCE	REUSE	RECYCLE
		
Social responsibility Change of the consumption habits	Refill and Reuse	Recyclability for a better feedstock management

Circular economy



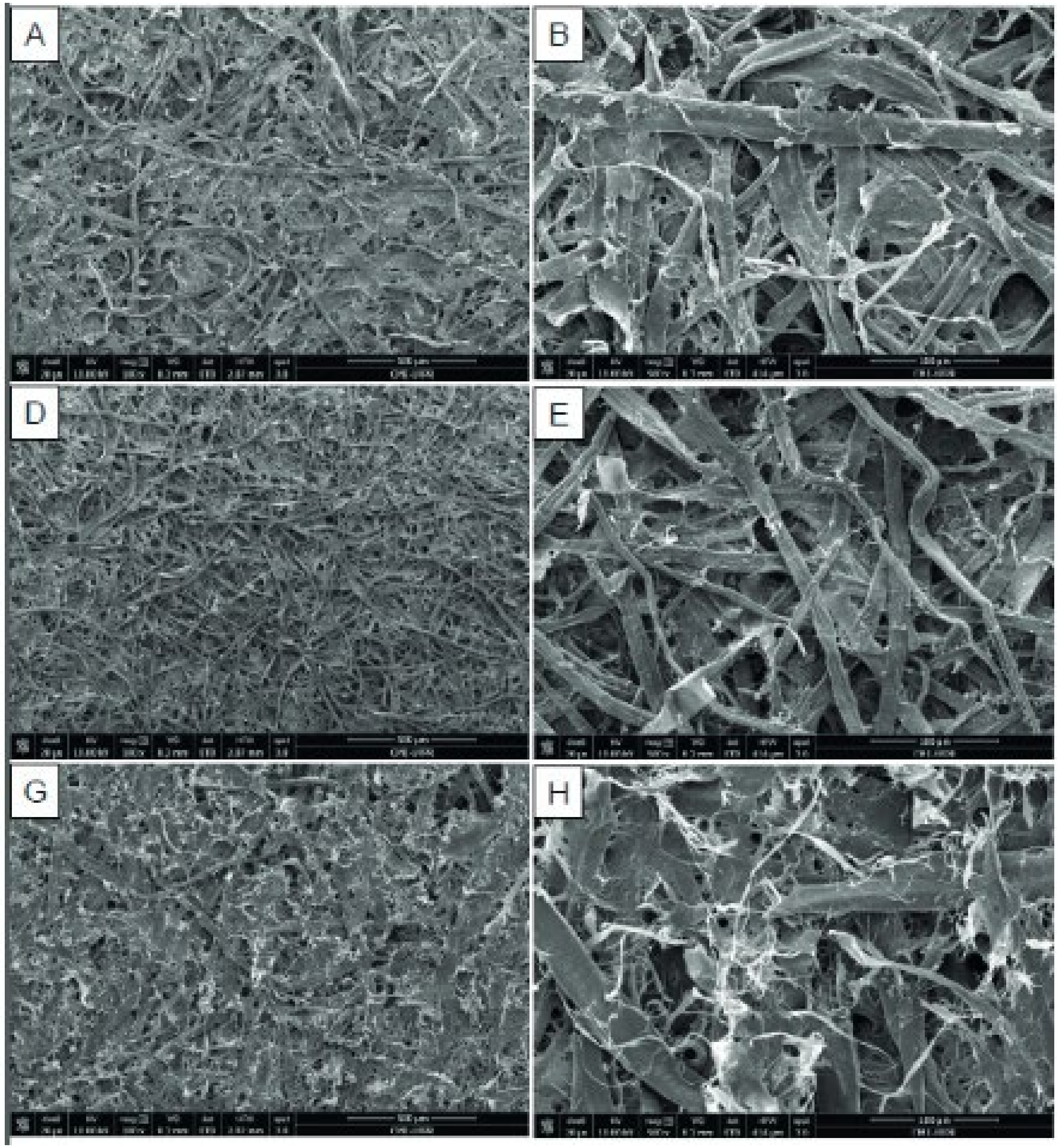
Linear economy

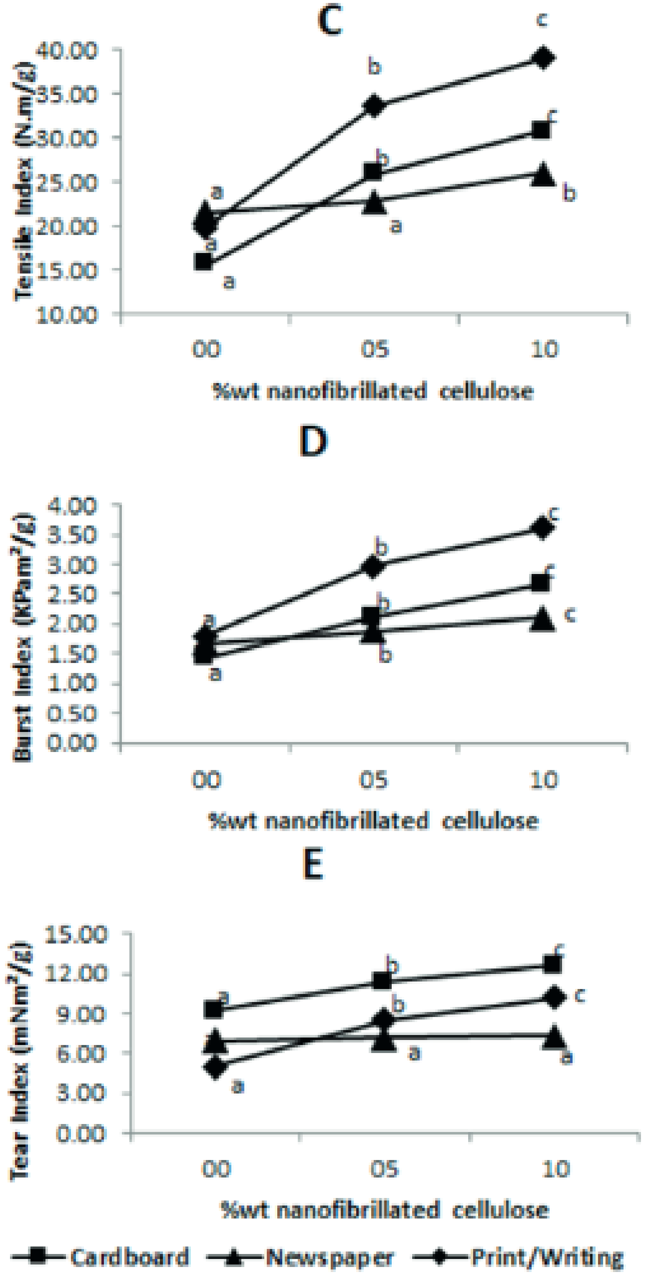


Circular economy

- Ellen MacArthur Foundation, *The New Plastic Economy – Rethinking the future of plastics.* 2014.

Recyclable materials



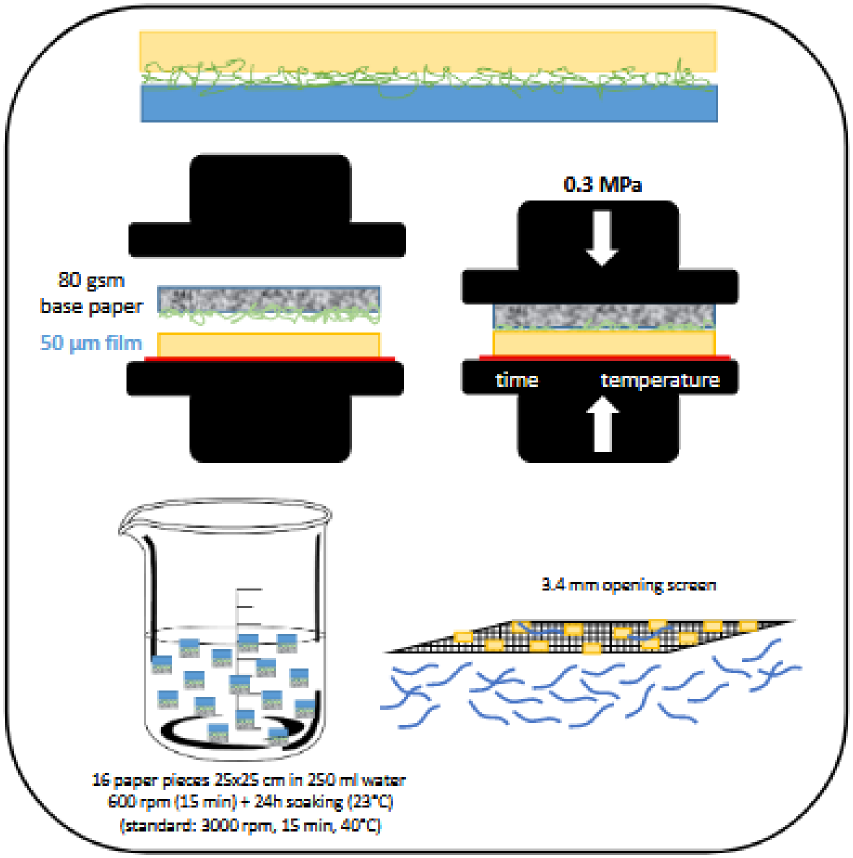


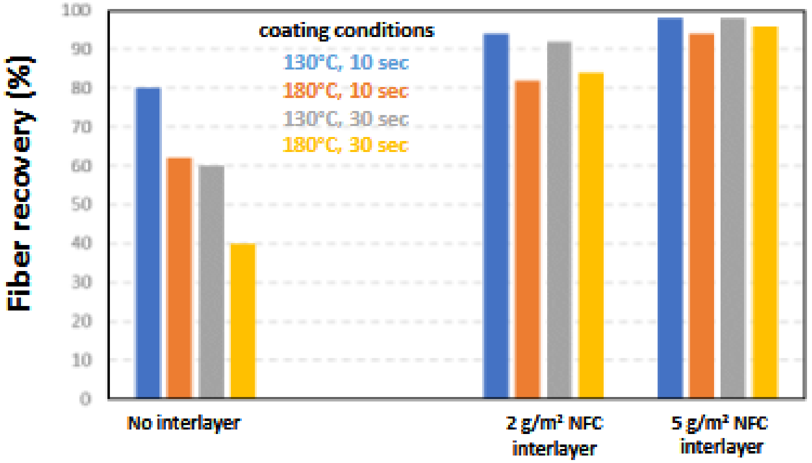
L VIANA, L. C.; POTULSKI, D. C.; MUNIZ, G. I. B.; ANDRADE, A. S.; SILVA, E. L. Nanofibrillated cellulose as an additive for recycled paper. CERNE, v. 24, n. 2, p. 140-148, 2018

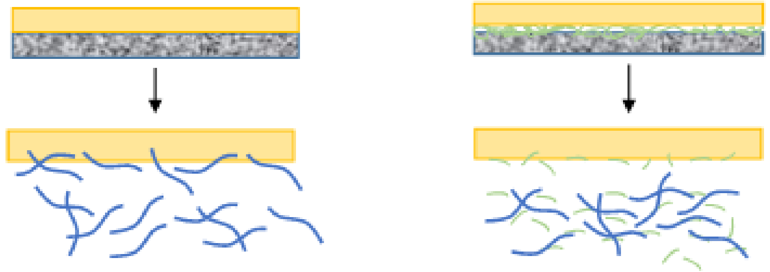
Recyclable materials

End-of-Life: Role of Nanocellulose in Paper Recycling

Preliminary testing on the lab-scale recyclability (fiber recovery) of experimental laminated paper coatings of PE/paper and PP/NFC/paper, which were disintegrated by mixing, soaking in water and screening.





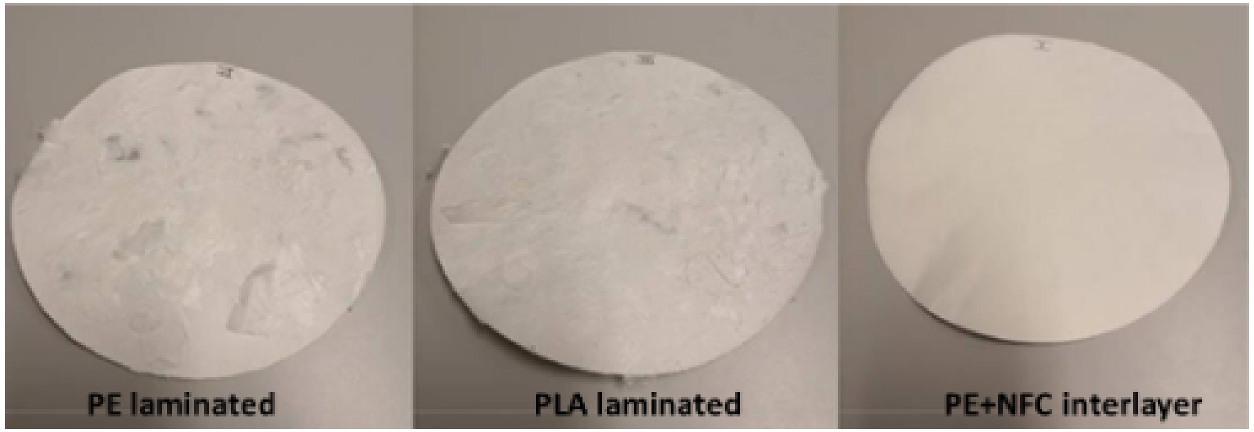


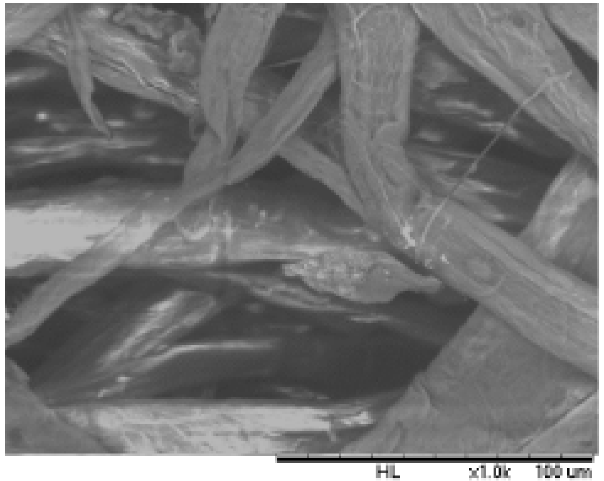
- Fiber recovery = weight based calculated from weight change in PE film (with embedded fibers) after drying. Relative measurements different from actual recycling system.
- NFC "release layer" prevents penetration of PE in the paper structure. The release layer becomes flexible when wet and stiff when dried. Small amount of NFC remains in PE film, while rest recovered together with fiber fraction.

