Biobased polymers as construction materials

Antoine DUVAL

BACKGROUND – ANTOINE DUVAL

2010 – Ingénieur Science et Génie des Matériaux

2013 – Doctorat – Université Grenoble Alpes

2014 - 2015 – Post-doctorat (1 an) – KTH (Stockholm, Suède)

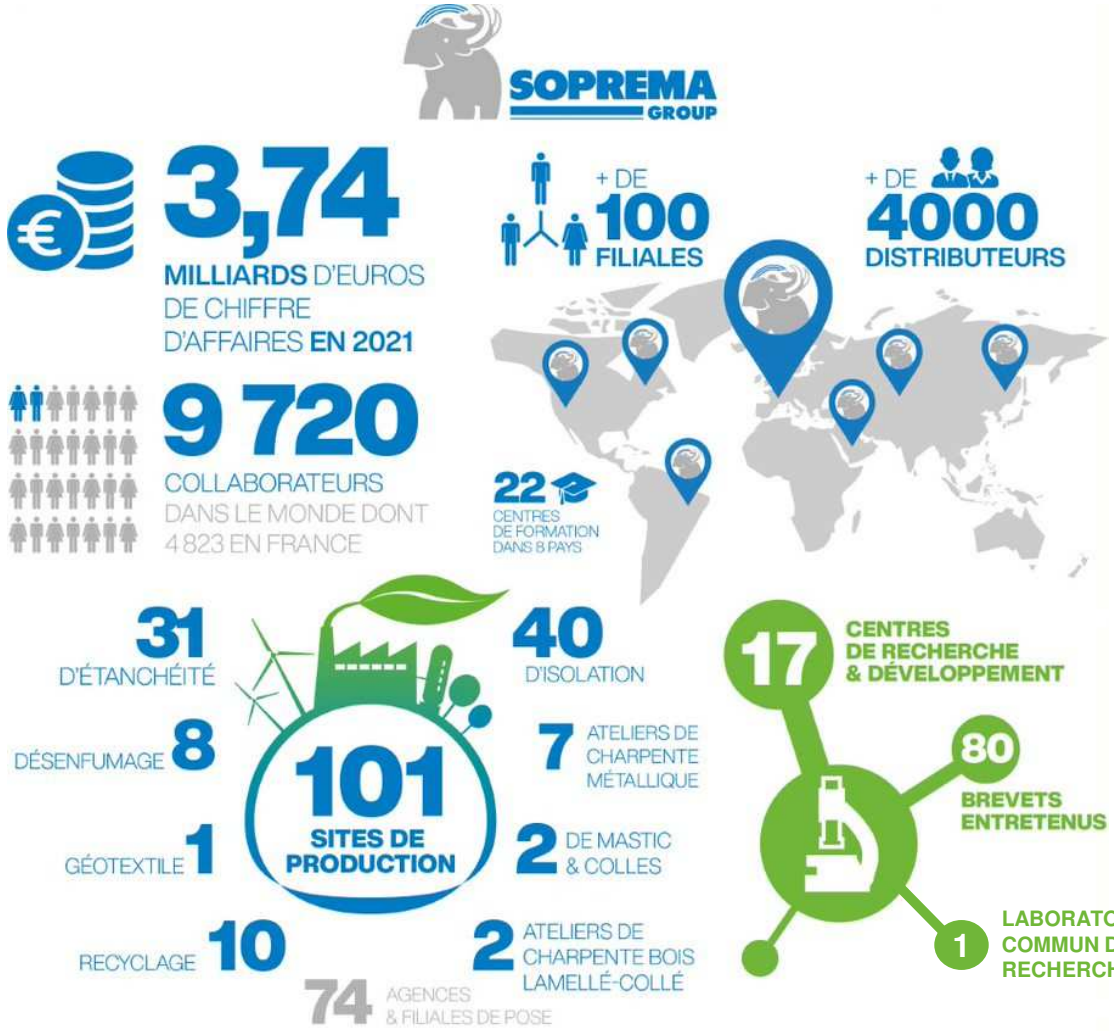
2015 - 2017 – Post-doctorat (2 ans) – ICPEES (Strasbourg)

2017 - 2018 – Directeur R&D Eco-matériaux (18 mois) – Neolife (Limonest)

2019 - 2021 – Ingénieur de recherche – ICPEES (Strasbourg)

Depuis 2021 – Responsable R&D Chimie Verte – Soprema (Strasbourg)

SOPREMA GROUP – WORLDWIDE PRESENCE



1908

1909

1941

SOciété des Produits et Revêtements d'Etanchéité MAmmouth

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JOINT RESEARCH LABORATORY MUTAXIO

Mutation axée sur des matériaux biosourcés pour un bâtiment durable

ICPEES
Institut de Chimie et Procédés pour l'Énergie, l'Environnement et la Santé

BioTeam led by Pr. Luc Avérous

Biobased and Sustainable Polymers for Environmental & Biomedical Applications

Collaborative projects

bpifrance

anr agence nationale de la recherche

Horizon2020 European Union Funding for Research & Innovation

BBI JU

Bio-based Industries Consortium

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POLYMERS IN BUILDING APPLICATIONS

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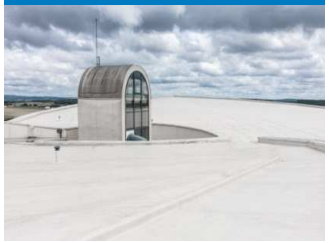
SOPREMA GROUP – APPLICATIONS

WATERPROOFING

Bituminous membranes

Synthetic membranes



Liquid systems

Green roofs

Photovoltaic

Cool roof

THERMAL INSULATION

Polyurethane foams

Wood fiber panels

Polystyrene (XPS)

Cellulose wadding

R&D AT SOPREMA

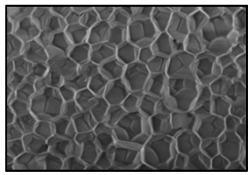
Objectives of R&D

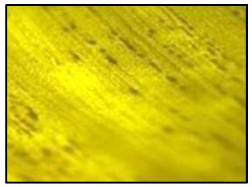
Le Labo
the inventive factory

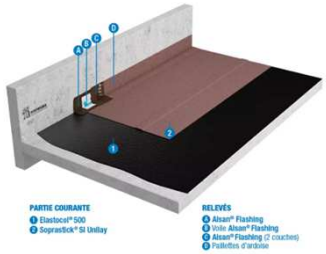
- **Improve the properties** of products and systems
- **Facilitate the work** of the operators, installers, customers…
- **Reduce the carbon footprint** of the products

Recycled raw materials	Biobased raw materials
up to 10 times less CO_2 eq than oil-based raw materials	up to negative CO_2 emissions

- **Manage end-of-life** of products



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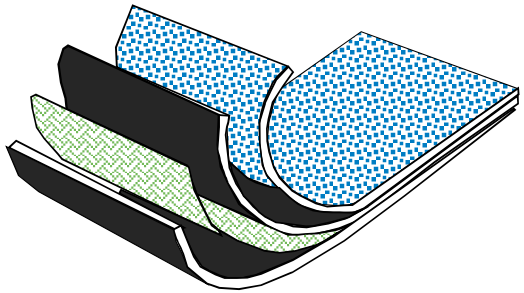
01 TOWARDS BIOBASED WATERPROOFING MEMBRANES

BITUMINOUS WATERPROOFING MEMBRANES



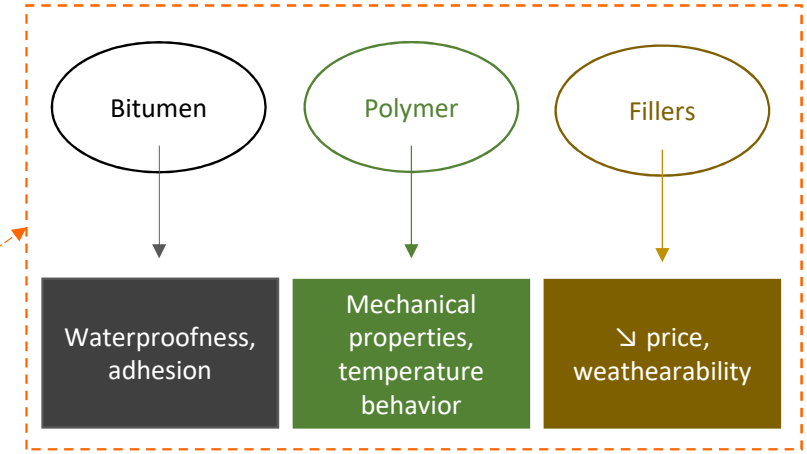
Frame

Top layer (finish, UV protection…)

