2022

COMPOSIFORUM
ACTAS DE LA CONFERENCIA

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Organiza

Cátedra aitiip Universidad Zaragoza

Colabora

AEMAC Asociación Española de Materiales Compuestos

Agenda

***La conferencia cuenta con servicio de intérpretes para las ponencias (Español-Inglés / Inglés-Español)**

9:00 – 9:30 | Bienvenida y Acreditación

9:30 – 10:00| Apertura institucional de la jornada

D. Juan Manuel Blanchard, Presidente de Aitiip Centro Tecnológico

D. Carlos Toledo, Punto Nacional de contacto Cluster 4 Industry-NCP del CDTI

Dña. Gloria Cuenca, Vicerrectora de Transferencia e Innovación Tecnológica de la Universidad de Zaragoza

Dña. Yolanda Sancho, Directora General de Universidades del Gobierno de Aragón

10:00 – 10:45 | Conferencia inaugural

Nuevos conceptos para el diseño de aeroestructuras basados en el uso de laminados poliméricos no convencionales

Prof. Pedro Camanho, Profesor catedrático de Mecánica Aplicada de la Universidade do Porto

10:45 – 11:45 | Sesión de Sostenibilidad

Sesión I – Composites Reforzados con Fibra de Carbono basados en resinas epoxy termoestables con aplicaciones en el sector espacial y aeroespacial

Prof. Alice Mija, Catedrática de Química en el Instituto de Química de Niza de la Université Cote D'Azur

Sesión II - Liderando el camino hacia los plásticos reforzados con fibra de carbono más sostenibles

Dra. Caroline Petiot, Científica Senior en el grupo de Nuevos Materiales y Procesos de Airbus

Sesión III – Fabricación avanzada y utillajes sostenibles para el procesado de composites termoplásticos con fibra de carbono

Dr. José Antonio Dieste, Responsable de Ingeniería y Procesos Avanzados en Centro Tecnológico Aitiip y Profesor asociado en el Departamento de Ingeniería Mecánica de la Universidad de Zaragoza

11:45 – 12:15| Pausa Café- Networking (sala "13 Heroínas")

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Cátedra aitiip Universidad Zaragoza

AEMAC ASOCIACIÓN ESPAÑOLA DE MATERIALES COMPUESTOS

Agenda

12:15 – 13:15 | Sesión de Circularidad

Sesión IV – Tecnologías de reciclado de materiales termoestables para su integración en una Economía Circular

D. Julio Vidal, PhD(c) Investigador Senior de composites y plásticos| Centro Tecnológico Aitiip

Sesión V – Ingeniería de enzimas mediante evolución dirigida y resurrección ancestral para la degradación y valorización de composites termoestables

Dr. Miguel Alcalde|Co-fundador y consejero en EvoEnzyme | Profesor Investigador en el Instituto de Catálisis CSIC

Sesión VI – Biocarbono circular: transformando los residuos orgánicos urbanos en productos con valor añadido

Dra. Natalia Alfaro, Responsable de proyectos I+D+i | Urbaser| Coordinadora Proyecto Circular Biocarbon

13:15 – 14:15 | Mesa Redonda sobre aplicaciones industriales

Sector Aeronáutico: Dr. Alejandro Ibrahim| CEO del Aeropuerto de Teruel

Sector Construcción: D. Fernando Pardo Cobo, Responsable Economía Circular |Placo® e Isover

Sector Automoción: Dr. Raúl Gallego, Responsable de Materiales Avanzado | Grupo Antolín Ingeniería

14:15 – 14:30 | Conclusiones y Cierre de la jornada

14:30 – 15:30 | Lunch - Networking (sala "13 Heroínas")

15:30 – 17:00 | Traslado en bus a Aitiip Centro Tecnológico

17:00 | Cierre de la jornada

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Conferencia Inaugural

FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

inegi driving science & innovation

2022

Expanding the design envelope of aerospace structures using non-conventional polymer composite laminates