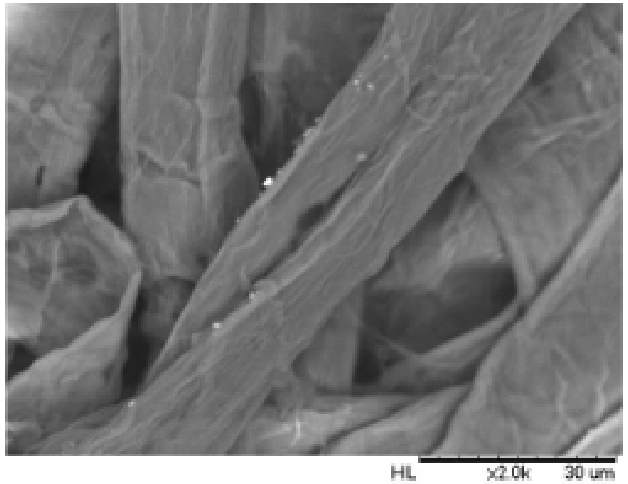
Coutesy to P. Samyn, webinar Matbiolearn , Dec 2022

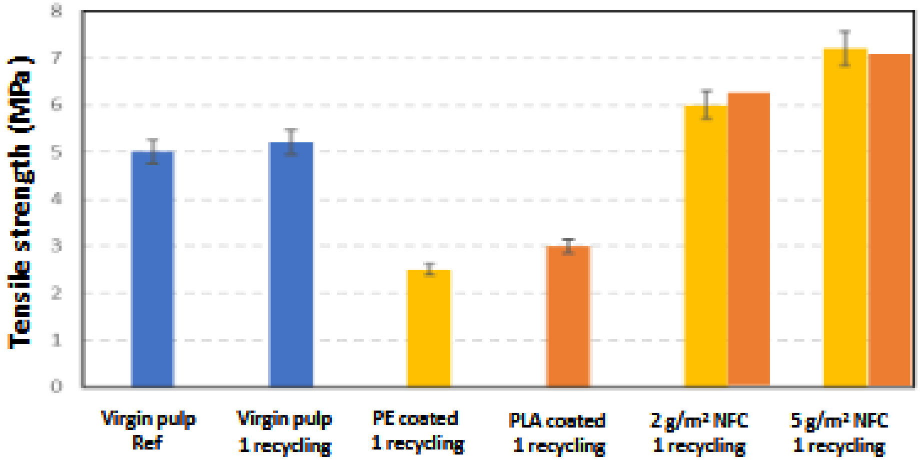
Recyclable materials

Visual and mechanical evaluation of handsheets with recycled pulp fibers









- Mechanical reinforcement effect of residual NFC fibers in recycled pulp comparable to reference testing with NFC as bulk reinforcement

- Further issues:
  - dewatering, accumulation of NFC, ...
  - reduced adhesive strength between PE-coating and NFC layer

    (eventually corona treatment, cationic starch additives/precoat)

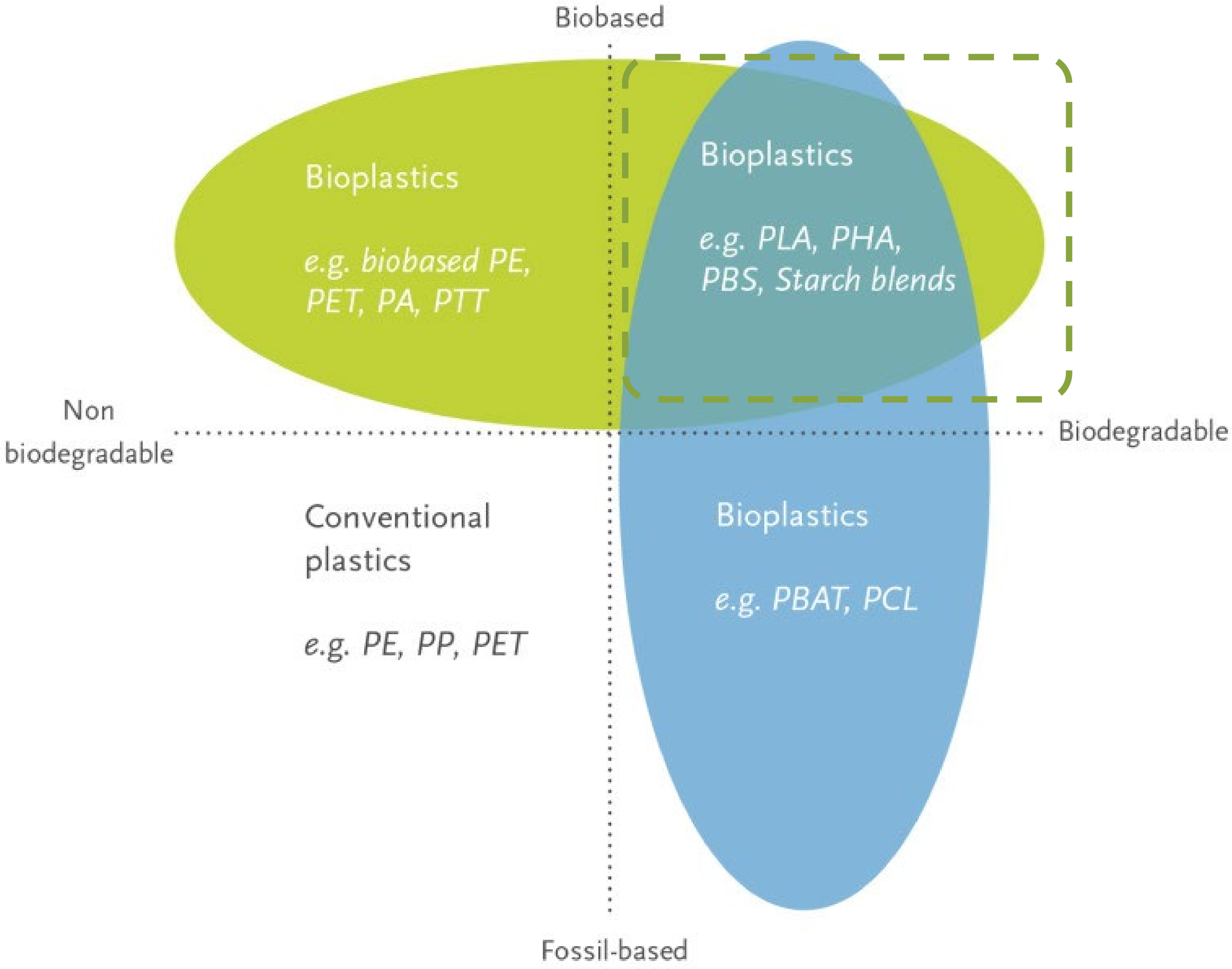
Coutesy to P. Samyn, webinar Matbiolearn , Dec 2022

Orientations

Cellulose Valley
BY FONDATION GRENOBLE INP

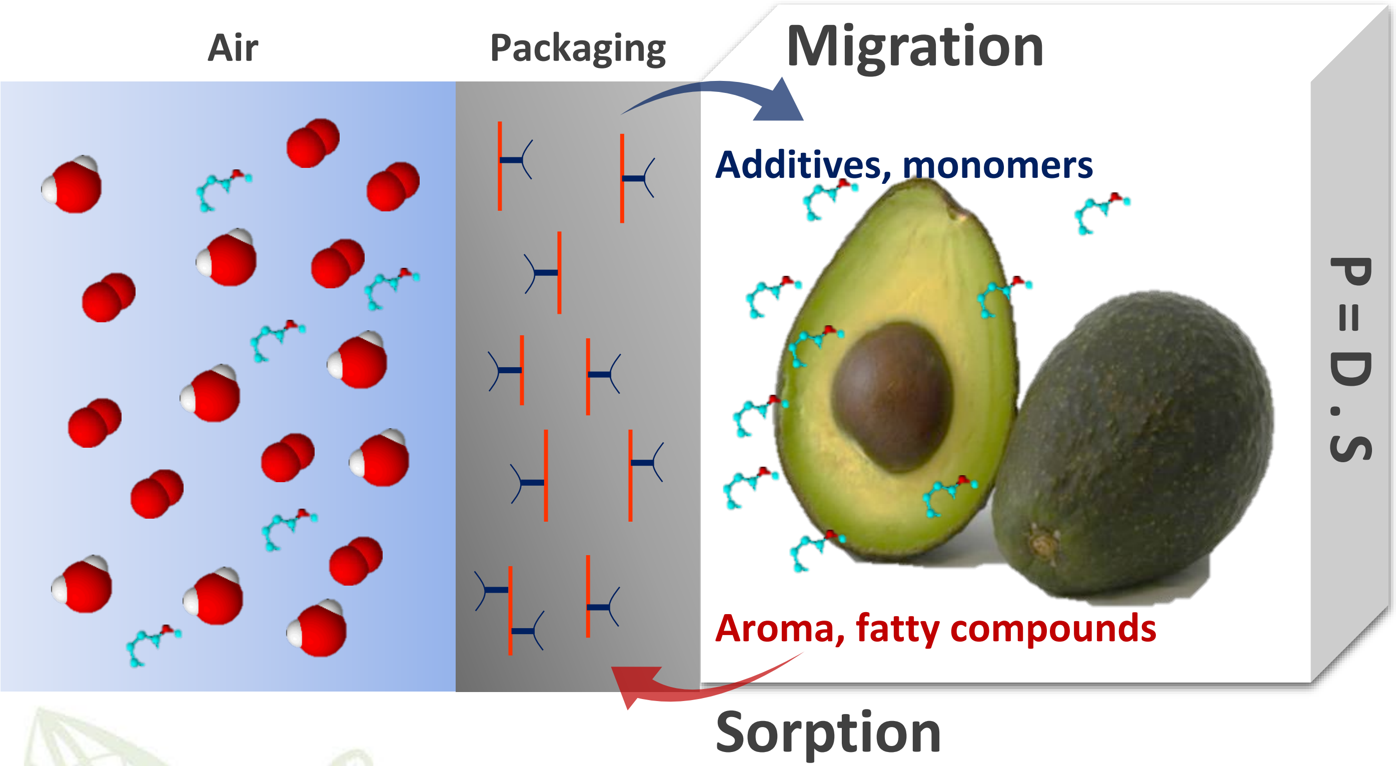
☑ REDUCE	☒ REUSE	☑ RECYCLE	BIOBASED & BIODEGRADABLE
			
Social responsibility Change of the consumption habits	Refill and Reuse	Recyclability for a better feedstock management	Biodegradability to limit the impact of leakage in nature

BioPlastics



Source: European bioplastics

Barrier of biocomposites



Develop materials with functional barriers by the inclusion of biobased nanoadsorbents (CNC) in a polymer matrix

Ref

PLA

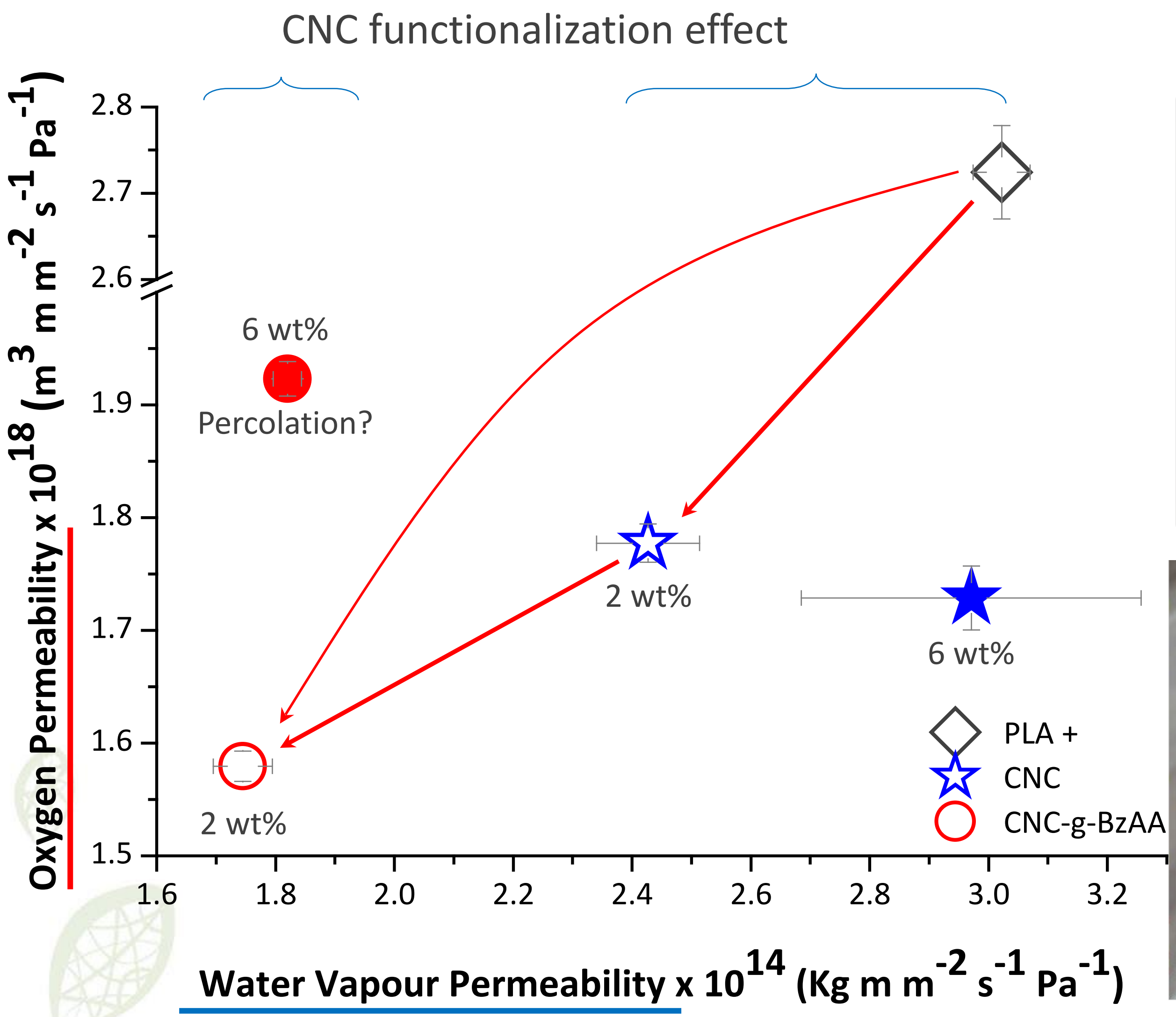
PLA-CNC

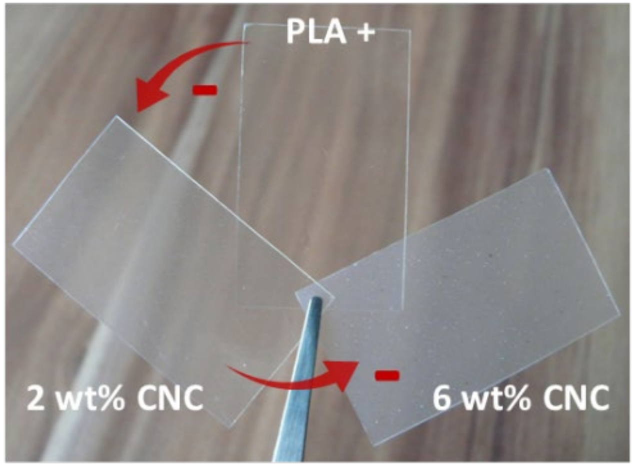
11 h   24 h   48 h

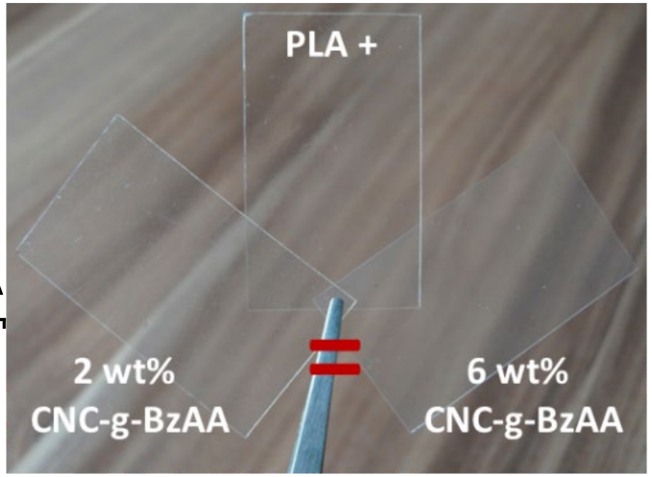
Wongthanaroj, et al, Sustainable and eco-friendly poly (Lactic acid)/cellulose nanocrystal nanocomposite films for the preservation of oxygen-sensitive food, Applied Food Research,Vol 2, 2022,100222,

Espino-Perez, E; Bras, J; Almeida, G; Relkin, P; Belgacem, N;; Plessis, C. Domenek, S. , Cellulose nanocrystal surface functionalization for the controlled sorption of water and organic vapours, Cellulose, (2016)

Barrier of biocomposites







Espino-Perez, E; Bras, J; et al, Designed cellulose nanocrystal surface properties for improving barrier properties in polylactide nanocomposites , Carb Pol (2018), 183, 267-277.