Bituminous binder

Bituminous binders specifications

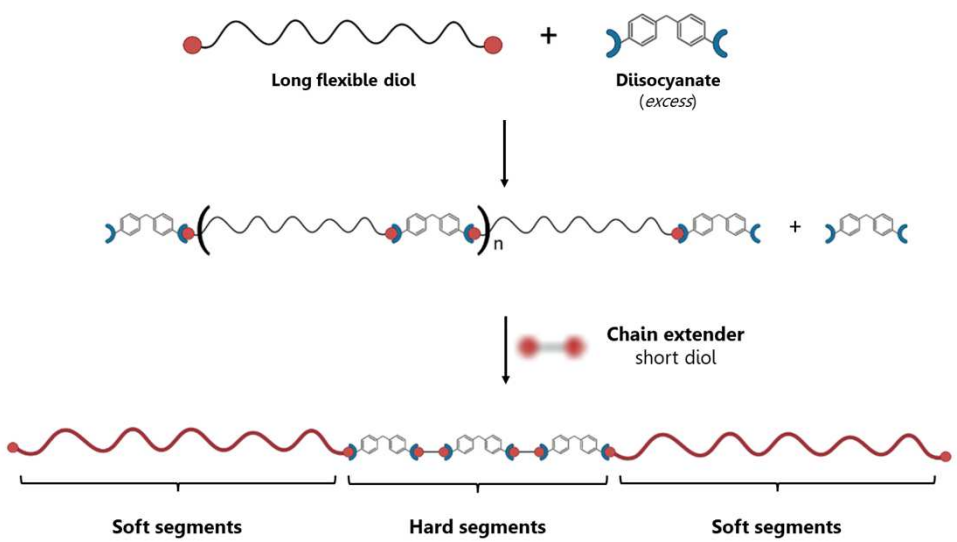
- Waterproofness, hydrophobicity
- Strong adhesion to various supports
- Softening point > 120 °C (bitumen: fluid at 100 °C)
- Thermal stability higher than 230 °C
- Mechanical properties (σ = 0.4 – 0.8 MPa, ε = 1000 %)
- Flexibility at – 25 °C



BIOBASED WATERPROOFING MEMBRANES

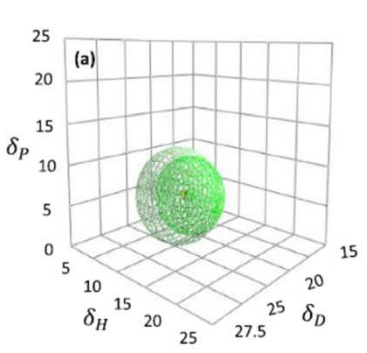
Replacement of petro-based polymer by biobased polymer

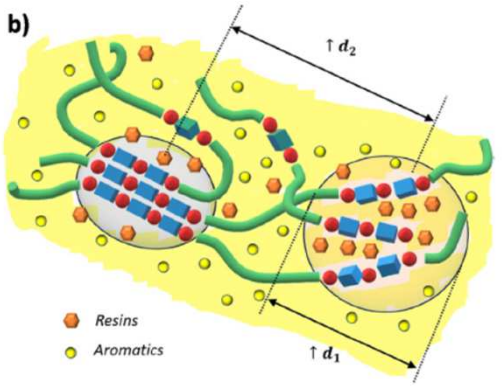
Biobased thermoplastic polyurethane (TPU) synthesis

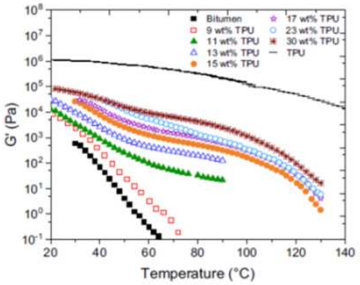


Design of experiment approach: nature of polyol and chain extender, HS content…
Validation of polymer properties (thermal, mechanical…)

Study of polymer – bitumen compatibility







Commercial product

mammoth neo

R. Gallu, F. Méchin, F. Dalmas, J.-F. Gérard, R. Perrin and F. Loup, *Polymer*, 2020, **207**, 122882.
R. Gallu, F. Méchin, F. Dalmas, J.-F. Gérard, R. Perrin and F. Loup, *Construction and Building Materials*, 2020, **259**, 120404.
R. Gallu, F. Méchin, F. Dalmas, J.-F. Gérard, R. Perrin and F. Loup, *Construction and Building Materials*, 2021, **289**, 123151.

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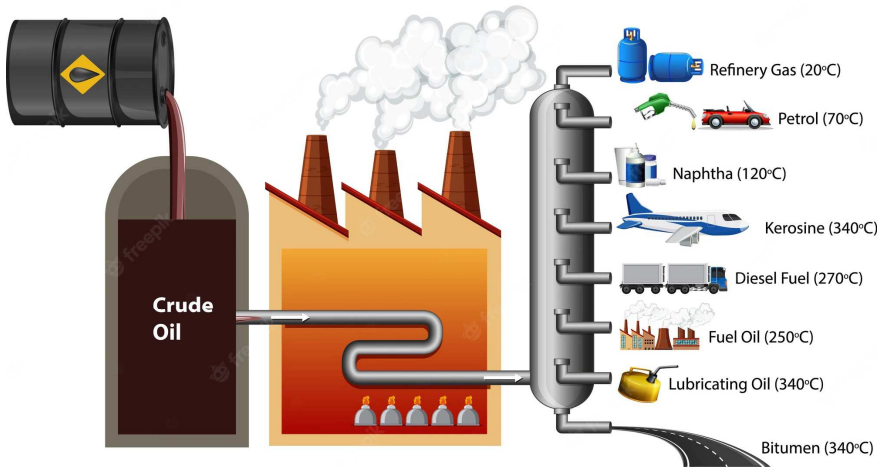
BIOBASED WATERPROOFING MEMBRANES

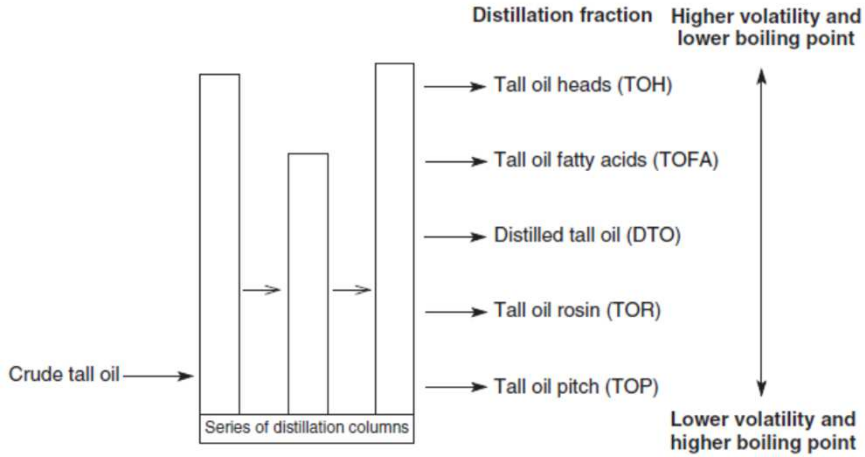
Biobased alternative to bitumen

Crude Oil Distillation Process



Bitumen = heaviest fraction of crude oil distillation
Used in asphalt pavement and roofing

Crude Tall Oil Distillation Process



Tall oil pitch = heaviest fraction of tall oil distillation
Potential biobased alternative to bitumen

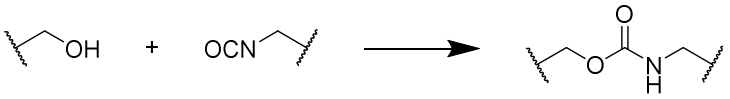
Tall Oil = by-product of Kraft paper pulp, derivative of pine resins and extractives (fatty acids, resinic acids, sterols, etc)