Pedro M. P. R. de Castro Camanho

Department of Mechanical Engineering

University of Porto, Portugal

pcamanho@fe.up.pt

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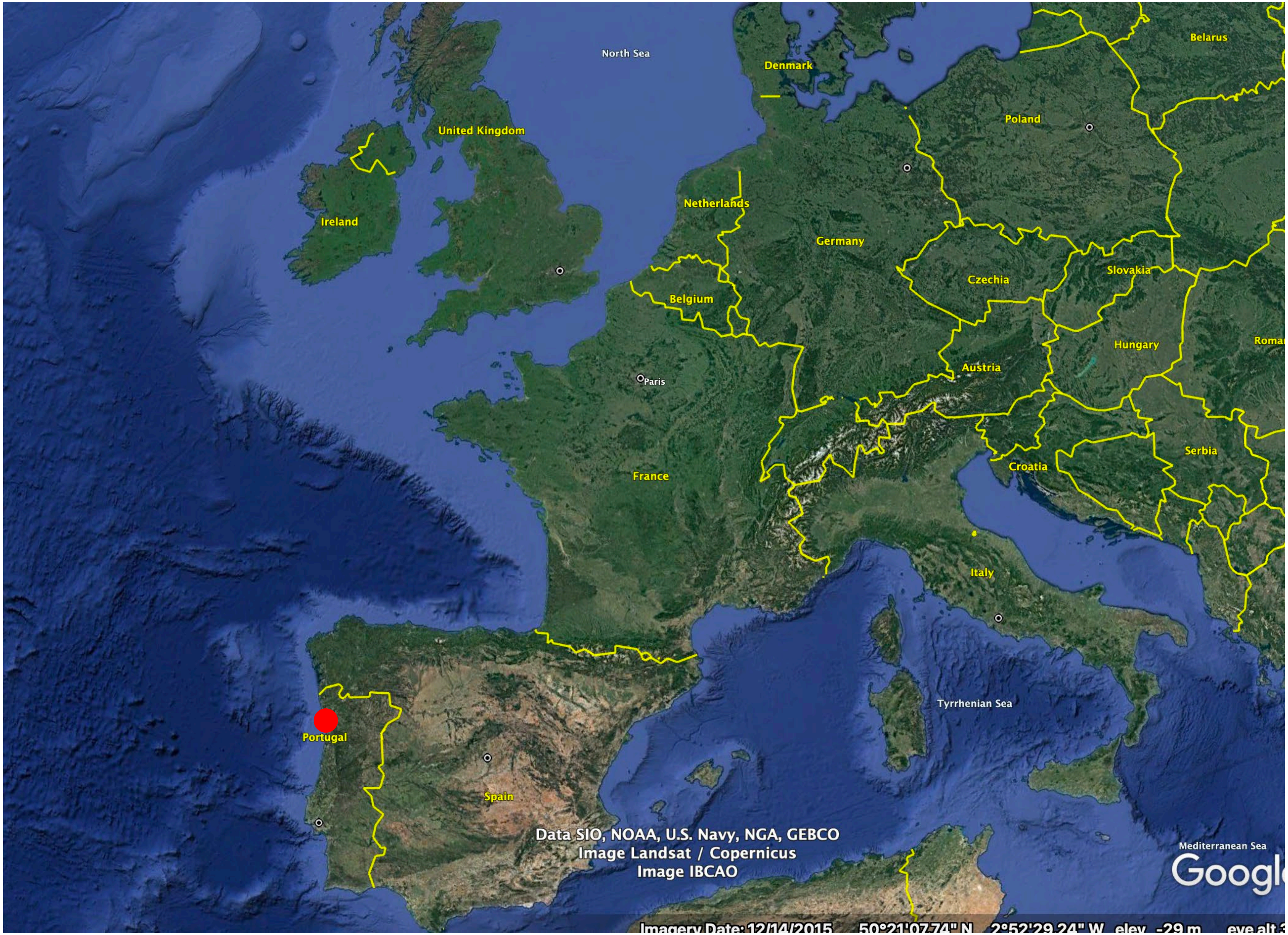
North Sea
Denmark
Belarus
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United Kingdom
Ireland
Netherlands
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Czechia
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Hungary
Austria
Paris
France
Croatia
Serbia
Italy
Portugal
Spain
Tyrrhenian Sea
Mediterranean Sea
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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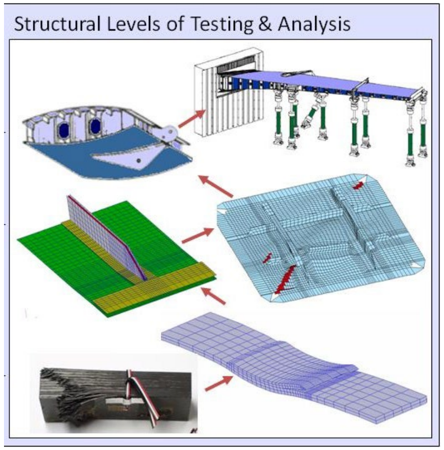
Contents