Barrier of biocomposites

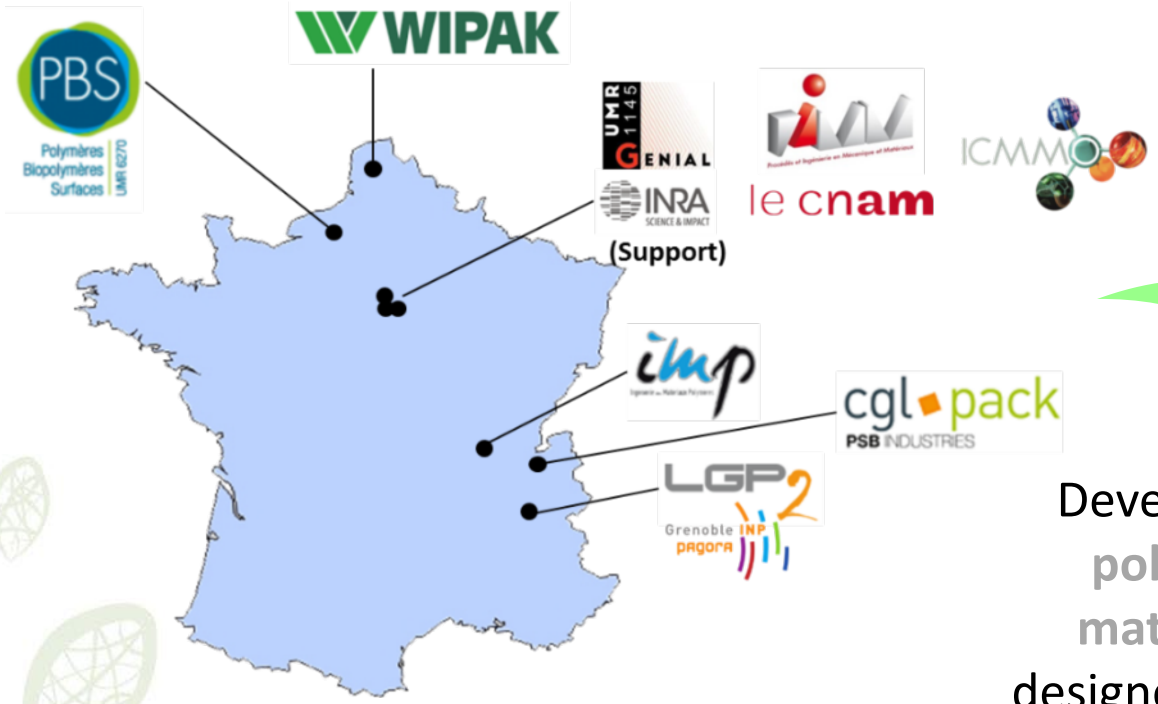
An ANR Project

GASP

Biobased High Gas and Vapor Barrier Polymers for Packaging

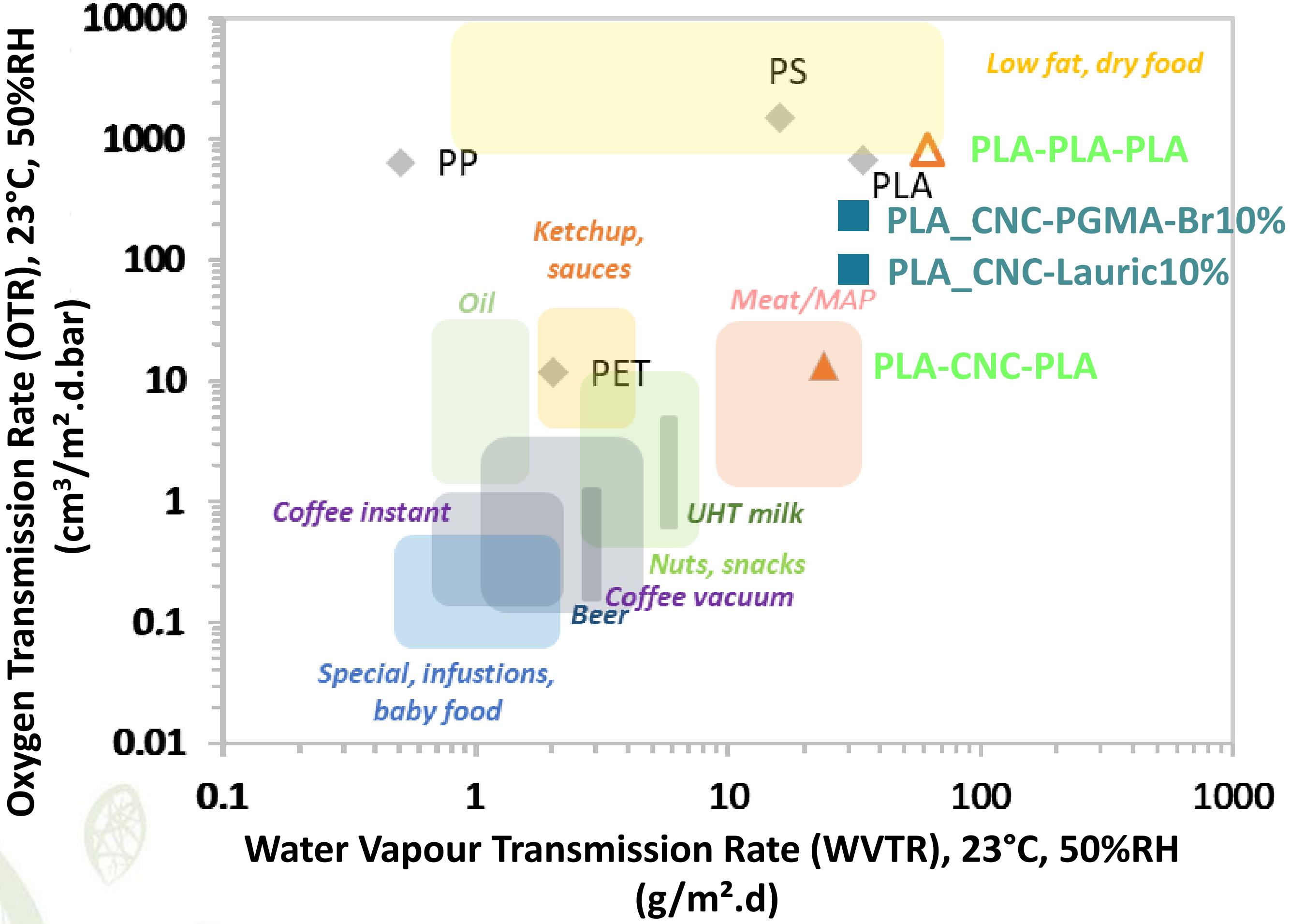
Total budget *: 2 635 082 €*

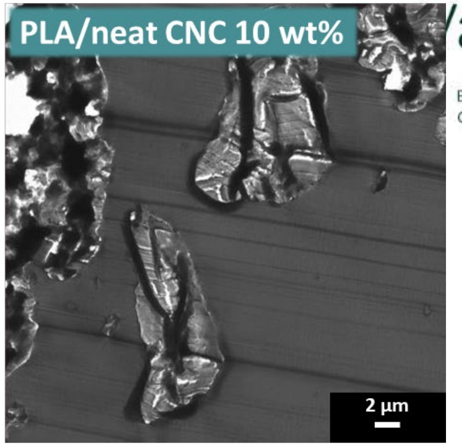
Duration *: 48 months (2016-2021)*

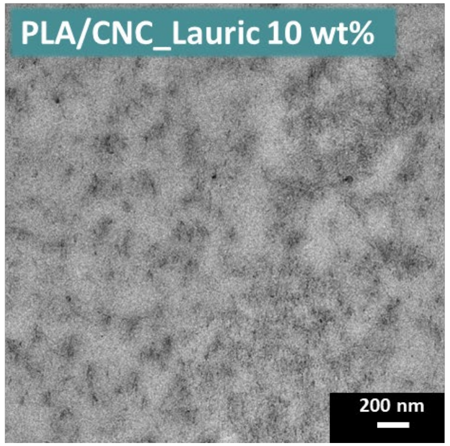


Development of 100% biobased polylactide nanocomposites materials including CNCs with designed barrier properties for food packaging applications

Barrier of biocomposites





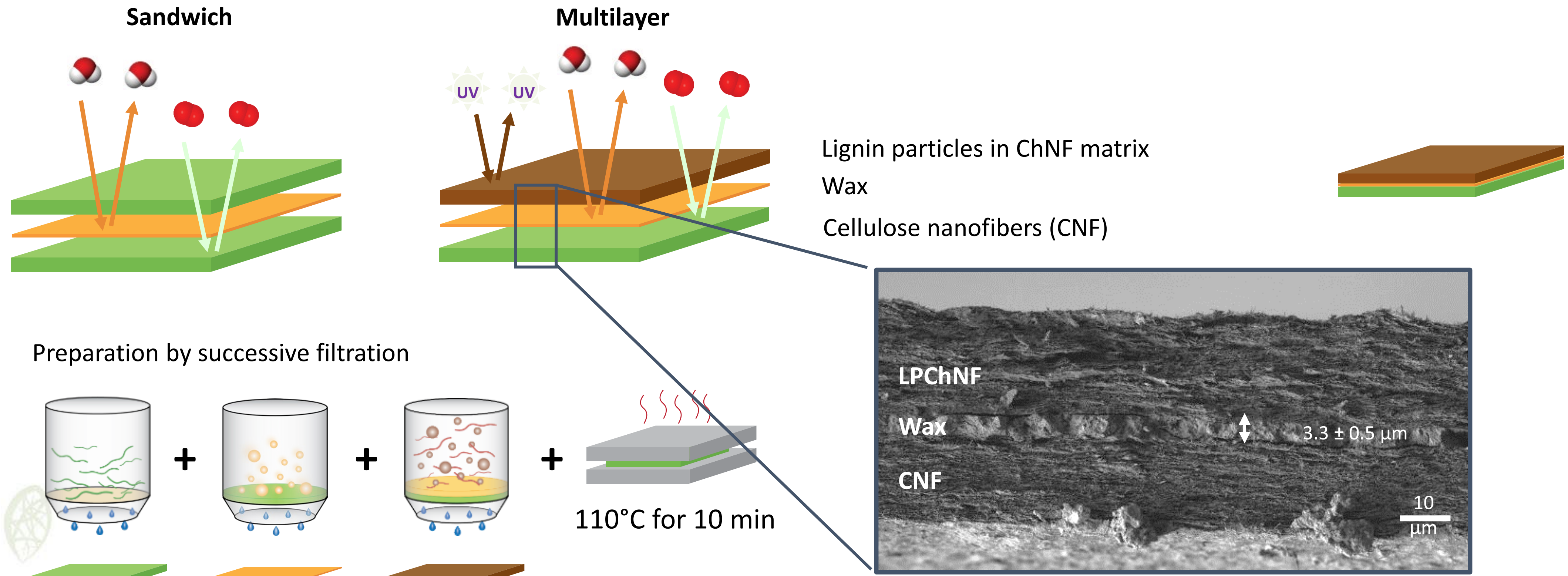


1. M Le Gars, **Bras J**, H Salmi-Mani, M Ji, D Dragoe, H Faraj, S Domenek, N; Belgacem, P.Roger, Polymerization of glycidyl methacrylate from the surface of cellulose nanocrystals for the elaboration of PLA-based nanocomposites, Carbohydrate Polymers (2020) 234, 115899 2
2. M Le Gars, A Delvart, P Roger, MN Belgacem, **Bras J**, Amidation of TEMPO-oxidized cellulose nanocrystals using aromatic aminated molecules, Colloid and Polymer Science (2020), 1-15 2
3. M Le Gars, B Dhuiège, A Delvart, MN Belgacem, K Missoum, **Bras J**, High-Barrier and Antioxidant Poly (lactic acid)/Nanocellulose Multilayered Materials for Packaging, ACS omega (2020) 5 (36), 22816-22826
4. H Faraj, C Sollogoub, A Guinault, M Gervais, Bras J, H Salmi-Mani, P Roger, M Le Gars, S Domenek, A comparative study of the thermo-mechanical properties of polylactide/cellulose nanocrystal nanocomposites obtained by two surface compatibilization strategies, Materials Today Communications, (2021), 102907