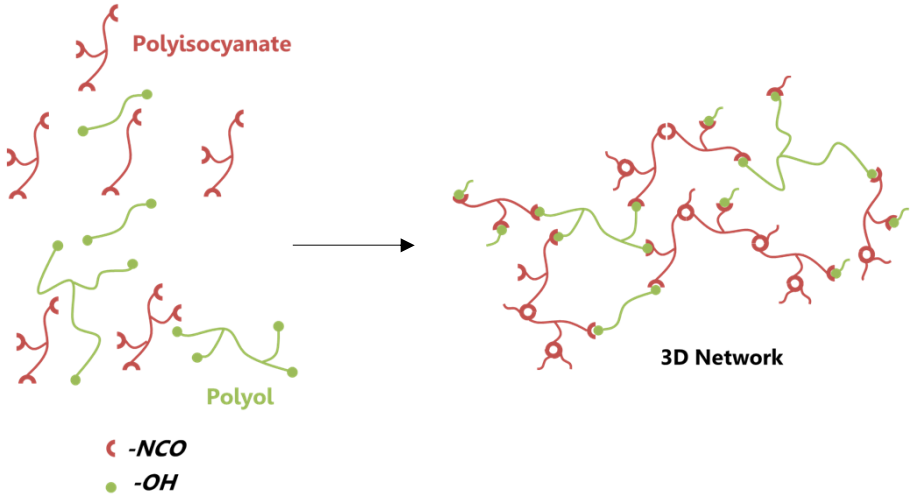
02

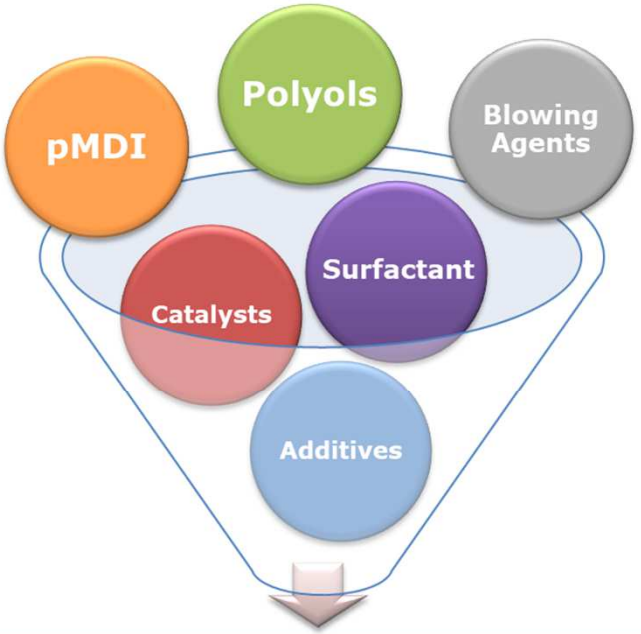
TOWARDS BIOBASED INSULATION MATERIALS

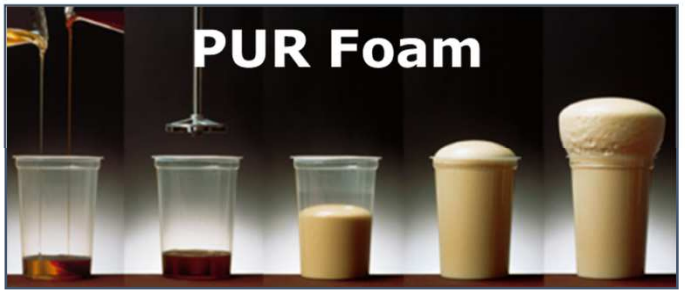
POLYURETHANE INSULATION FOAMS

Polyurethane chemistry

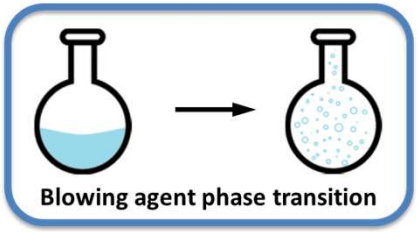








Complex Process
Starts in **5 sec**
Ends after **2 min**



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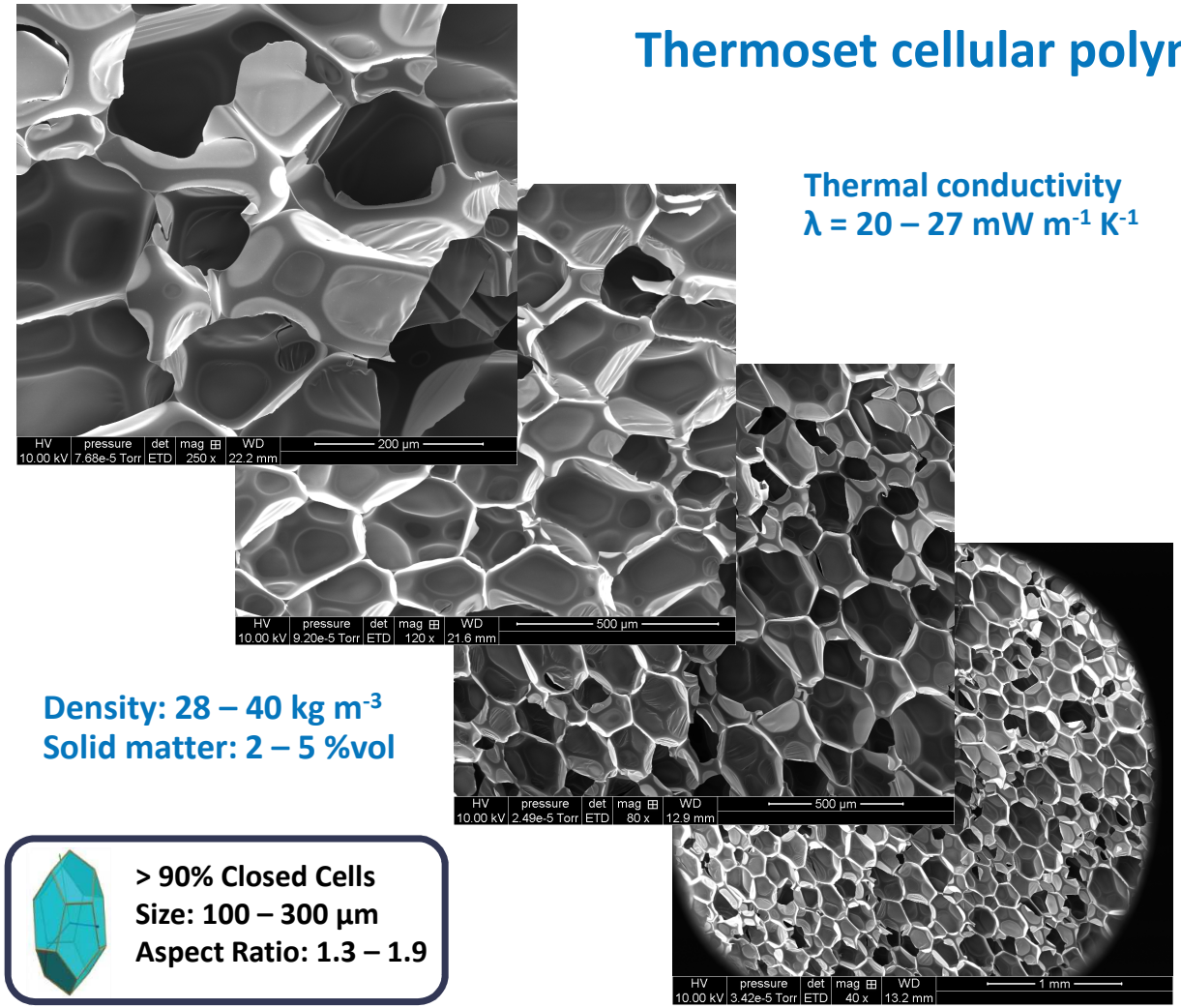
POLYURETHANE INSULATION FOAMS

Thermoset cellular polymer with closed pores



Thermal conductivity
$\lambda = 20 – 27$ mW m^{-1} K^{-1}

Density: 28 – 40 kg m^{-3}
Solid matter: 2 – 5 %vol

> 90% Closed Cells
Size: 100 – 300 µm
Aspect Ratio: 1.3 – 1.9

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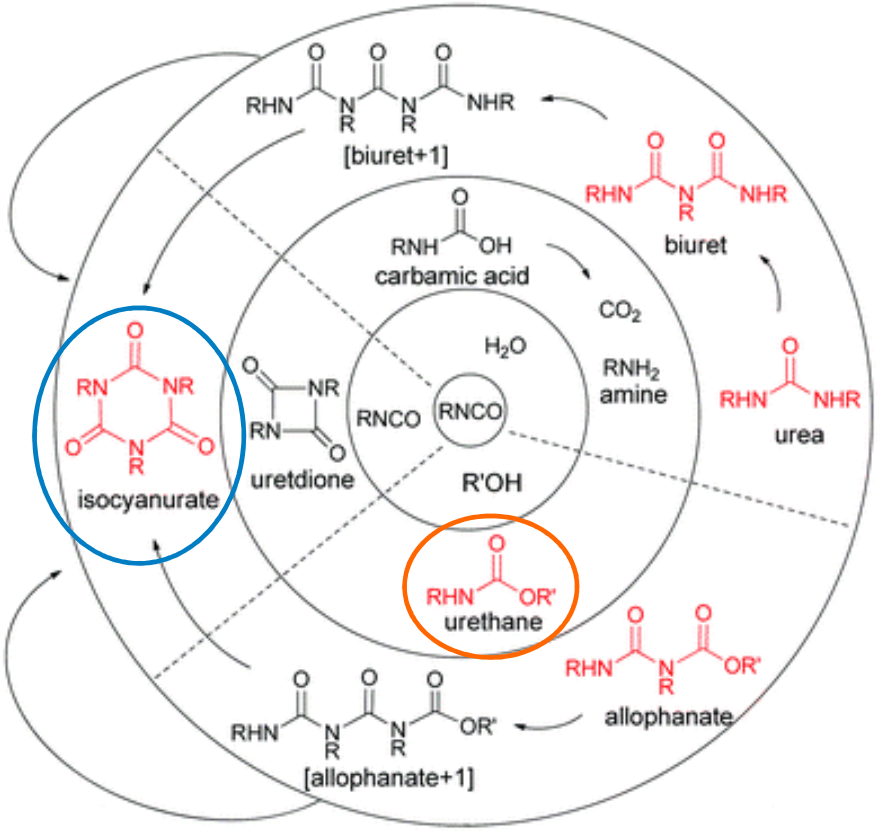
PUR AND PIR FOAMS

Isocyanate chemistry



Foam type	PUR	PIR
Main linkage type	urethane	isocyanurate
NCO/OH ratio	≈ 1.1	≈ 3
Polyol type	polyether	polyester

BIOBASED POLYOLS FOR POLYURETHANE FOAMS

Similar isocyanate reactivity

Thermal and mechanical performance

Challenges

Maximum biobased substitution ratio

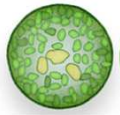
Standard raw material compatibility

Various biobased feedstocks

Sugar derivatives

Lignin

Vegetable oils



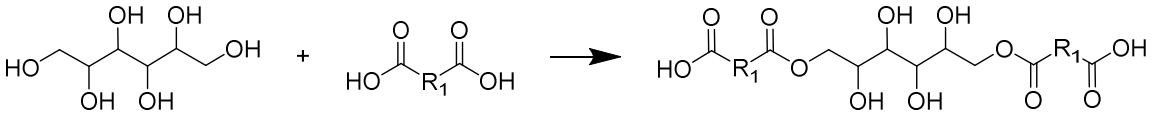
Micro-algae

BIOBASED POLYOLS FROM SORBITOL

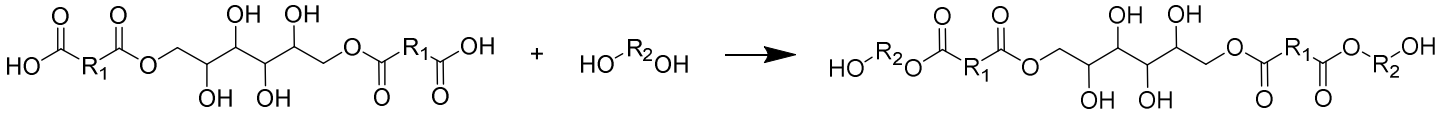
Joint project

Synthesis of sorbitol-based polyol

Successive esterifications

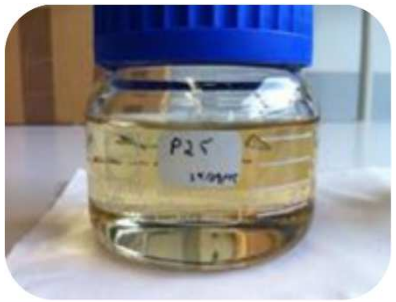


Sorbitol



Advantages:

- ✓ Simple 2-step process
- ✓ Bulk synthesis
- ✓ Water as by-product
- ✓ Bio-based

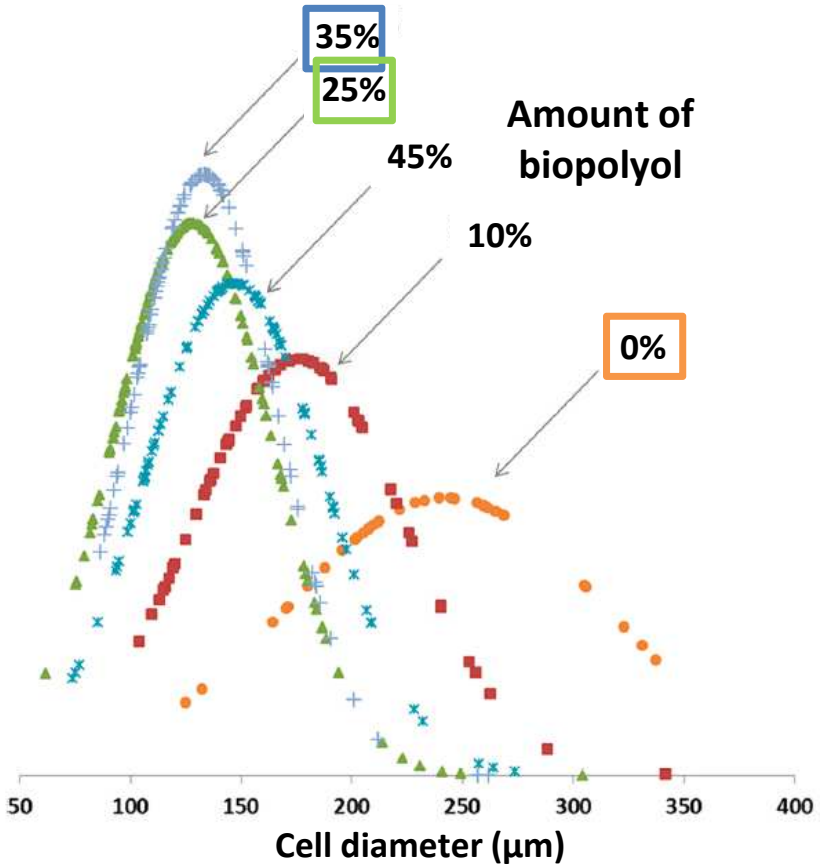


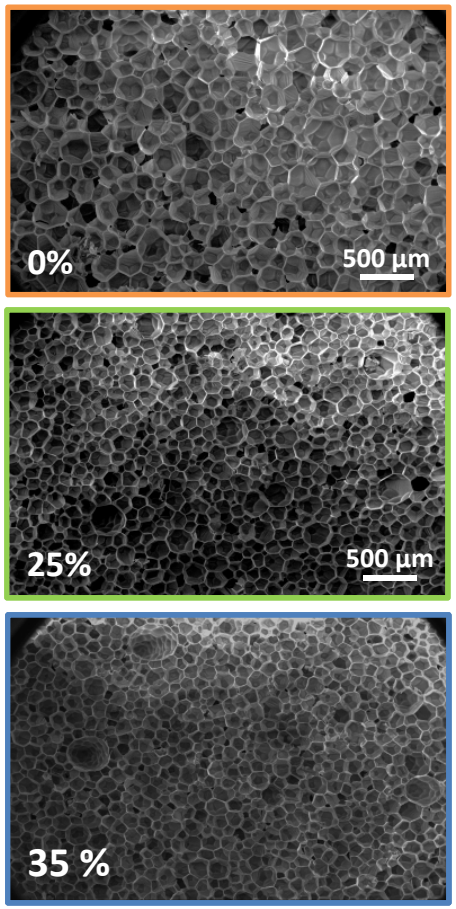
Polyol properties		
OH-value	mg KOH g^{-1}	570
Acid value	mg KOH g^{-1}	1.9
Viscosity @ 25°C	mPa.s	14 000
Functionality		≈ 4

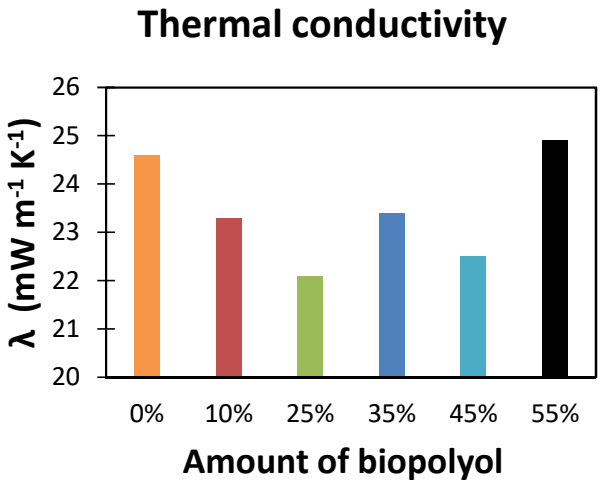
BIOBASED POLYOLS FROM SORBITOL

Joint project

PIR foams from sobitol-based polyols



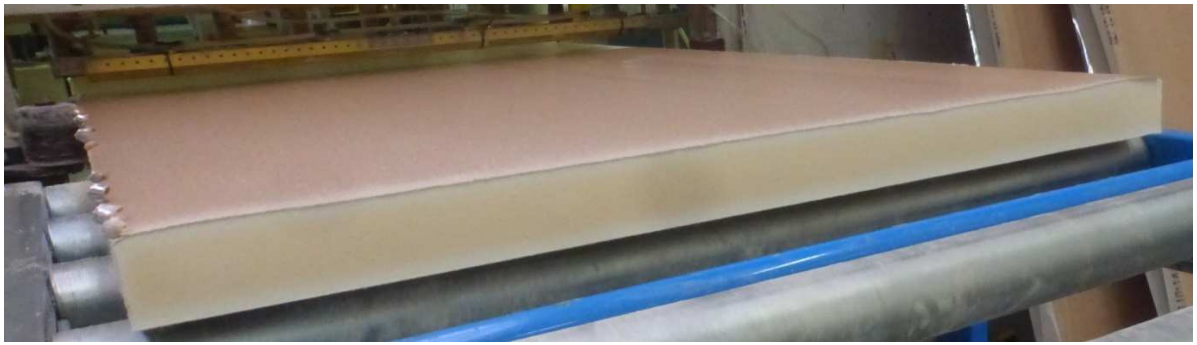




BIOBASED POLYOLS FROM SORBITOL

Joint project

Scale-up of sorbitol-based polyol production



Polyol produced at ton scale

Industrial tests on Soprema production lines
(Saint-Julien-du-Sault, 89)

P. Furtwengler, R. Perrin, A. Redl and L. Avérous, *European Polymer Journal*, 2017, **97**, 319–327.

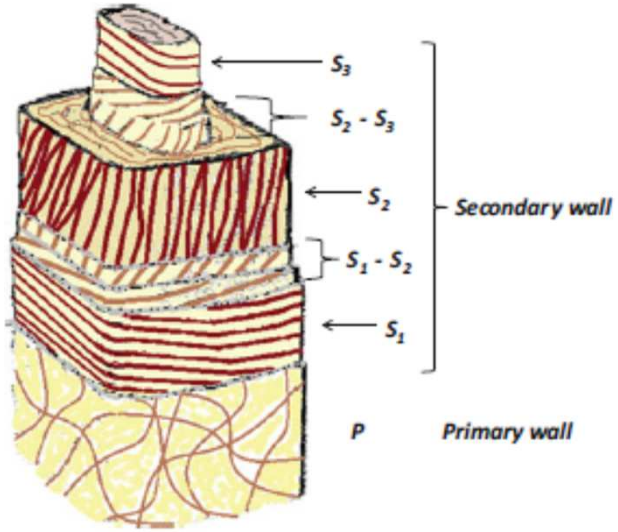
P. Furtwengler, R. M. Boumbimba and L. Avérous, *Macromolecular Materials and Engineering*, 2018, **303**, 1700501.