Bioplastic and multilayer approach

H. Kangas, 2022, PFI Rise Nanocellulose seminar

Bioplastic and multilayer approach



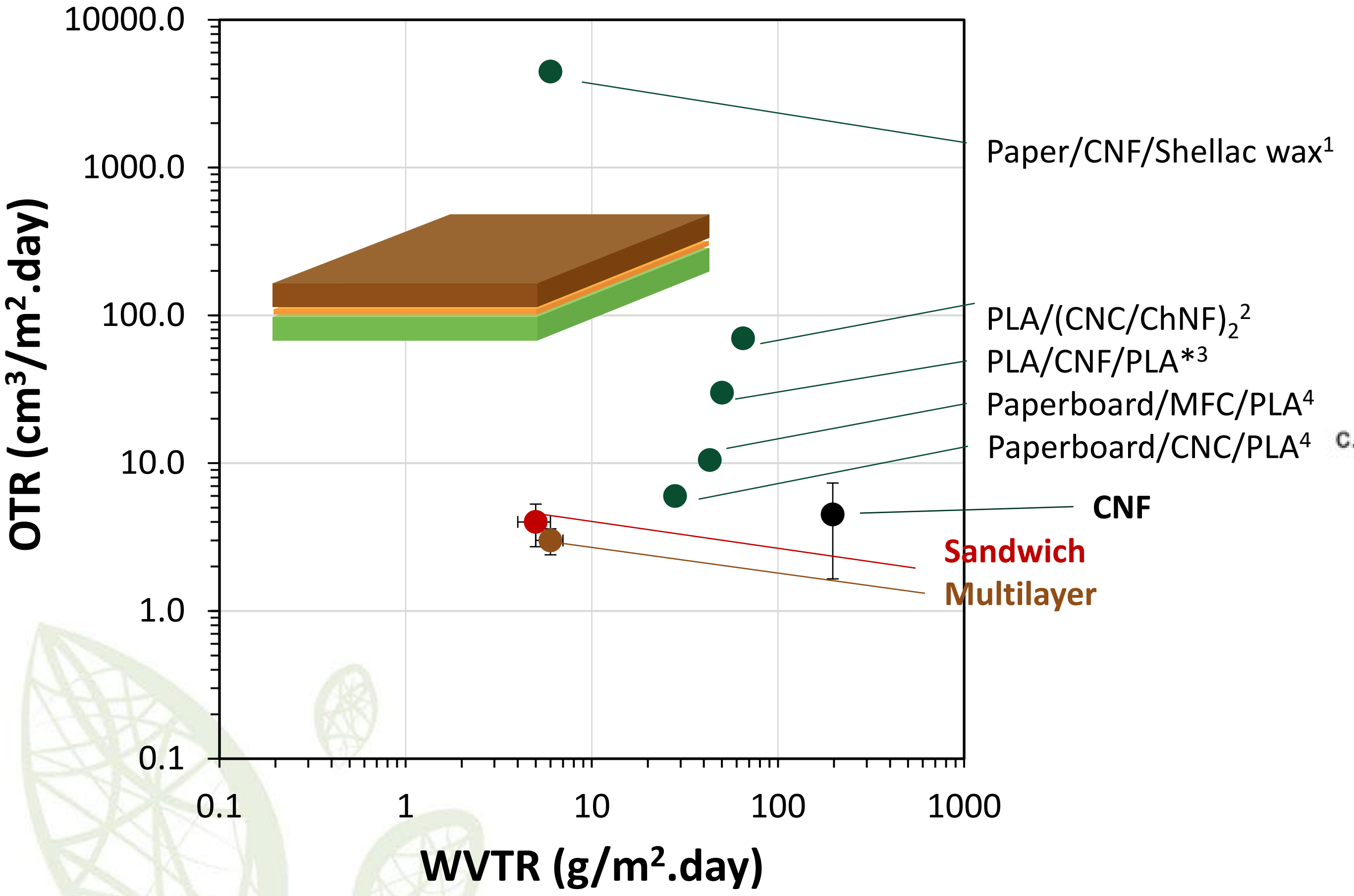
Structure of the cross-section

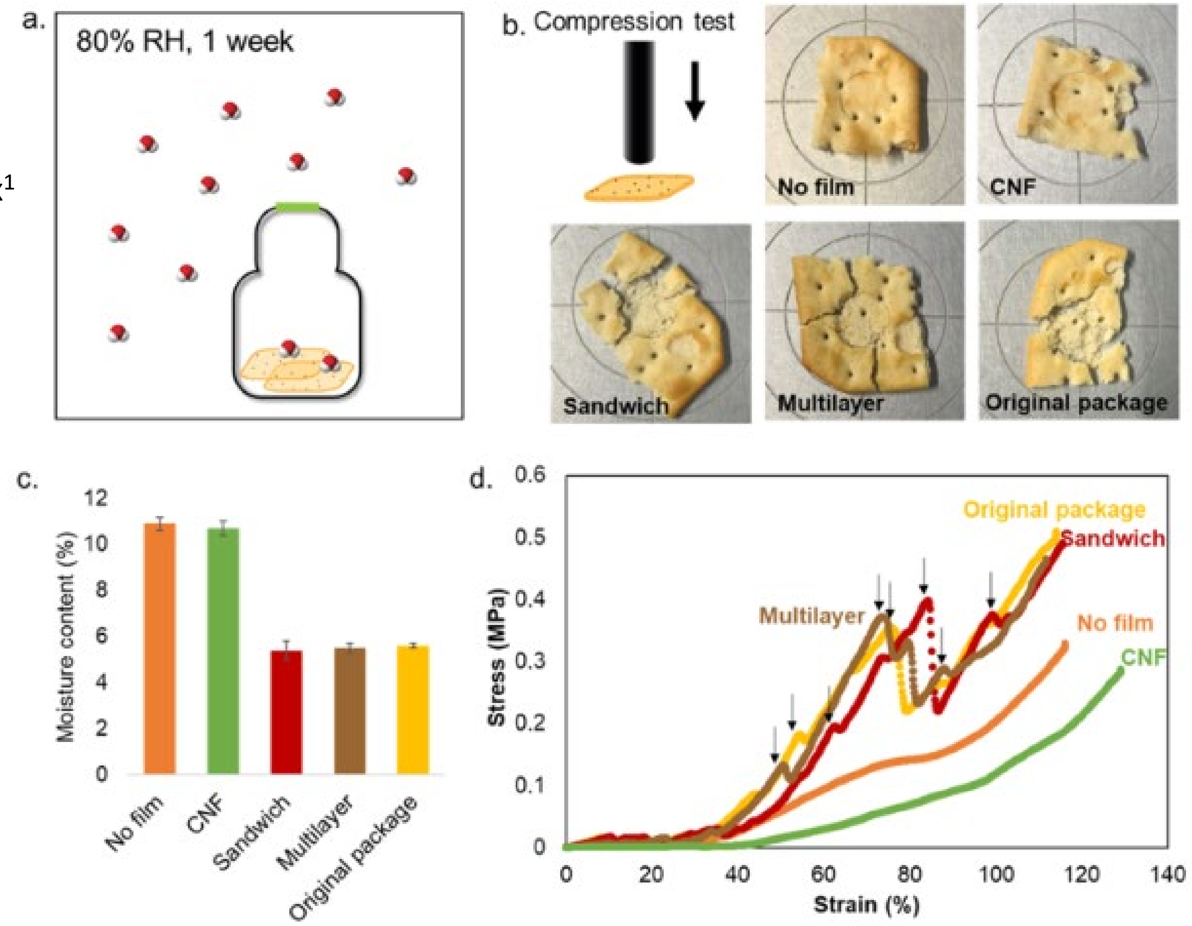
Film thickness: 45 ± 4 µm

E Pasquier, BD Mattos, H Koivula, A Khakalo, MN Belgacem, OJ Rojas, J. Bras, ACS Appl. Mater. Interfaces 2022, 14, 26, 30236–30245

Bioplastic and multilayer approach

Comparison with biobased multilayers in literature (23°C, 50% RH)



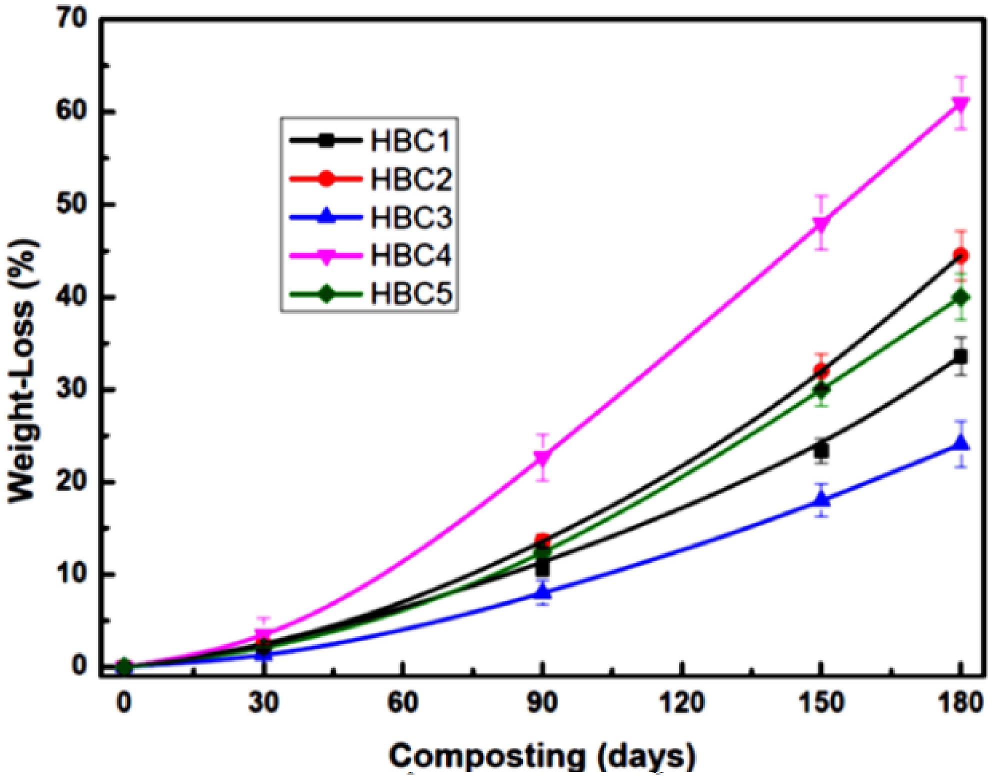


*OTR measured at 0% RH

E Pasquier, BD Mattos, H Koivula, A Khakalo, MN Belgacem, OJ Rojas, J. Bras, ACS Appl. Mater. Interfaces 2022, 14, 26, 30236–30245

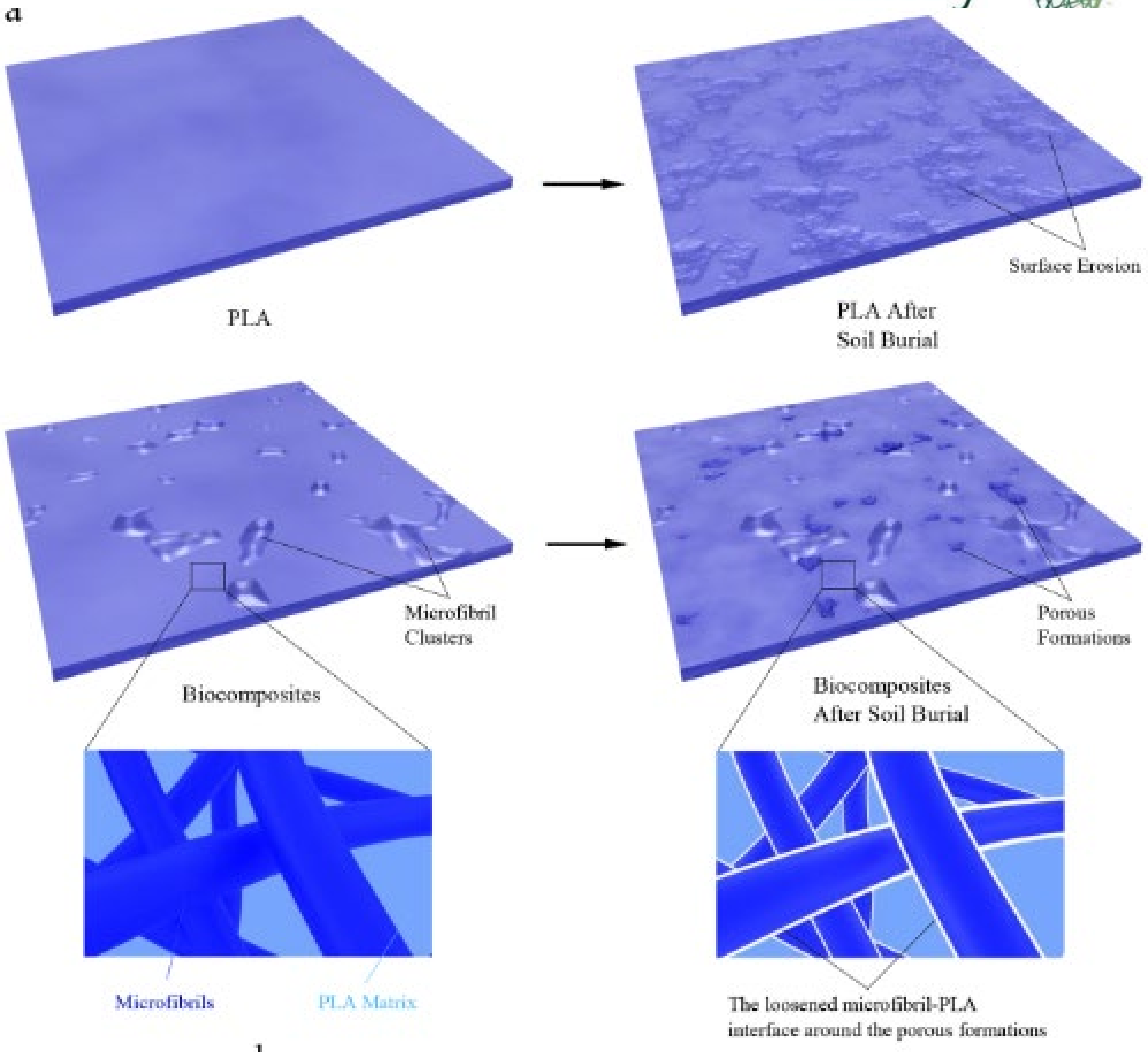
1.Hut *et al.*, *Cellulose*, **2010**, 17, 3, 575
2.Satam *et al.*, *ACS Sustainable Chem*. Eng., **2018**, 6, 8, 10637
3.Le Gars *et al.*, *ACS Omega*, **2020**, 5, 36, 22816
4.Koppolu *et al., ACS Appl. Mater. Interfaces*, **2019**, 11, 12, 11920

Impact on biodegradability



	PLA (wt.%)	MFC (wt.%)	CNC (wt.%)
HBC1	100	0	0
HBC2	80	20	0
HBC3	95	0	5
HBC4	75	20	5
HBC5 (central point)	87.5	10	2.5

Galera Manzano, L.M et al Effect of Cellulose and Cellulose Nanocrystal Contents on the Biodegradation, under Composting Conditions, of Hierarchical PLA Biocomposites. Polymers 2021, 13, 1855.



Yetiş, F., Liu, X., Sampson, W.W. et al. Biodegradation of Composites of Polylactic Acid and Microfibrillated Lignocellulose. J Polym Environ 31, 698–708 (2023).

Orientations

☑

REDUCE

Social responsibility
Change of the consumption habits

☒

REUSE

Refill and Reuse

☑

RECYCLE

Recyclability for a better feedstock management

☑

BIOBASED & BIODEGRADABLE

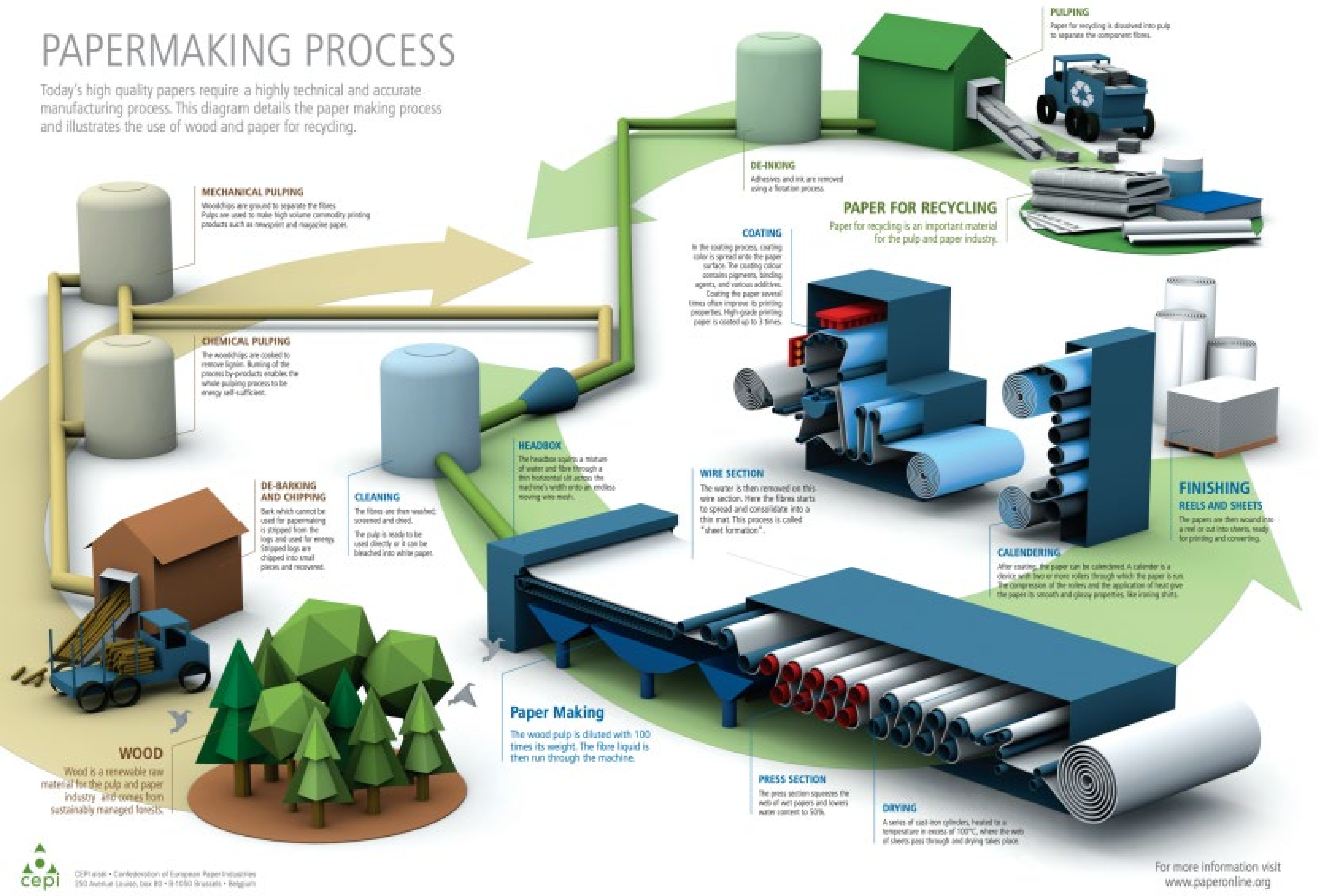
Biodegradability to limit the impact of leakage in nature

Fibre & Paper Based Materials

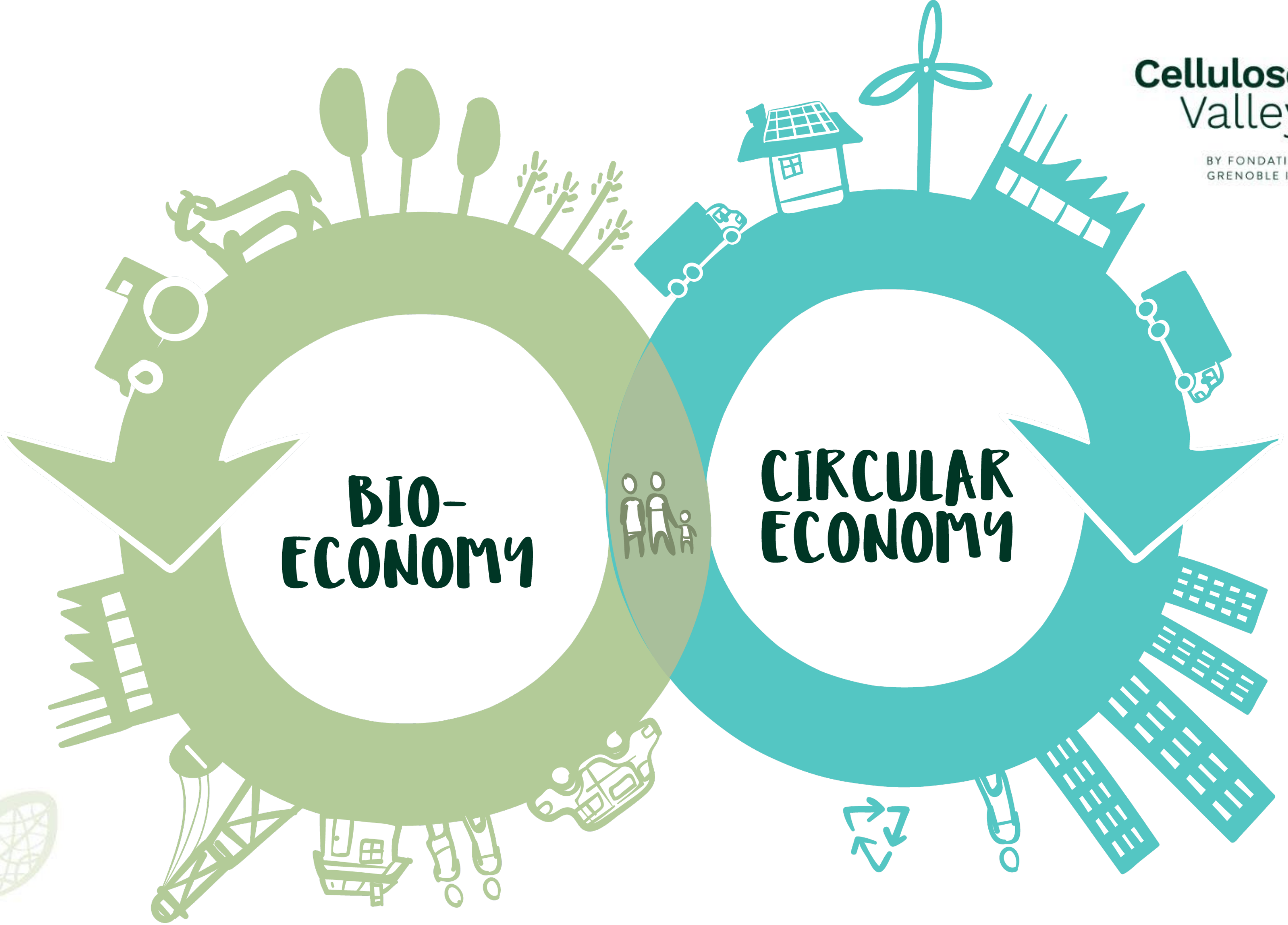
Biosourced & Renewable
Recyclable
Biodegradable

Cellulose Valley

BY FONDATION GRENOBLE INP



Cellulose Valley
BY FONDATION GRENOBLE INP



Towards paperization

ACCESSORIES

- Paper straws
- Paper cups

SECONDARY PACKAGING

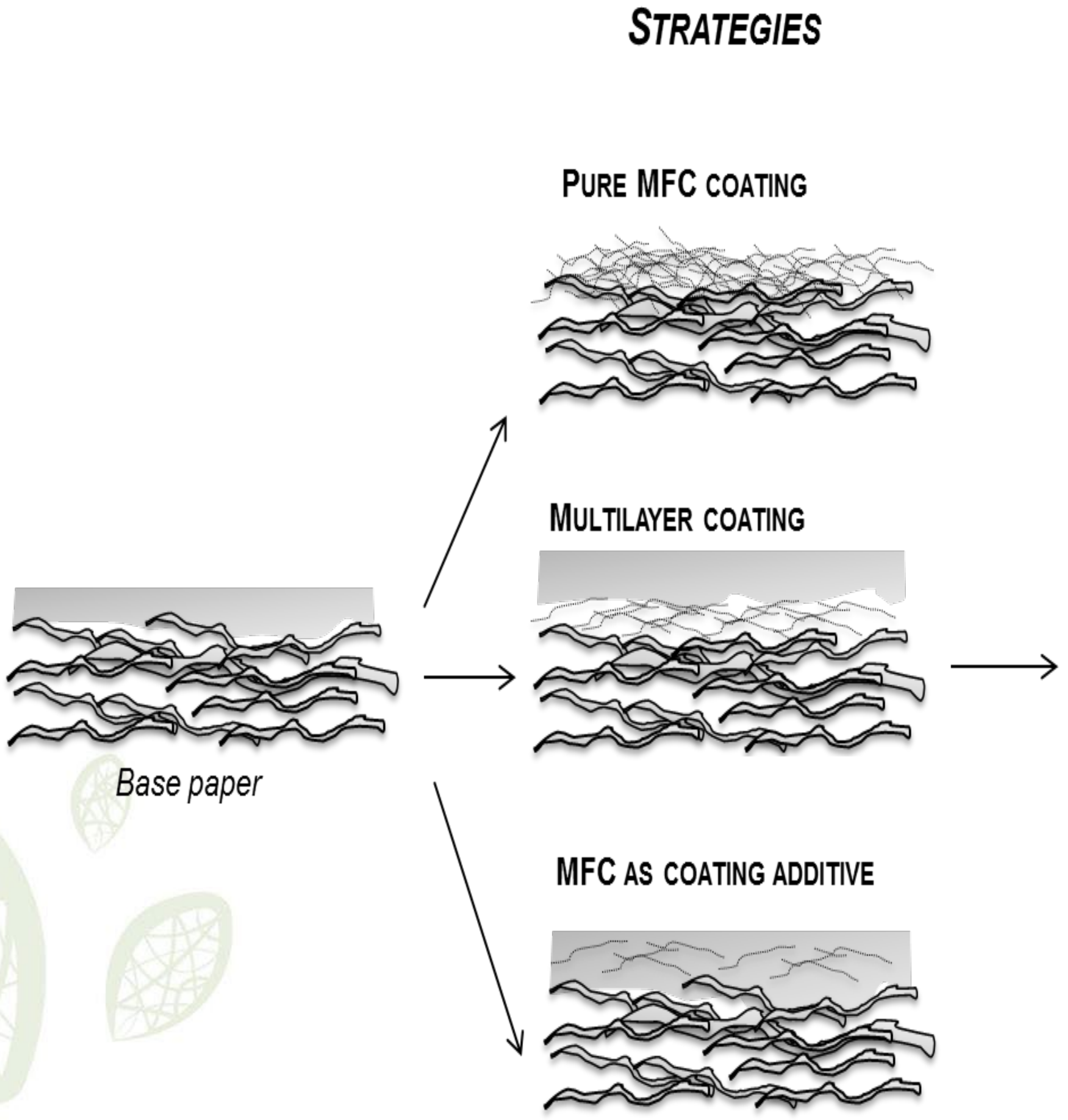
- Re-groupment pouches
- Boxes or envelopes

PRIMARY PACKAGING

- Beverage powder pouches
- Chocolate flow-packs
- Ice cream wrappers
- Bouillon cube wrappers

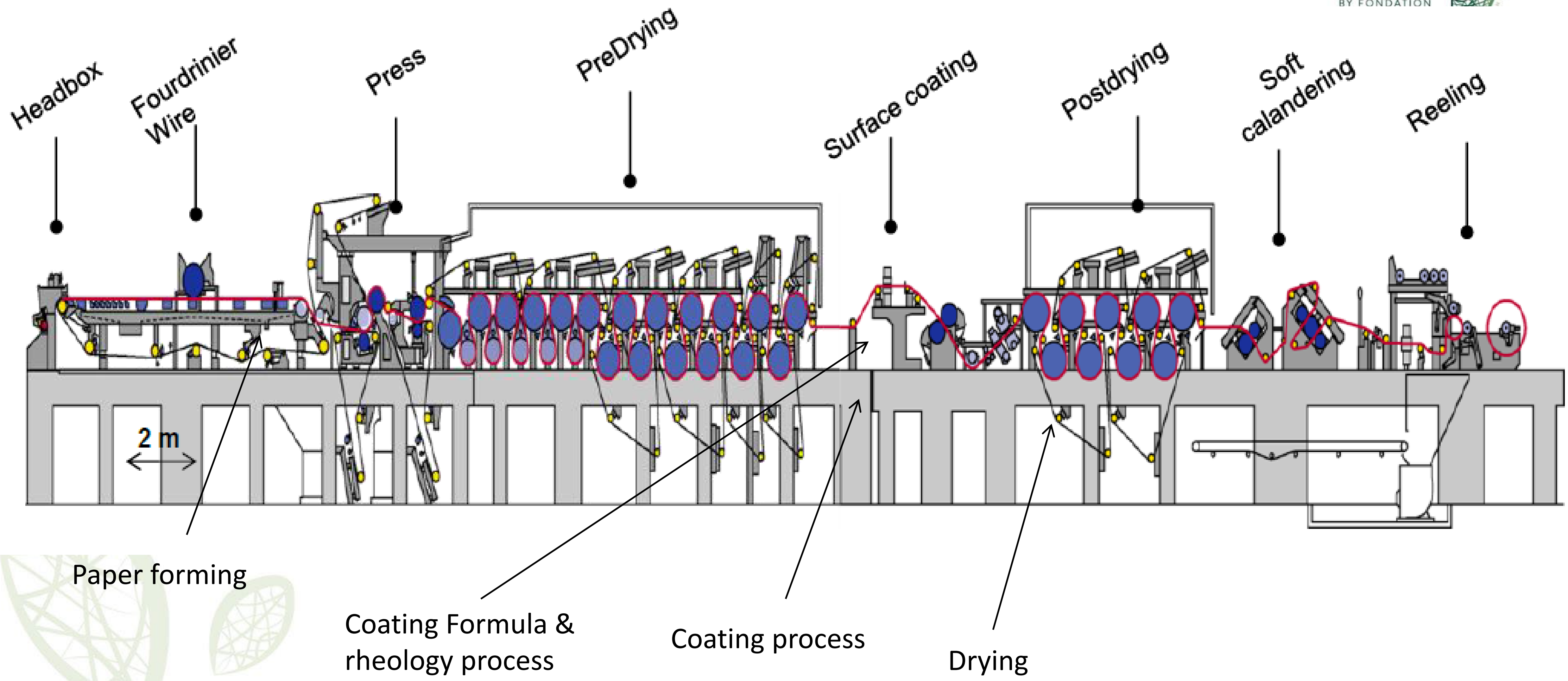
Press Release, Sept 2020

Classic strategies



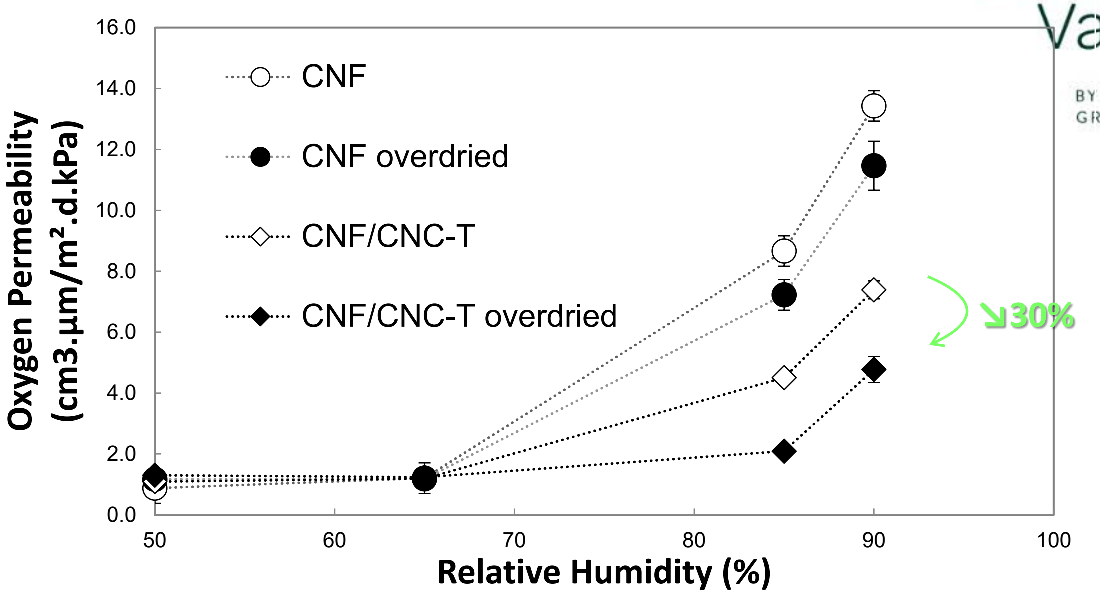
- **(I) BARRIER PROPERTIES**
  Air, Oxygen, Grease, Water vapor ,...
- **(II) PRINTING PROPERTIES**
  Flexography, offset, inkjet
- **(III) FUNCTIONNAL PROPERTIES**
  Antimicrobial , hydrophobic paper , conductive paper