P. Furtwengler, R. Matadi Boumbimba, A. Sarbu and L. Avérous, *ACS Sustainable Chem. Eng.*, 2018, **6**, 6577–6589.

INTELLECTUAL PATENTED PROPERTY

PCT/IB2017/055107
PCT/IB2017/055110
PCT/IB2017/055116
FR 17/00351
FR 18/00072

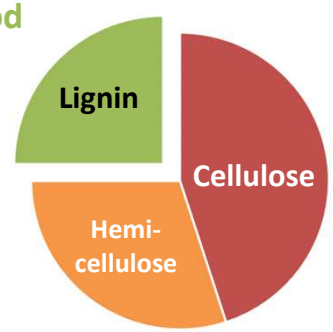
BIOBASED POLYOLS FROM LIGNIN

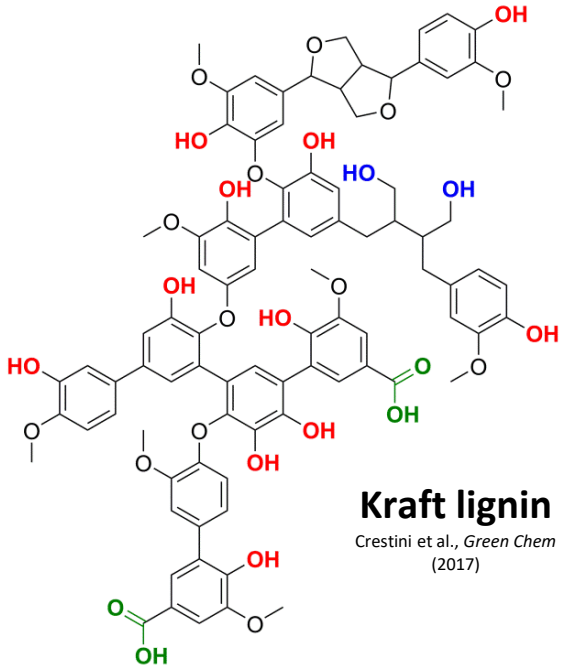


Salmen, in *Plant Biomechanics* (2018)

Vegetal cell wall = matrix of lignin and hemicellulose reinforced by cellulose microfibrils

≈ 20-30 %wt in wood



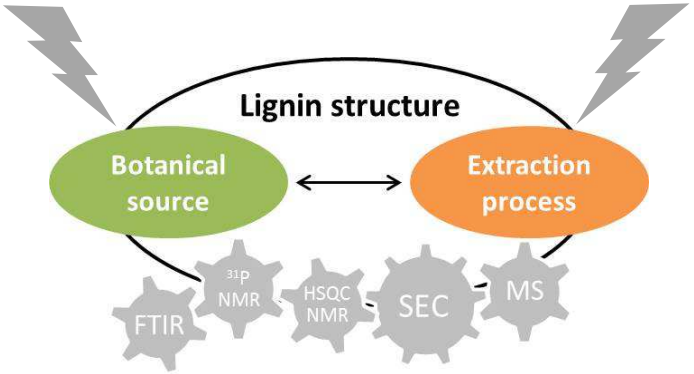


Kraft lignin

Crestini et al., *Green Chem* (2017)

1st source of diversity

2nd source of diversity



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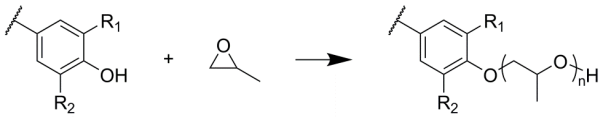
BIOBASED POLYOLS FROM LIGNIN

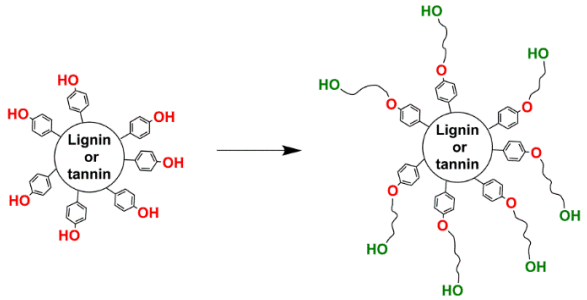
Synthesis of lignin-based polyols by oxypropylation

Lignins
Ph-OH and Al-OH groups

Lignin-based polyols
Al-OH groups

Oxypropylation reaction





Characteristic	Unit	KLP	Polyester polyol	Polyether polyol
OH-value	mg KOH/g	200-300	180-250	500-600
Viscosity @ 25°C	mPa.s	700-3000	2000-5000	1000-3000
Functionality		?	2	3.3

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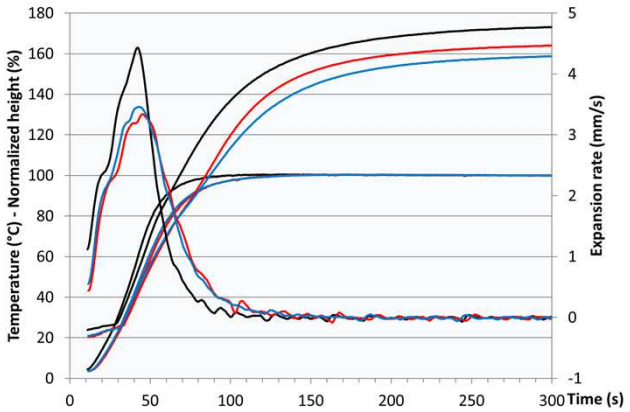
BIOBASED POLYOLS FROM LIGNIN

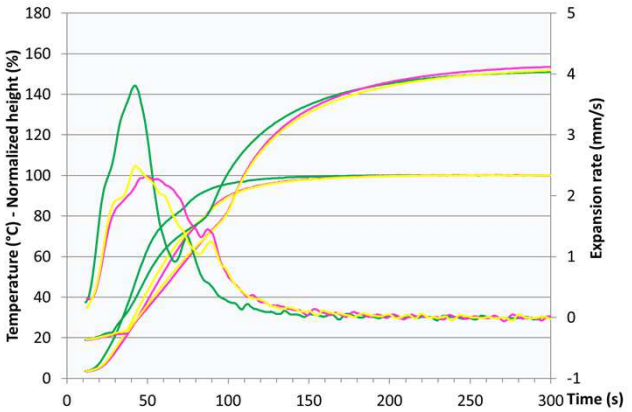
PUR and PIR foams from oxypropylated lignins

PUR foams – 50% substitution



		Standard	KLP 1	KLP 2
Density	kg/m^3	29.1	29.0	29.7
Compr. strength	kPa	335	276	270
Lambda	mW/(m.K)	24.0	24.0	24.2
Closed cells	%	92	95	95

PIR foams – 25% substitution



		Standard	KLP 1	KLP 2
Density	kg/m^3	28.8	29.4	29.9
Compr. strength	kPa	288	268	275
Lambda	mW/(m.K)	23.5	24.4	24.3
Closed cells	%	97	94	94

BIOBASED POLYOLS FROM LIGNIN

Scale-up of oxypropylated lignin production

Scale-up with industrial partner

ARKEMA

1500 m^2 pannels produced on Soprema industrial lines

INTELLECTUAL PATENTED PROPERTY

FR3056986 - WO18065727 - EP3523357 - FR3056985 - WO18065728 - EP3523358 - FR3065218 - WO18189495

Issues

Propylene oxide

bp = 34 °C
Pressurized reactor

Complex scale-up

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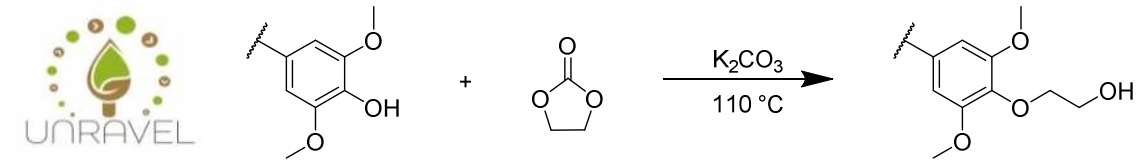
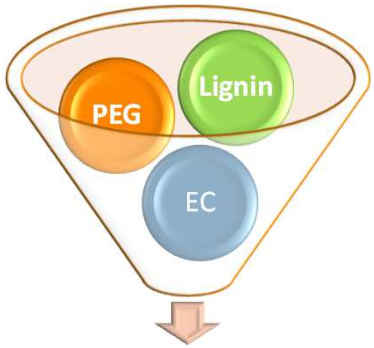
BIOBASED POLYOLS FROM LIGNIN

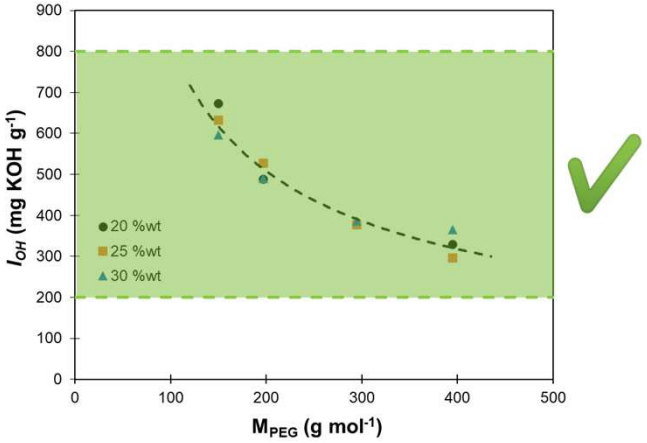
Alternative polyol synthesis using cyclic carbonates