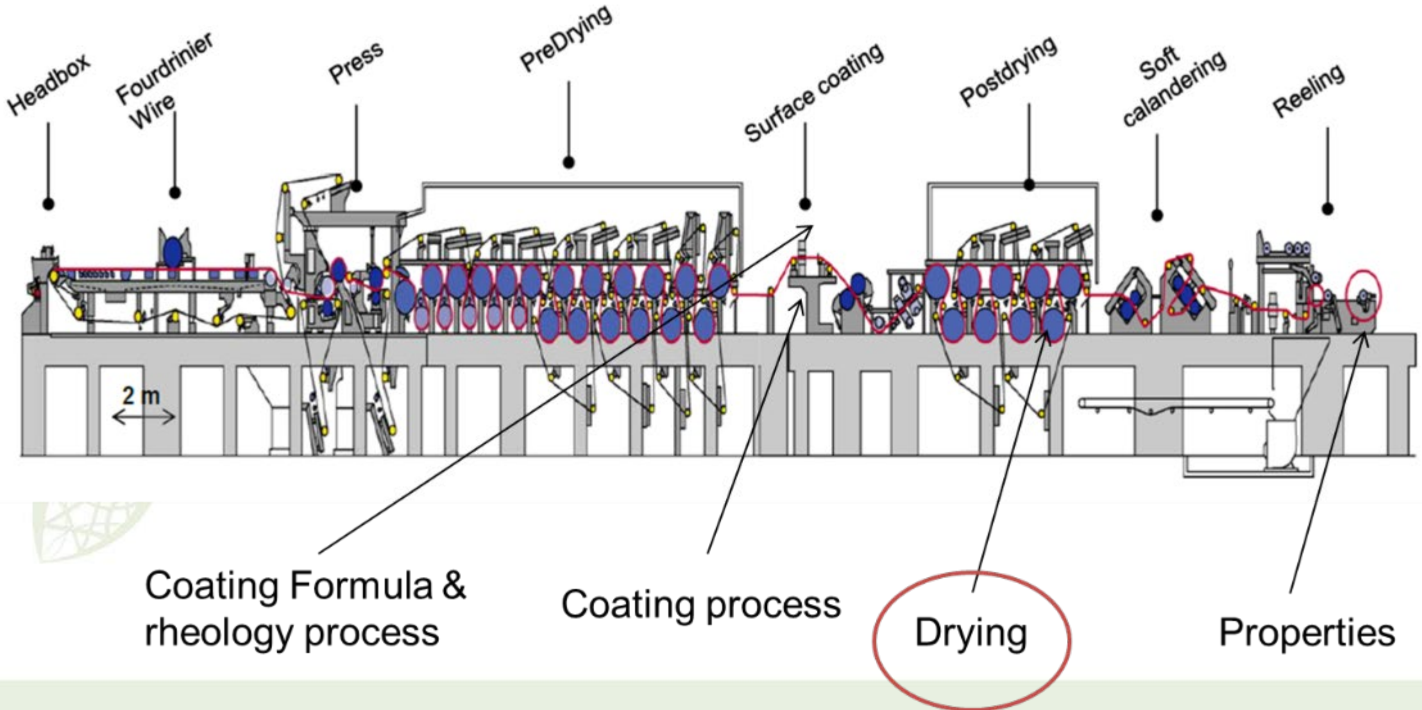
Classic strategies



Classic strategies

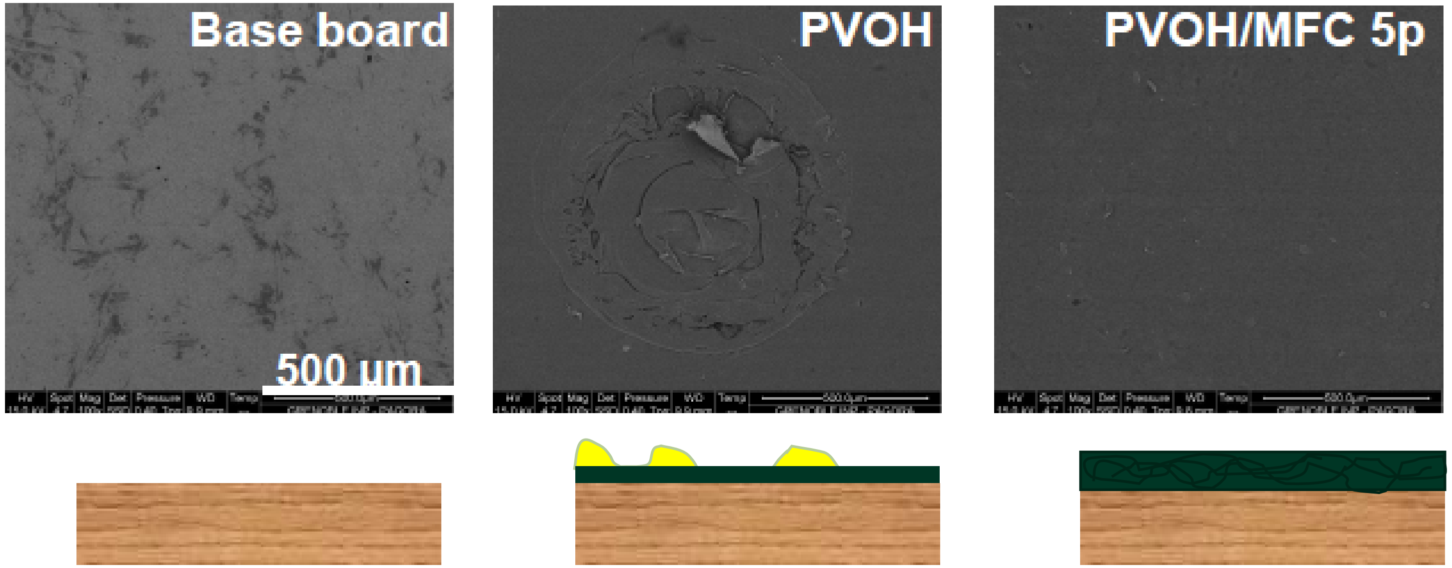
Bardet, Reverdy, Belgacem, Leirset, Syverud, Bras, J (2015)
Cellulose, 22(2), 1227-1241





Classic strategies

- **Drying behaviour**
  - Drying strategy very hard to monitore with PVOH:
    - ✓ Blistering
  - Improvement of the layer drying with PVOH/MFC
    - ✓ Blistering reduction
- **SEM pictures**



=> CNF = network controlling-dispersing drying energy
=> No more Blistering

Adapted from Guezennec et al, SunPap conference, 2014

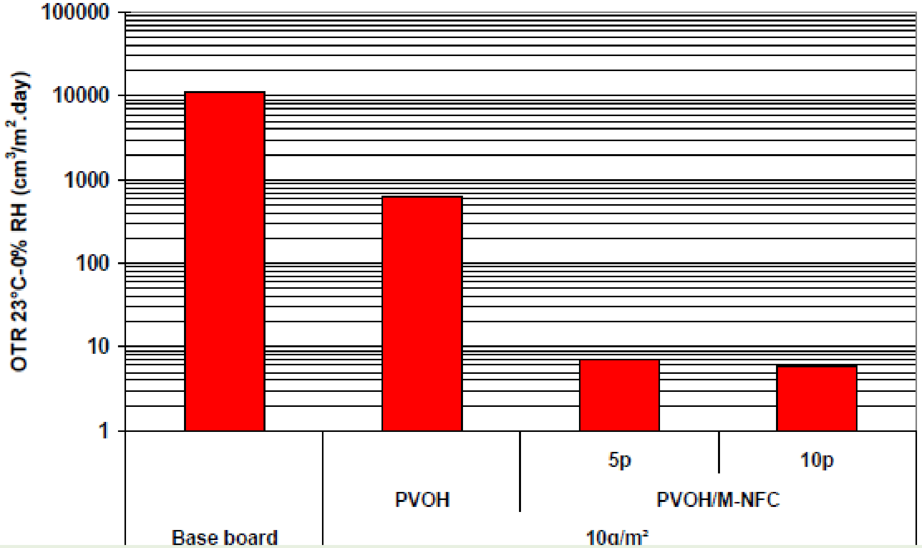
Classic strategies

- **Oil and grease resistance**
  - Cobb index 24H with coloured peanut oil

Base board **PVOH/MFC 5p - 10g/m²**

Cobb index: 200 g/m² **Cobb index: 2 g/m²**

- **Oxygen transmission rate 23°C-0% RH**

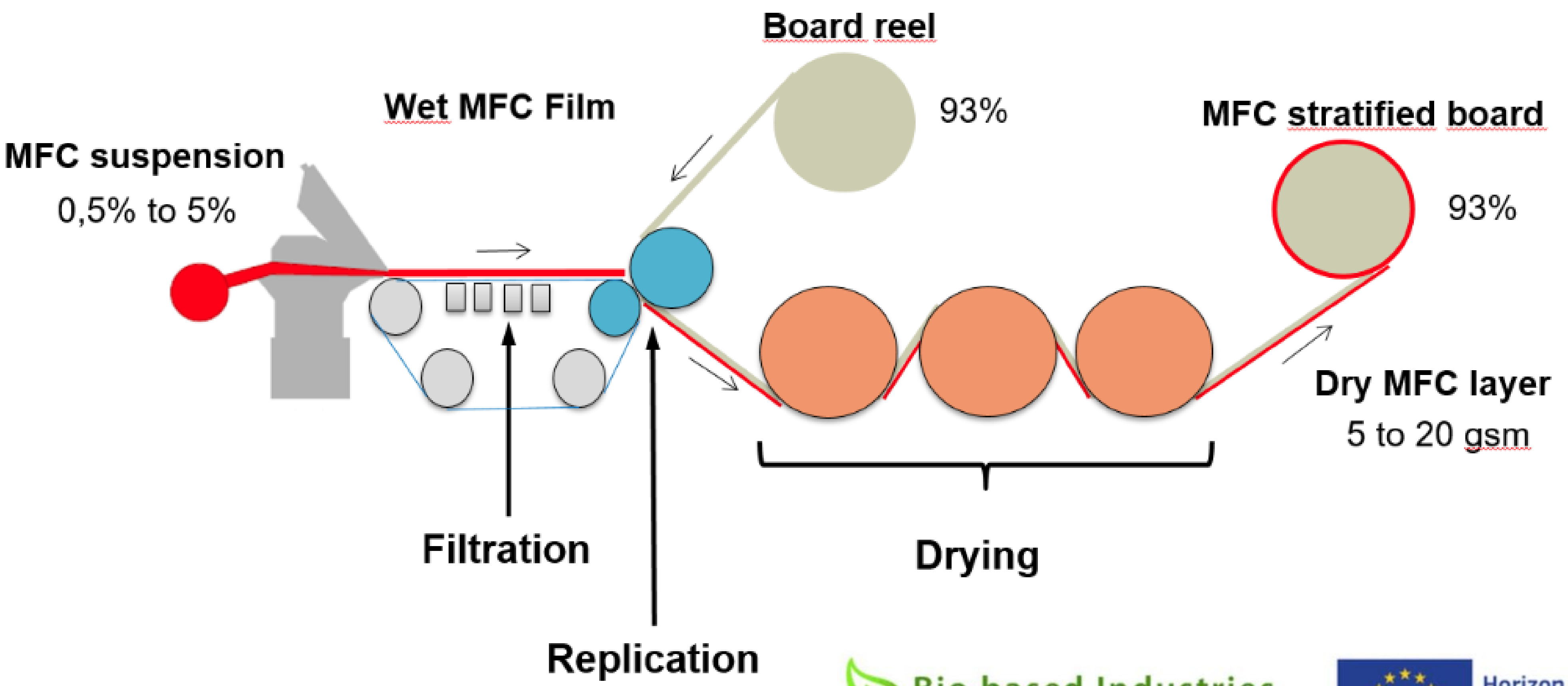


From lab to industry:
Pakocell project (3 years projects 2015-2018)

From lab to industry:
PaCow project (2 years projects 2021-2023)

New strategies

Process developments to obtain 100% cellulosic packaging material, barrier, recyclable and compostable

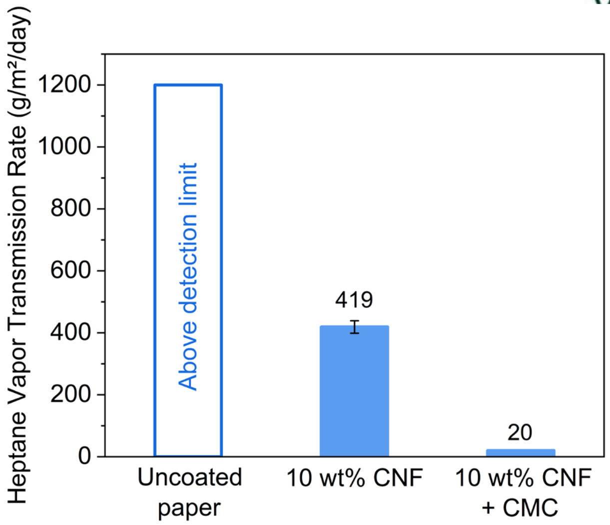


Bio-based Industries Consortium

Horizon 2020
European Union Funding
for Research & Innovation

New strategies

20 wt% CNF

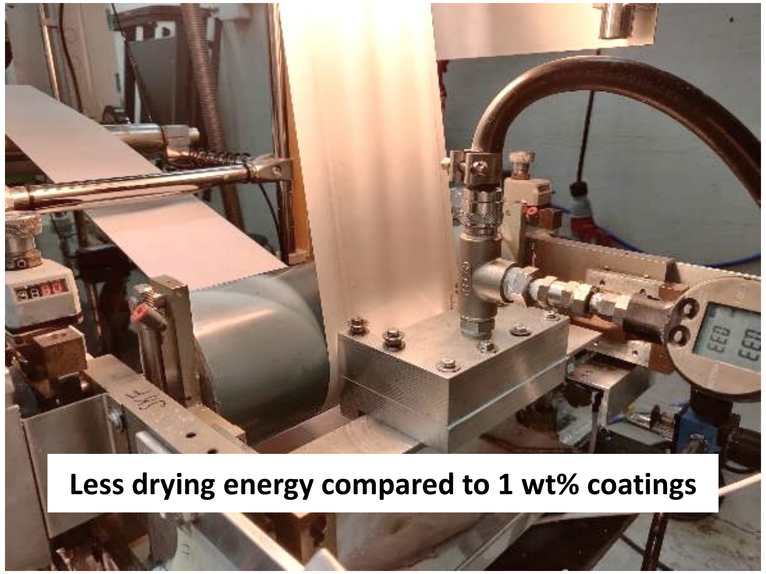


Roll-to-roll slot-die coater

10 wt% CNF coating, with/without CMC

Åbo Akademi University

M. Toivaka,
R. Koppulu



Cellulose Valley BY FONDATION GRENOBLE INP

New strategies

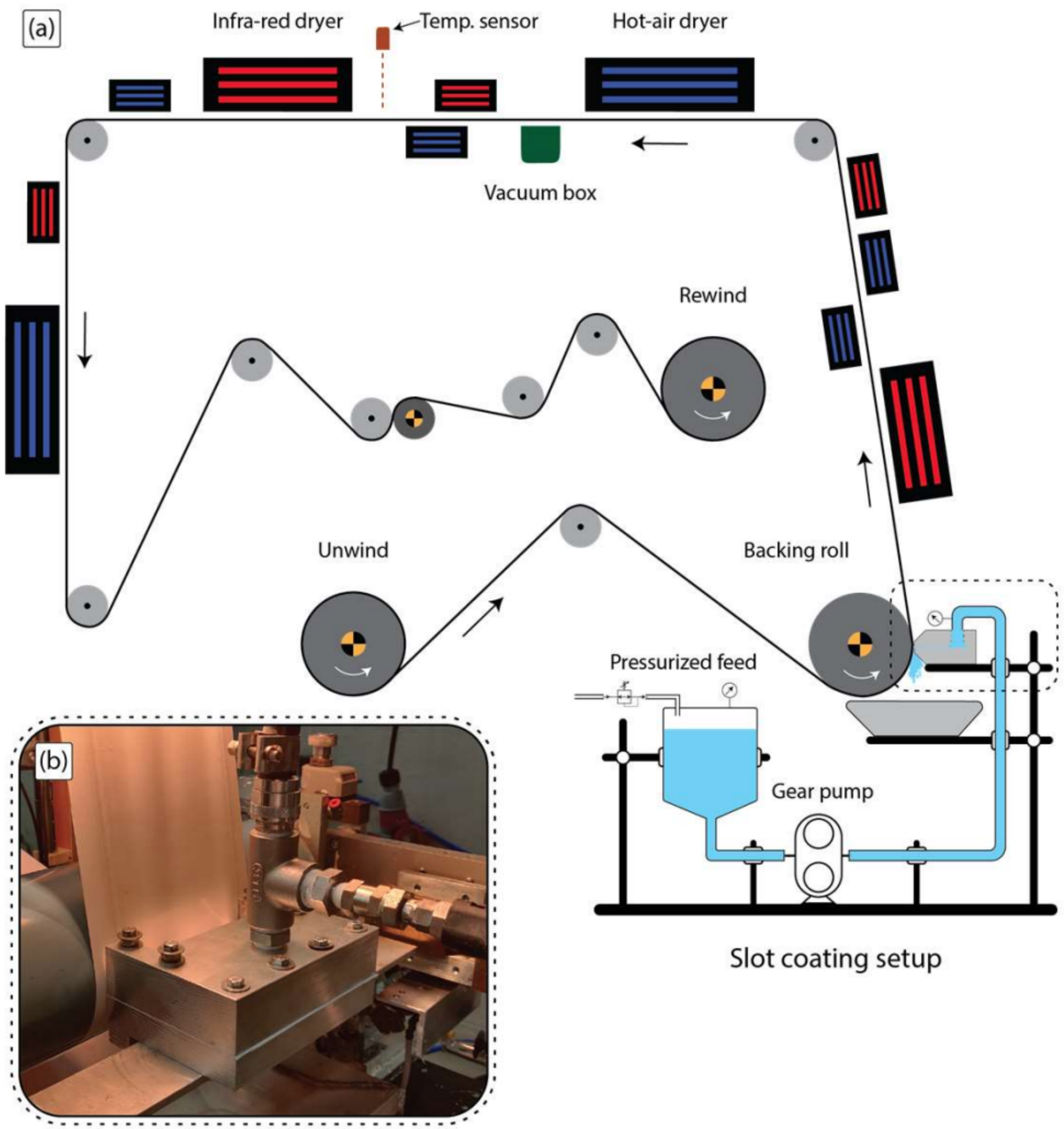
Cellulose Valley

Roll-to-roll coating

- Mini-pilot scale custom built setup based on RK Koater
- 300 mm max. web width, 50 m/min max. line speed

- Custom fitting of slot die (length: 50 mm, coating width: 100 mm, slot gap: 1000 µm)
- Adjustable gap between substrate and slot-lip for coat weight control

- ECNF coating:
  - Base substrate - Pigment coated paperboard (205 g/m^2, 270 µm)
  - Solids content – 12.5%
  - Three suspensions - ECNF, E5C, E5P (10% glycerol added as plasticizer to all suspensions)
  - Coating width – 100 mm
  - Wet thickness – 200 µm
  - Line speed – 4 min/min



New strategies

Barrier properties

Suspension	Coating thickness (µm)	Coat weight* (g/m^2)	HVTR (g/m^2.day)	KIT	Grease penetration** (hrs.)
ECNF	13.9 ± 3.1	21.5 ± 4.7	504 ± 71	5	< 0.2
+ 5% CMC	15.5 ± 1.7	24.0 ± 2.6	Below detection limit	12	1 - 31
+5% NaPA	19.2 ± 1.6	29.8 ± 2.4	440 ± 52	5	< 0.8

*calculated using SEM cross-section thickness and density of 1.55 g/cc, assuming fully dense nanocellulose layer
**Three parallel samples. Failure time is given as range (min – max)

- CMC has better barrier properties compared to NaPA addition or pure ECNF, which suffer from coating defects

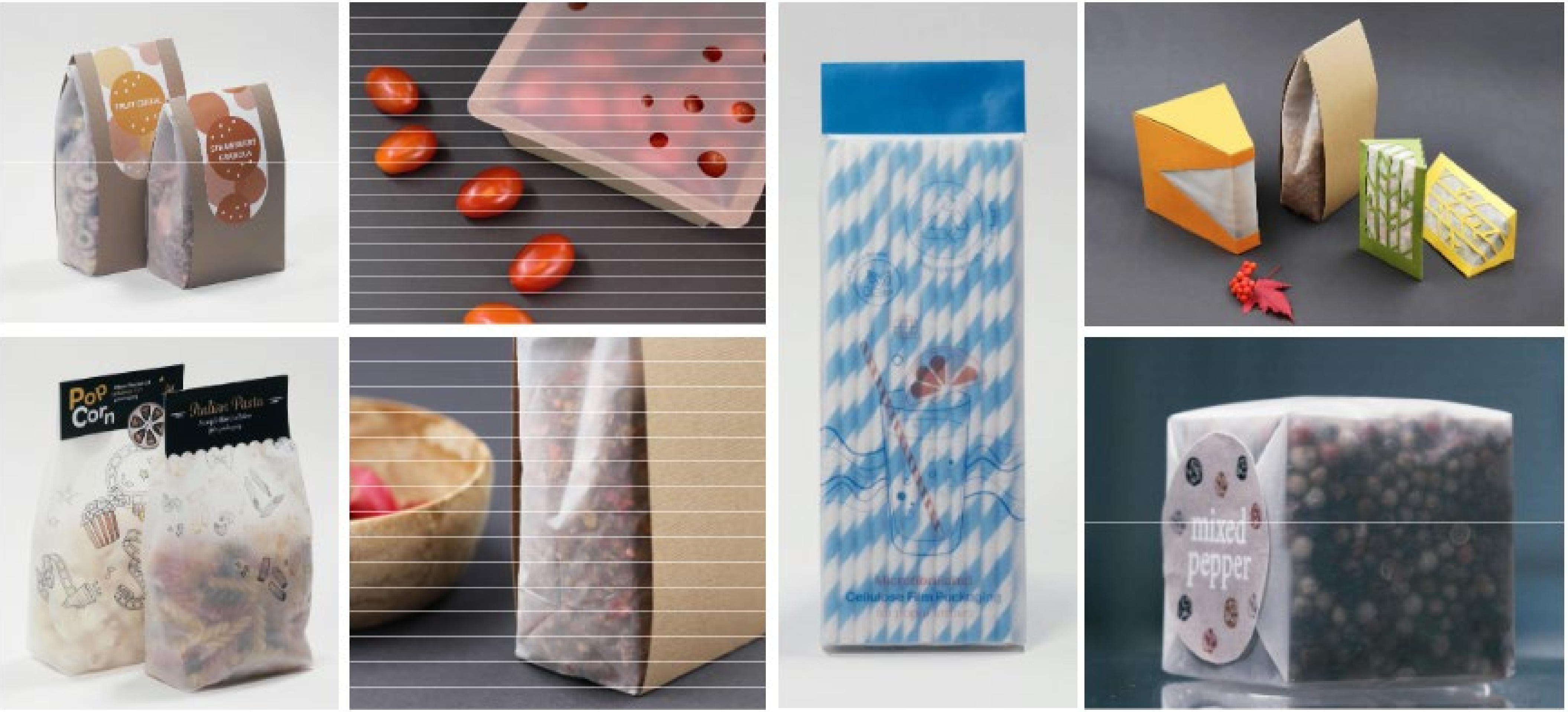
HVTR (Heptane vapor transmission rate) measured according to Miettinen P., et al., 27th PTS Coating Symposium, 16-18, (2015)
KIT value measured according to TAPPI T559 cm-12
Grease penetration measured according to ASTM F119-82

New strategies

Cellulose Valley

HiCMF demo packages

Well suited for e.g. pouches, windows and lids.



New strategies

Use atomic Layer deposition with nanocellulose



Revolutionary with only a few nanometers of ceramic …

Our technology makes it possible to provide a coating of any cellulosic materials (paper, cardboard, moulded fiber).

We are able to process any 2D/3D shape, either stacks, rolls, trays.

www.cilkoa.com

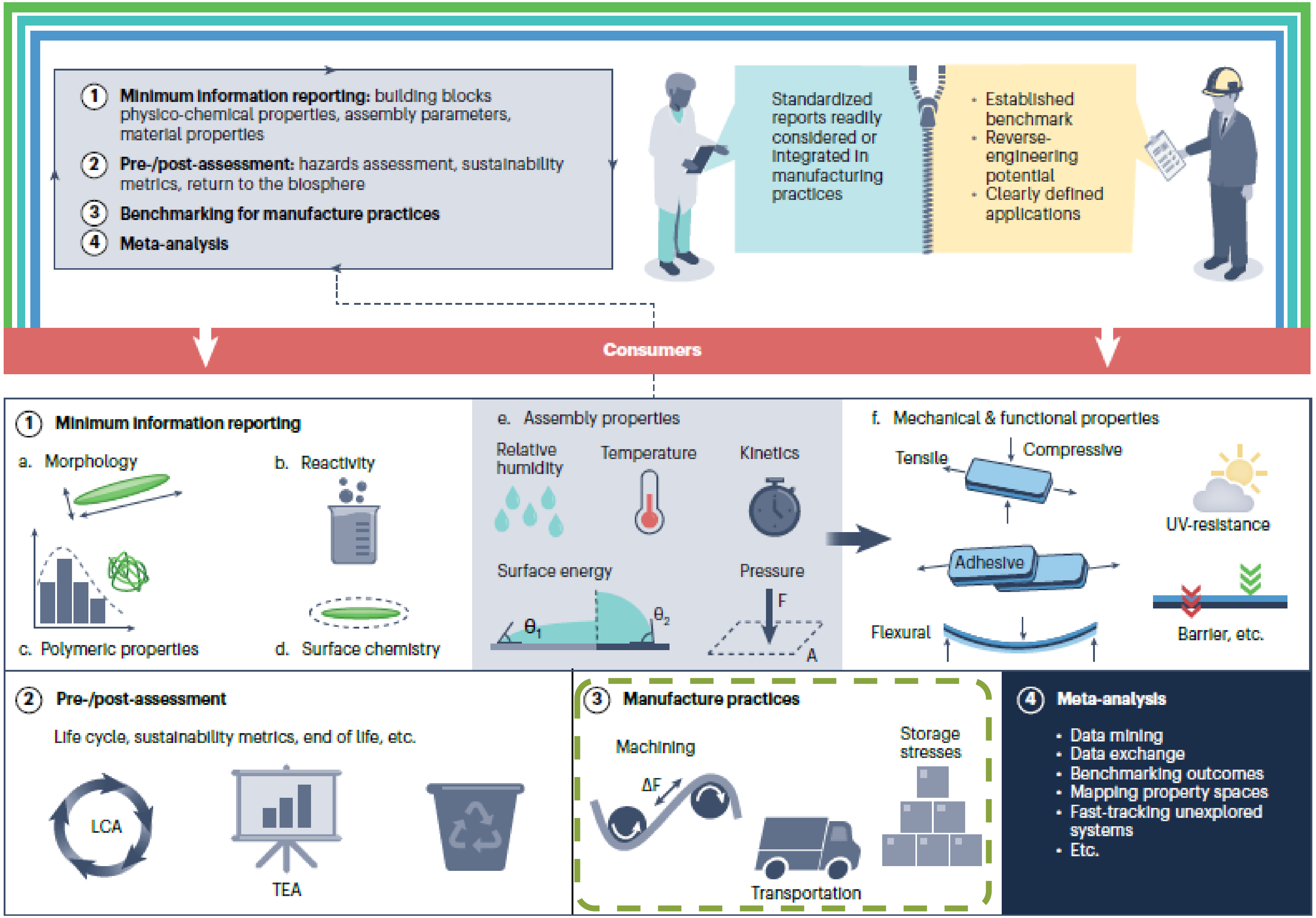


Barrier properties in action

Apple preserved from oxydation

Paper protected from water

Moisture absorber staying dry



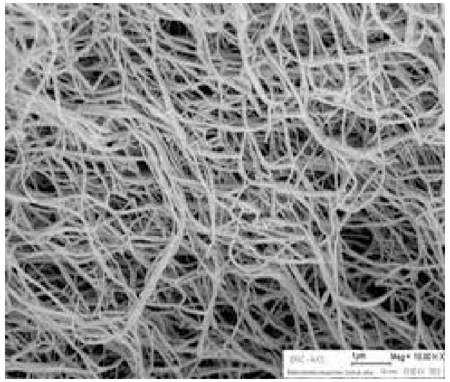
Cellulose Valley BY FONDATION GRENOBLE INP