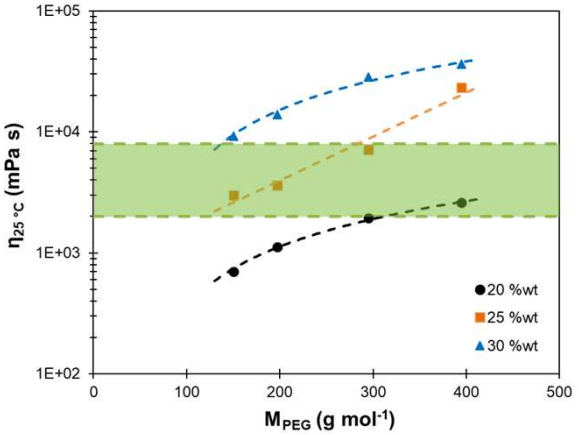


Solvent-free, ambient pressure, only water for work-up



Liquid polyol





Mild conditions

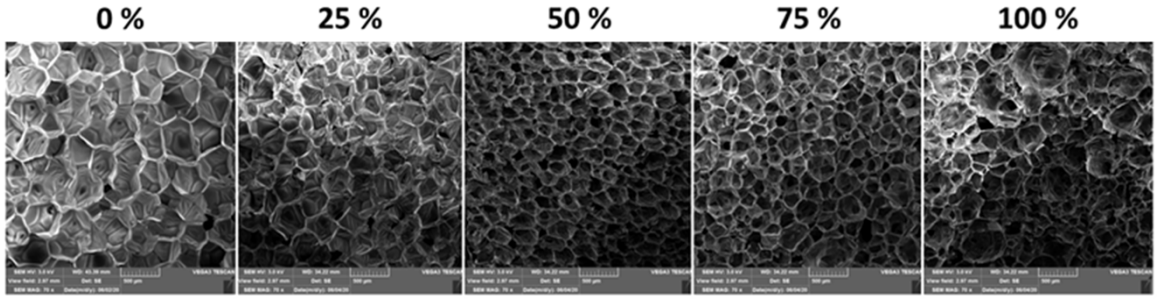
- no toxic chemicals
- ambient pressure
- 110 – 130 °C
- no purification

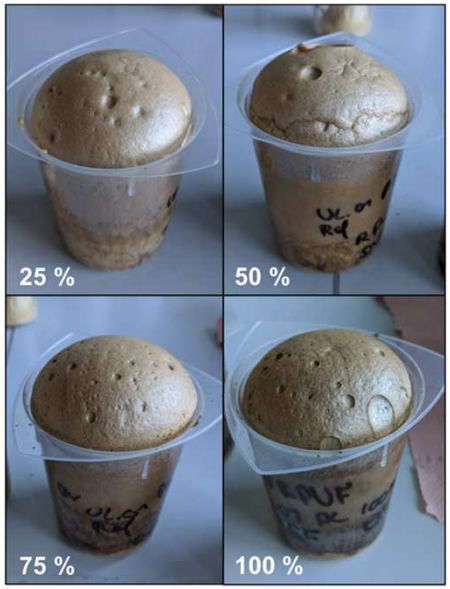
Polyol properties

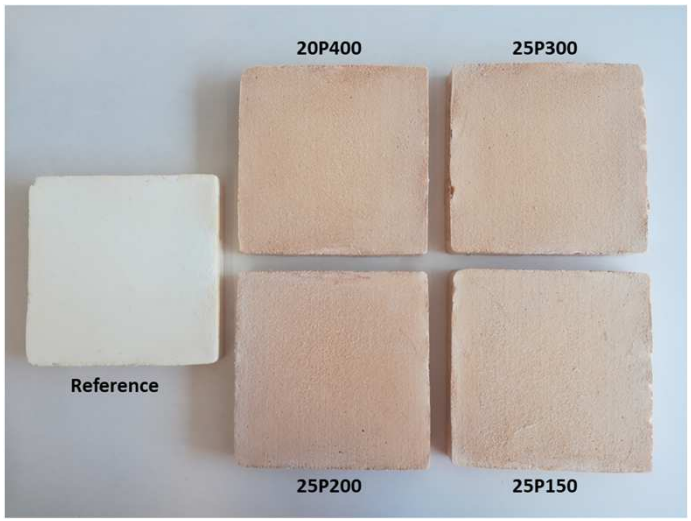
- only aliphatic OH groups
- good stability
- tunable OH content
- low viscosity

BIOBASED POLYOLS FROM LIGNIN

PUR foams from lignin-based polyols







Polyol name	20% lignin-based polyol			
	Closed cells (%)	*Cells diameter (µm)*	*Cells height (µm)*	$\lambda_{10\ °C}$ *(mW m^{-1} K^{-1})*
Standard	97	190	325	23.5
25P150	92	190	405	24.2
25P200	95	200	420	24.4
25P300	95	200	435	24.3
20P400	97	180	375	24.4

Current development

- scale-up of polyols synthesis
- improvement of formulation
- influence of lignin type and content

A. Duval, G. Layrac, A. van Zomeren, A. T. Smit, E. Pollet and L. Avérous, *ChemSusChem*, 2021, **14**, 387–397.

A. Duval, D. Vidal, A. Sarbu, W. René and L. Avérous, *Materials Today Chemistry*, 2022, **24**, 100793.

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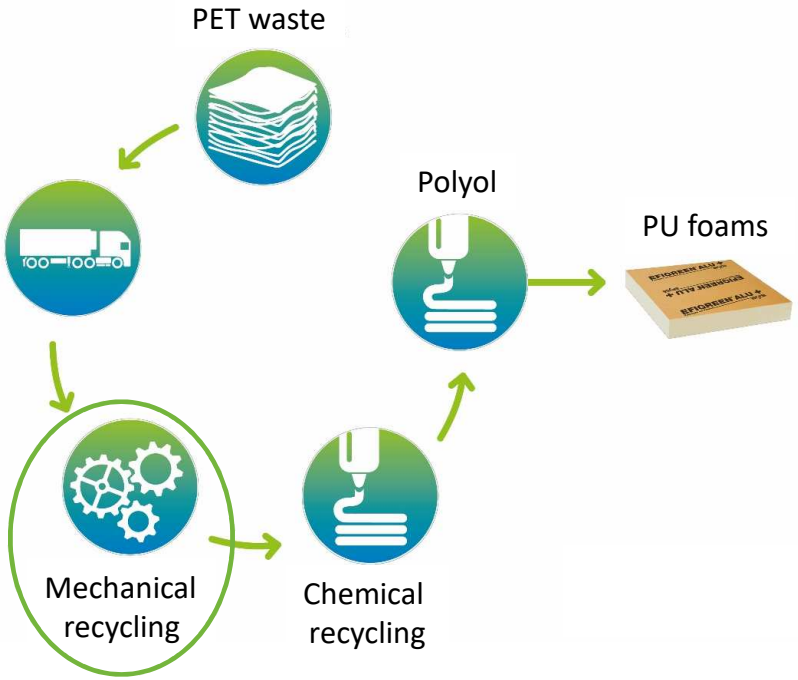
03

POLYMER RECYCLING TOWARDS NEW PRODUCTS

SOPRALOOP – THE CONCEPT



Post-consumer waste

Unpacking → Sorting → Grinding → Washing → Separation

Post-consumer PET waste

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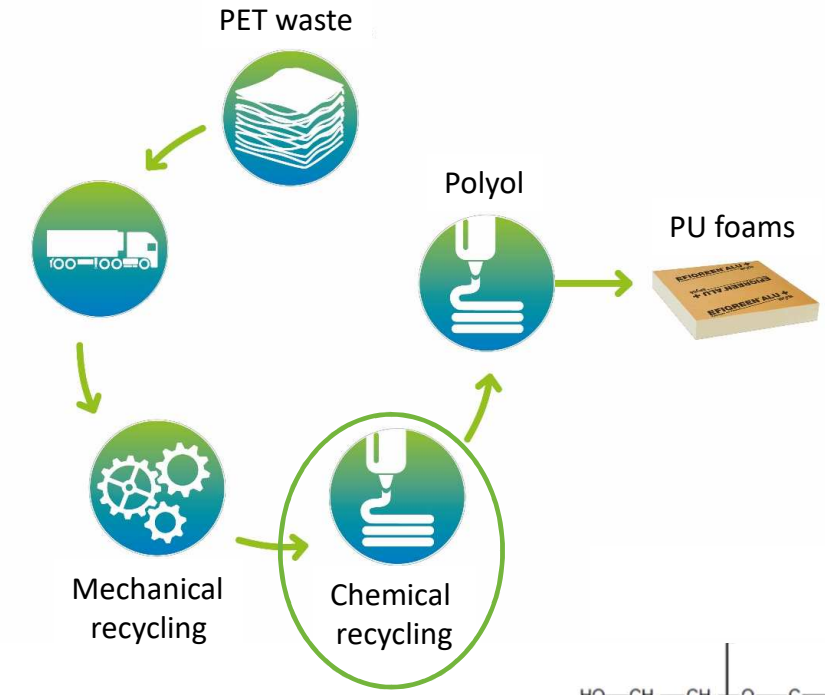
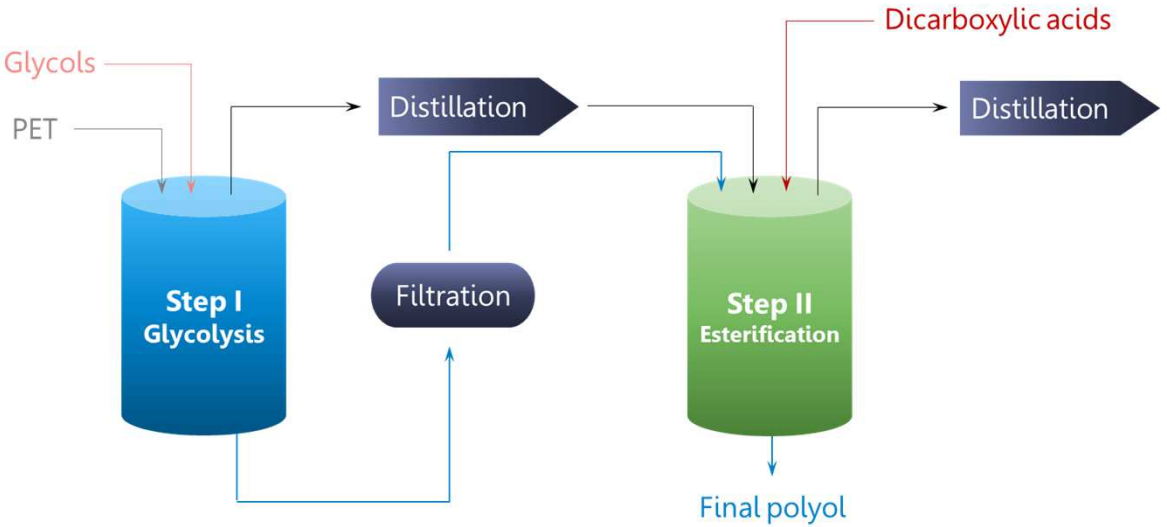
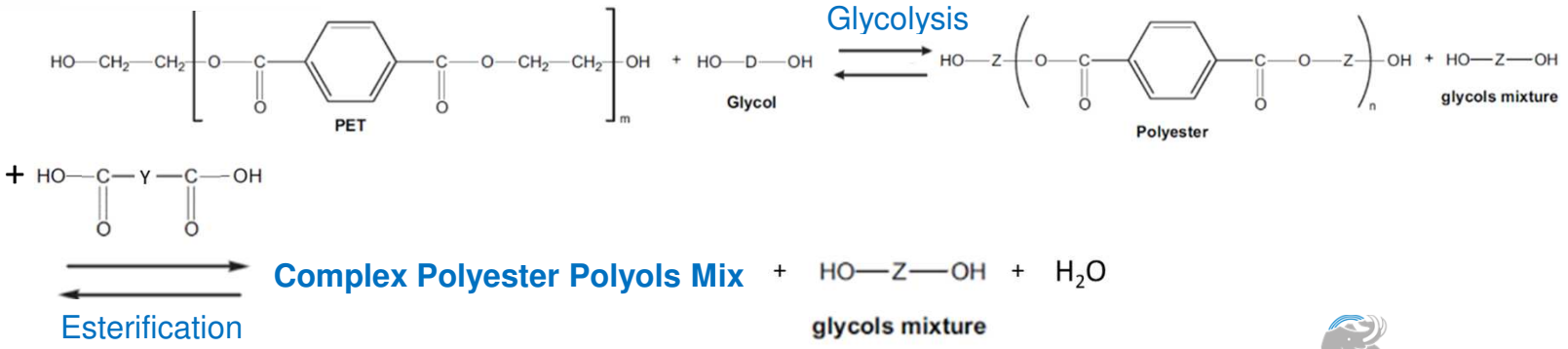
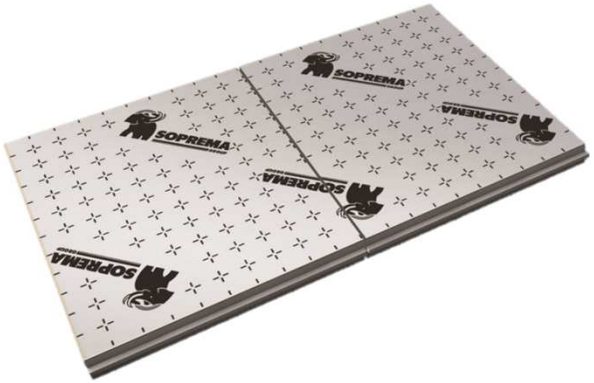
SOPRALOOP – THE CONCEPT





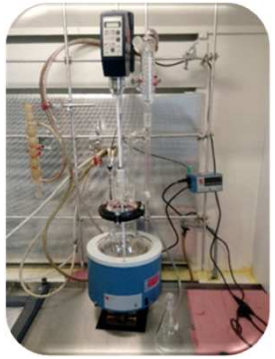


PU FOAMS RECYCLING



Excellent insulating material
BUT thermoset polymer

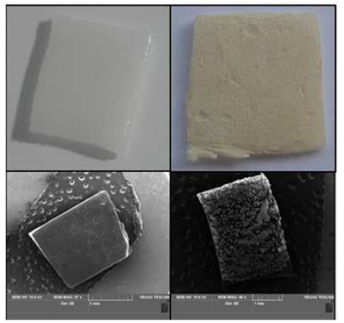
Chemical recycling



Solvolysis → **Polyols**

iceberg
Circular Economy of Building Materials

Biotech upcycling



Enzymes (esterases, amidases, laccases…)
→ **New building blocks**

P4SB
From Plastic waste to Plastic value using Pseudomonas putida Synthetic Biology

MOPLACE

mix-up 降塑再造

Enzycle

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CONCLUSIONS

TITRE 1

Tempestate praetorio

Praesens ipse quoque adrogantis ingenii, considerans

- incitationem eius ad multorum augeri discrimina
- non maturitate vel consiliis mitigabat
- ut aliquotiens celsae potestates iras principum

Cum parum congrueret, eum ad rabiem

- creberrime docens, idque, incertum qua mente

TITRE 2

Thalassius vero ea

Praesens ipse quoque adrogantis ingenii, considerans

- incitationem eius ad multorum augeri discriminane lateret adfectans.
- quibus mox Caesar acrius efferatus
- non maturitate vel consiliis mitigabat
- ut aliquotiens celsae potestates iras principum
- potius evibrabat, Augustum actus eius exaggerando
- velut contumaciae quoddam vexillum altius erigens

TITRE 3

Praefectus praetorio

Praesens ipse quoque adrogantis ingenii, considerans

- incitationem eius ad multorum augeri discrimina
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- ut aliquotiens celsae potestates iras principum

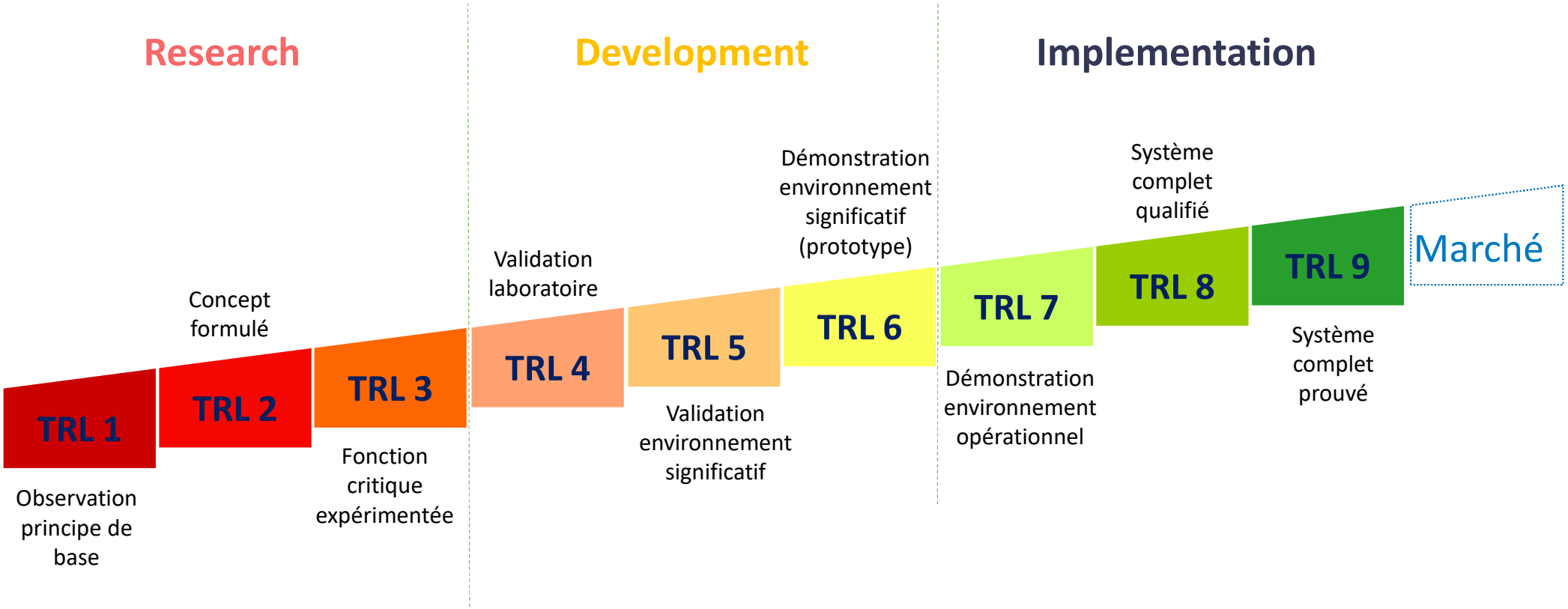
Cum parum congrueret, eum ad rabiem

- potius evibrabat, Augustum actus eius exaggerando

THANKS FOR YOUR ATTENTION

Antoine DUVAL
aduval@soprema.fr

MATURITE DES PROJETS R&D – TECHNOLOGY READINESS LEVEL



SOMMAIRE

01 VERS DES MEMBRANES D'ETANCHEITE BIOSOURCEES

SLIDE TEXTE SIMPLE

NIVEAU 1

Niveau 2

Niveau 3

Niveau4

- Niveau 5

SLIDE TEXTE ET IMAGE

THALASSIUS VERO EA

tempestate praefectus praetorio

praesens ipse quoque adrogantis ingenii, considerans incitationem eius ad multorum augeri discrimina, non maturitate vel consiliis mitigabat, ut aliquotiens celsae potestates iras principum

molliverunt, sed adversando iurgandoque

cum parum congrueret, eum ad rabiem potius evibrabat, Augustum actus eius exaggerando creberrime docens, idque, incertum qua mente, ne lateret adfectans. quibus mox Caesar acrius efferatus, velut contumaciae quoddam vexillum altius erigens, sine respectu salutis alienae vel suae ad vertenda opposita instar rapidi fluminis irrevocabili impetu ferebatur.