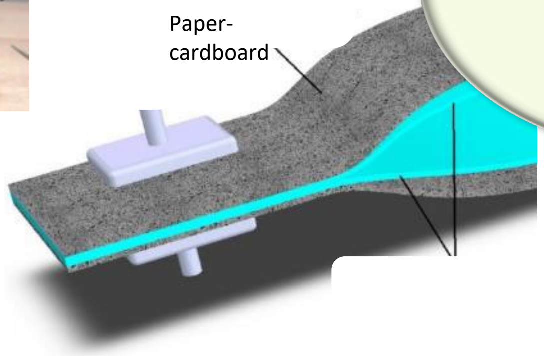
BL Tardy, JJ Richardson, LG Greca, J Guo, **Bras J.**, OJ Rojas, Advancing bio-based materials for sustainable solutions to food packaging, **Nature Sustainability**, 1-8 (2022)

Ultra Sound sealing

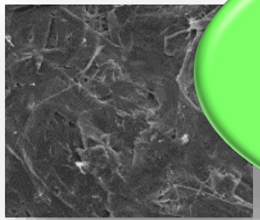
Cellulose Valley
BY FONDATION GRENOBLE INP

Nanocellulose design for ultrasounds welding





Ultrasounds welding process optimization

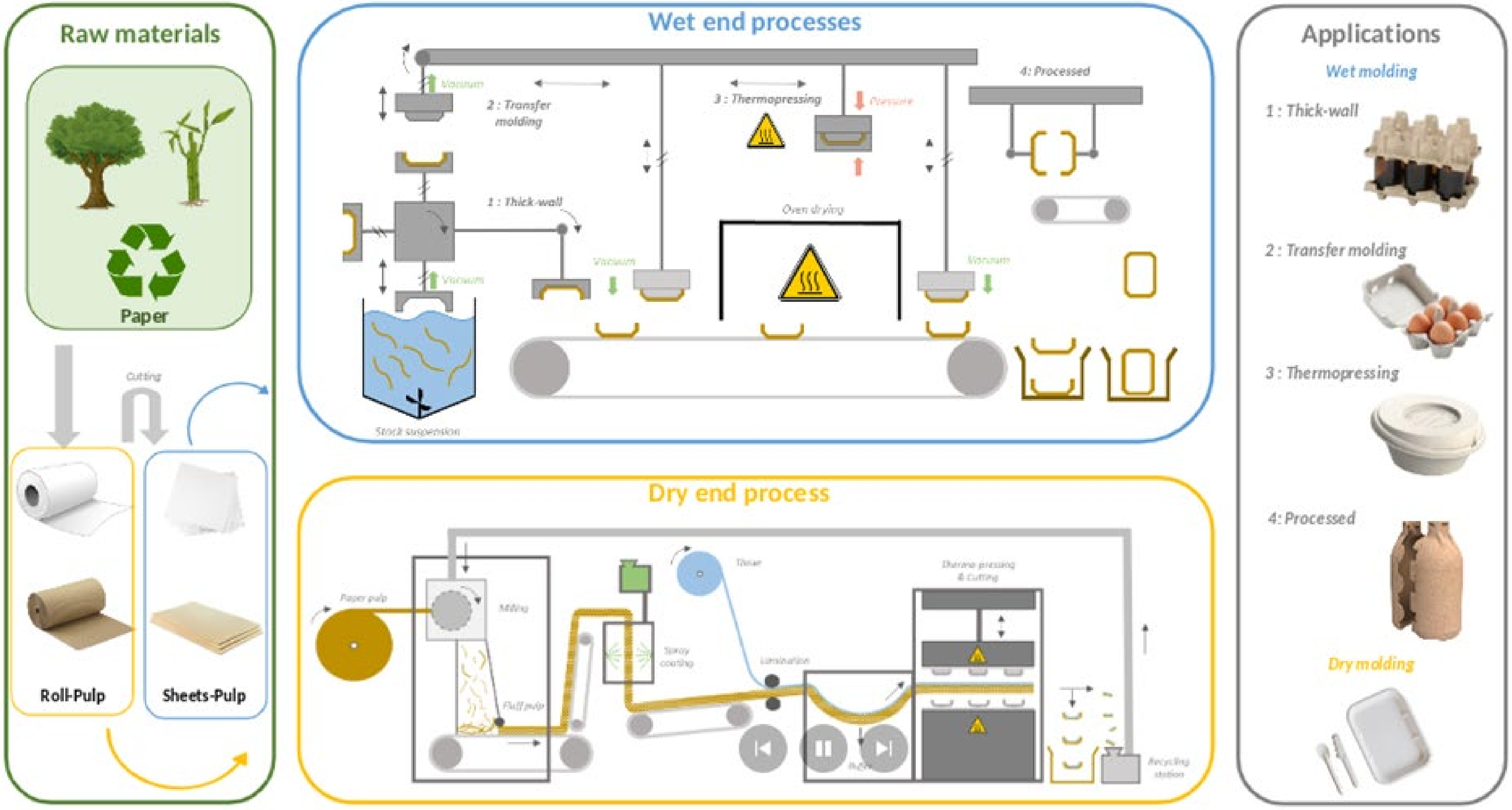


Adhesion understanding

Claire Monot, Jérémie Viguié, Quentin Charlier, Julien Bras, David Guérin, et al.. Ultrasonic welding of folding boxboards. *Bioresources*, 2021, 16 (3), pp.5766-5779.

Bras et al, WO2017207941 (A1) - FIXING METHOD

New 3D cellulose Materials



Freville, Pescheux-Sergienko et al, submitted

Orientations

REDUCE

Social responsibility
Change of the consumption habits

REUSE

Refill and Reuse

RECYCLE

Recyclability for a better feedstock management

BIOBASED & BIODEGRADABLE

Biodegradability to limit the impact of leakage in nature

Fibre & Paper Based Materials

Biosourced & Renewable
Recyclable
Biodegradable

Nanocellulose:
Is it really a good solution for Sustainable Packaging?

⬇

YES

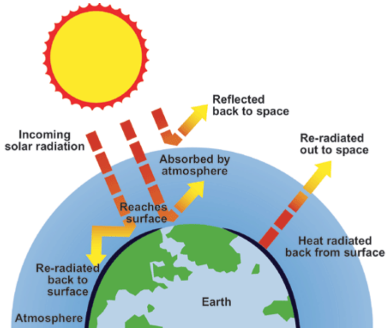
MOST OF THE TIME

But still some questions and challenges to overcome

Cellulose Valley

Cellulose Valley
BY FONDATION GRENOBLE INP

Society expectation

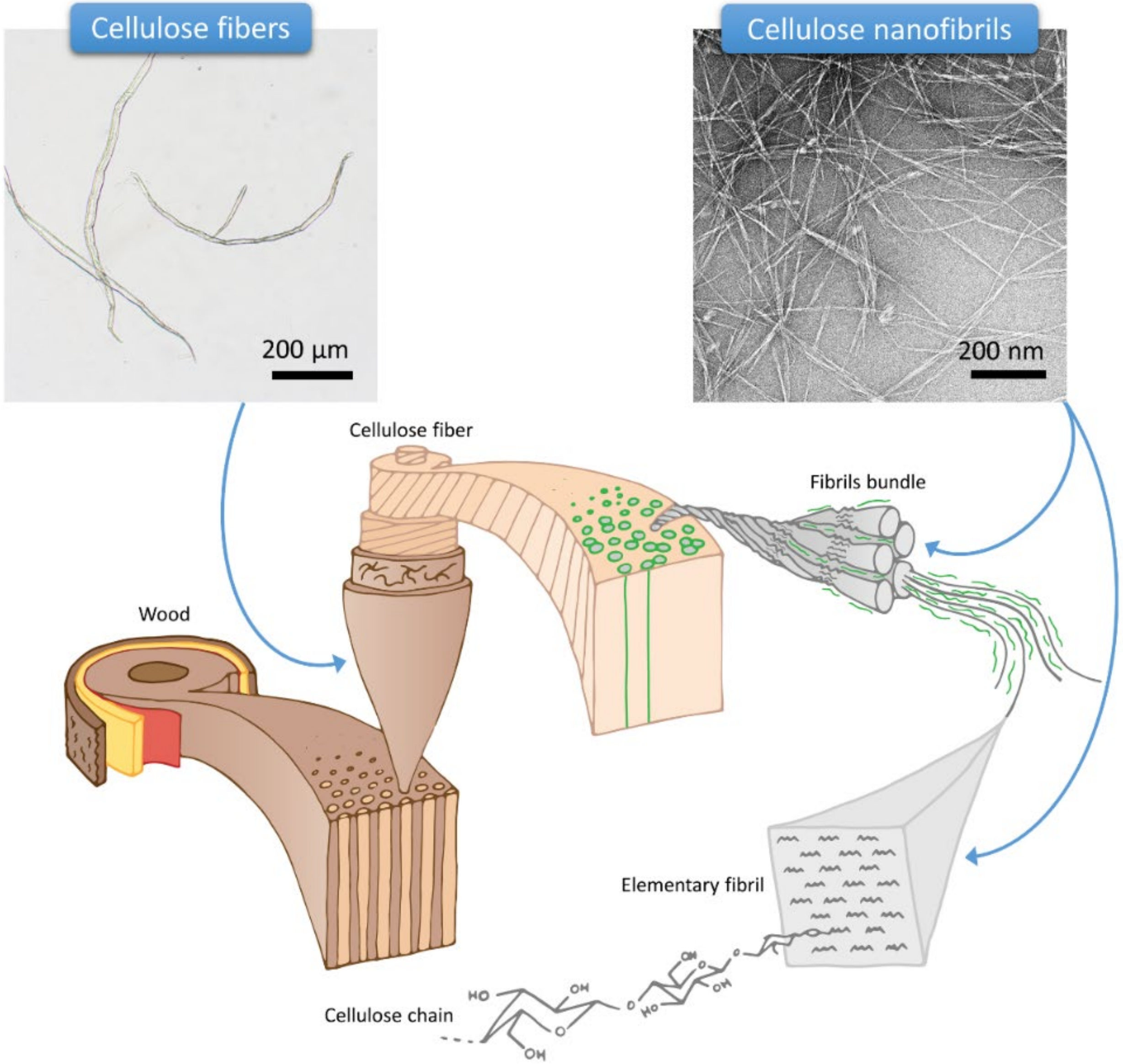


CHAIR CELLULOSE VALLEY

AHLSTROM MUNKSJÖ · Aptar · CHANEL · CITEO · DS Smith · DECATHLON · GUILLIN we protect your food · Marie

New Cellulose Solutions

Cellulose Valley Science



KEYWORDS

- Microfibrillated cellulose,
- Cellulose gel & regenerated cellulose
- Cellulose functionalization & derivatives
- Final cellulose materials: papers et cartons, molded cellulose, cellulose foam, cellulose biocomposites
- Transparent cellulose
- Water, grease and oil barrier properties
- Oxygen and water vapor barrier properties
- Cellulosic materials sealability & abrasiveness
- New process for cellulose surface coating & functionnalization
- New process for 3D forming of cellulose & extendible paper
- Other biobased materials, compatible with cellulose & inert in food contact
- Recyclability in cellulose stream
- Ecoconception & low carbon emission evaluation
- Packaging new approach, new consummer uses, viables alternatives (e.g. Reuse)

Cellulose Valley (2022-2026)

Long term innovation

3 PhD + 2 Post-doc

Cellulose Science
Disruptive ideas
Society expectation
Long term

↔

Short term innovation

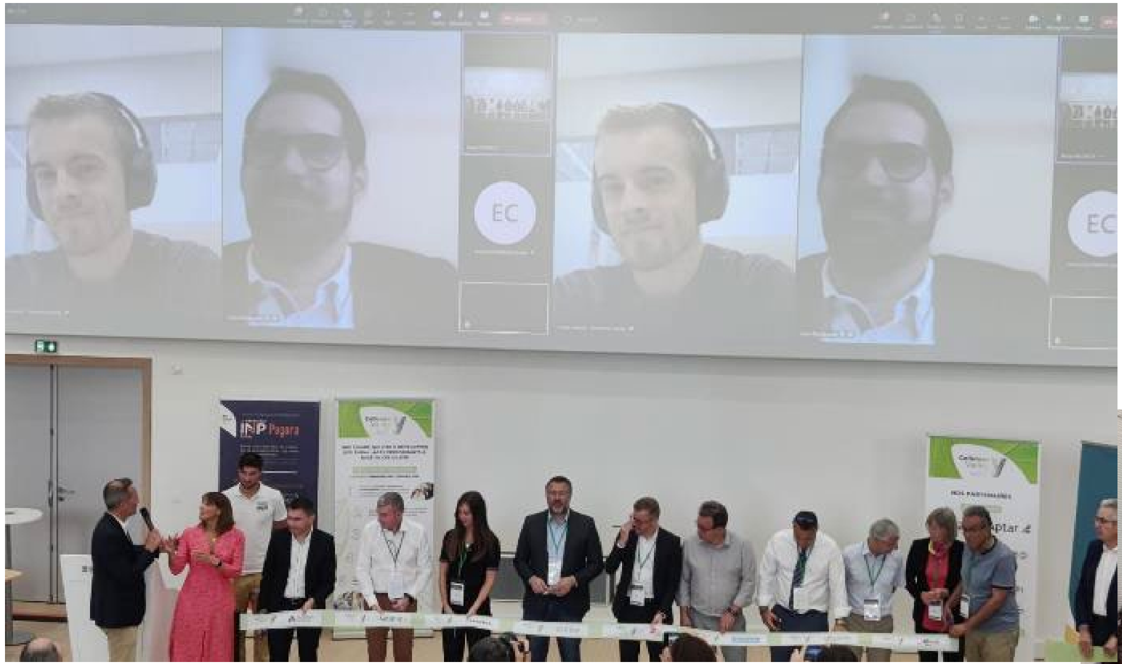
32 Master Students
+ 1 engineer

Cellulose application
Proof of concept
Industry expectation
Short term

Partner interaction – All value chain - No competitor – Multiple co-supervisor

- **Multi-disciplinary:** Materials – Process - Chemistry
- **Multi-rythm:** Short term innovation vs long term innovation
- **Multi-expertise:** Several collaborators – co-supervisors
- **Multi-partners:** 8 companies in different fields –all value chain
- **Multi-scale:** from nano to micro and macro

Work is in Progress

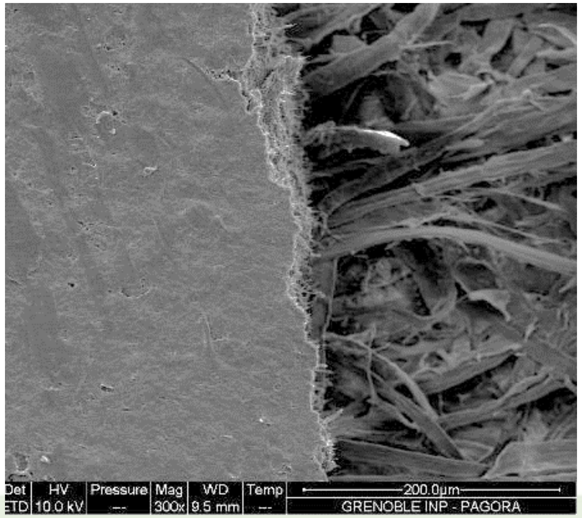


Perspectives

2D Materials





3D Materials










THANK YOU FOR YOUR ATTENTION

It is people that matters
Trust into the new generation

2 post-doc position available, contact me

Julien.bras@grenoble-inp.fr