SLIDE IMAGE ET LÉGENDE

Thalassius vero ea

- tempestate praefectus praetorio

SLIDE 2 IMAGES ET LÉGENDE

SLIDE TEXTE ET IMAGE

THALASSIUS VERO EA

Tempestate praefectus praetorio

Praesens ipse quoque adrogantis ingenii, considerans

- incitationem eius ad multorum augeri discrimina
- non maturitate vel consiliis mitigabat
- ut aliquotiens celsae potestates iras principum

Molliverunt, sed adversando iurgandoque

Cum parum congrueret, eum ad rabiem

- potius evibrabat, Augustum actus eius exaggerando
- creberrime docens, idque, incertum qua mente
- ne lateret adfectans. quibus mox Caesar acrius efferatus
- velut contumaciae quoddam vexillum altius erigens

TEMPESTATE PRAEFECTUS PRAETORIO

Thalassius vero ea

Praesens ipse quoque adrogantis ingenii, considerans

- incitationem eius ad multorum augeri discriminane lateret adfectans.
- quibus mox Caesar acrius efferatus
- non maturitate vel consiliis mitigabat
- ut aliquotiens celsae potestates iras principum

Ded adversando iurgandoque

Parum congrueret, eum ad rabiem

- potius evibrabat, Augustum actus eius exaggerando
- velut contumaciae quoddam vexillum altius erigens

SLIDE TEXTE ET IMAGE

THALASSIUS VERO EA

Tempestate praefectus praetorio

Praesens ipse quoque adrogantis ingenii, considerans

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PRAEFECTUS PRAETORIO

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- ut aliquotiens celsae potestates iras principum

Cum parum congrueret, eum ad rabiem

potius evibrabat, Augustum actus eius exaggerando

SLIDE 3 PARTIES

TITRE 1

Tempestate praetorio

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- creberrime docens, idque, incertum qua mente

TITRE 2

Thalassius vero ea

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TITRE 3

Praefectus praetorio

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- ut aliquotiens celsae potestates iras principum

Cum parum congrueret, eum ad rabiem

- potius evibrabat, Augustum actus eius exaggerando

SLIDE 3 PARTIES - ALTERNATIVE

TITRE 1

Tempestate praetorio

Praesens ipse quoque adrogantis ingenii, considerans

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Cum parum congrueret, eum ad rabiem

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TITRE 2

Thalassius vero ea

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Cum parum congrueret, eum ad rabiem

- potius evibrabat, Augustum actus eius exaggerando

SLIDE 4 PARTIES

1

Thalassius vero ea

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- incitationem eius ad multorum augeri discriminane lateret adfectans.
- quibus mox Caesar acrius efferatus
- non maturitate vel consiliis mitigabat
- ut aliquotiens celsae potestates iras principum
- potius evibrabat, Augustum actus eius exaggerando
- velut contumaciae quoddam vexillum altius erigens

2

Tempestate praetorio

Praesens ipse quoque adrogantis ingenii, considerans

- incitationem eius ad multorum augeri discrimina
- non maturitate vel consiliis mitigabat
- ut aliquotiens celsae potestates iras principum

Cum parum congrueret, eum ad rabiem

- creberrime docens, idque, incertum qua mente

3

Praefectus praetorio

Praesens ipse quoque adrogantis ingenii, considerans

- incitationem eius ad multorum augeri discrimina
- non maturitate vel consiliis mitigabat
- ut aliquotiens celsae potestates iras principum

Cum parum congrueret, eum ad rabiem

- potius evibrabat, Augustum actus eius exaggerando

4

Thalassius vero ea

Praesens ipse quoque adrogantis ingenii, considerans

- incitationem eius ad multorum augeri discriminane lateret adfectans.
- quibus mox Caesar acrius efferatus
- non maturitate vel consiliis mitigabat
- ut aliquotiens celsae potestates iras principum
- potius evibrabat, Augustum actus eius exaggerando
- velut contumaciae quoddam vexillum altius erigens

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GRAPHIQUES ET SCHÉMAS

CONSIDERANS

incitationem eius ad multorum augeri discriminane lateret adfectans.

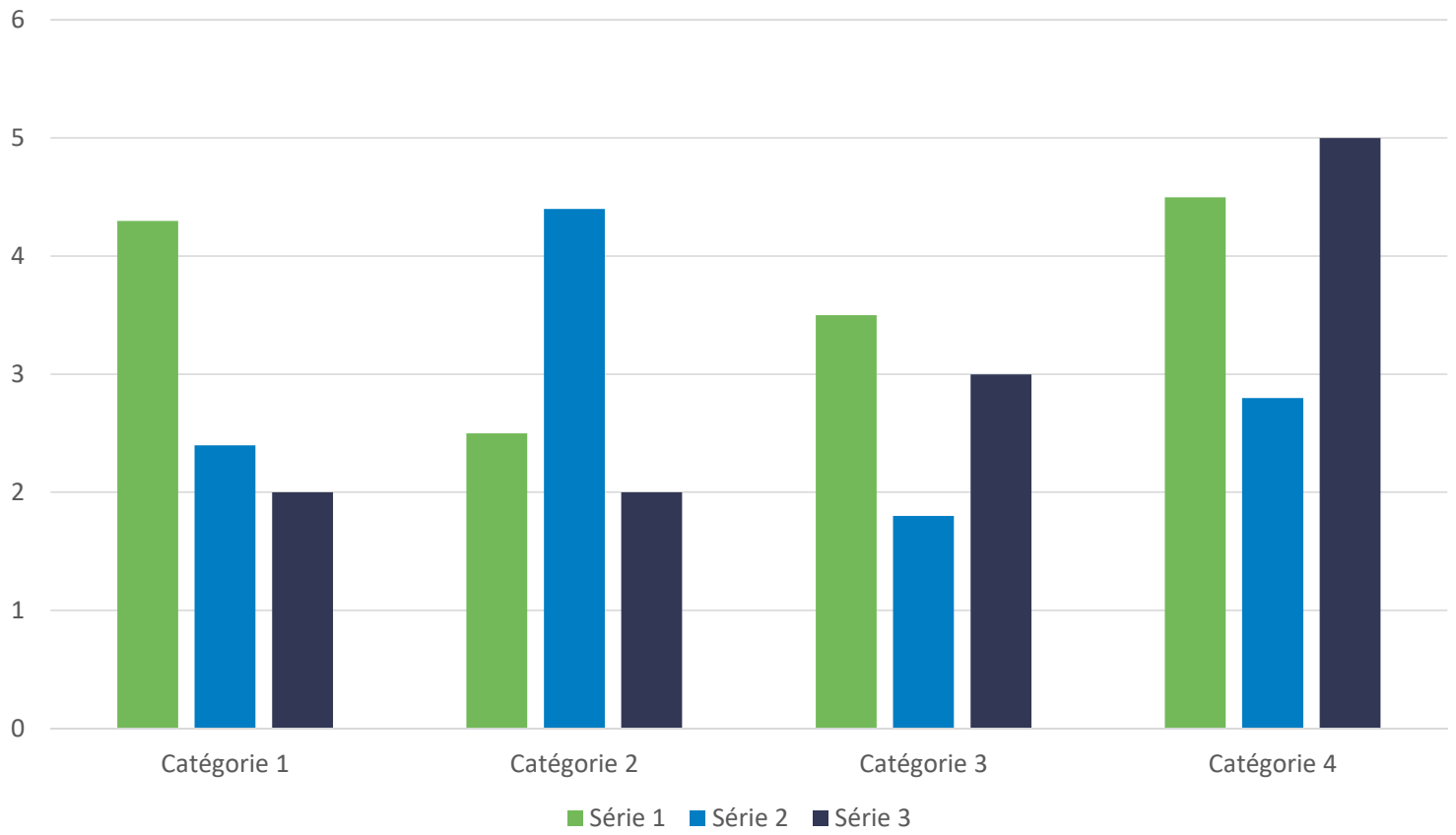
quibus mox Caesar acrius efferatus

NON MATURITATE

consiliis mitigabat

adfectans

quibus mox Caesar



CHIFFRES CLÉS - ALTERNATIVE

2M€

DO IUNSKJHKJH

32%

DCUZN KLQPS

1/3

OISUS OILKJLB

MERCI POUR
VOTRE ATTENTION

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ANNEXE | BIBLIOTHÈQUE DE CONTENUS

Pour intégrer une photo dans une « Forme » :

- Réaliser la forme souhaitée
- Cliquer sur « Remplissage »
- Choisir « Image »
- Sélectionner votre image
- Cliquer sur Insérer

Blabla

Blabla