Important innovation drivers in the aerospace industry

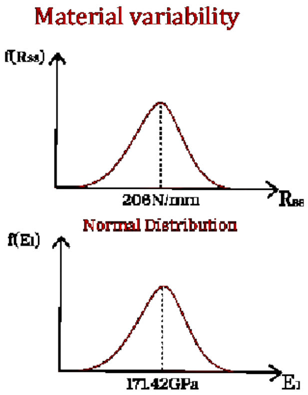


- Digitalization of processes/digital transformation, leading to reductions in cost and lead time. 50% reduction of certification costs by 2050 (ACARE vision for 2050). End-to-end simulation, including design, manufacturing and certification.

"Certification and testing will be much tougher for novel airframe configurations or propulsion systems, new certification procedures will have to be developed for some of them to ensure the undisputed safety level required for commercial aviation."

(Waypoint 2050, Air Transport Action Group, 2nd ed., Sept. 2021).

- Uncertainty quantification and management.

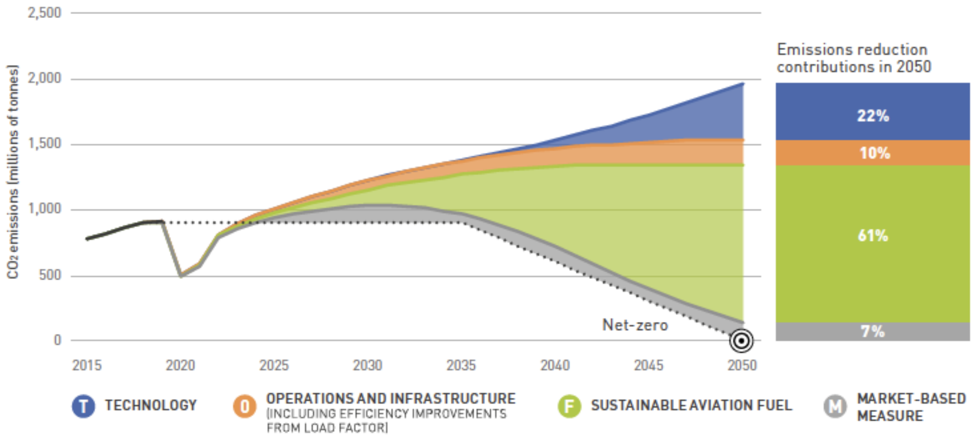


"In practice, today's simulation are providing a single result. In front of the authorities, we wish to provide an envelop of uncertainty associated to the results accounting for variations of specimens …"

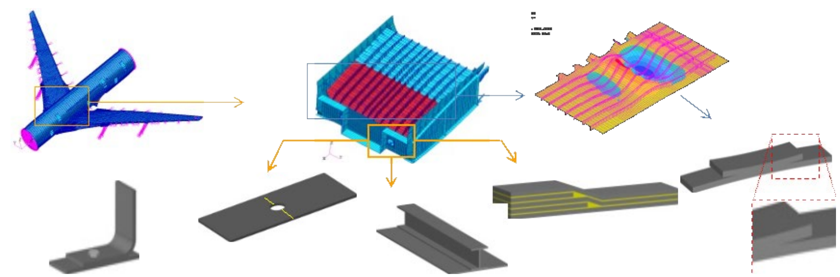
(M. Fouinneteau, Airbus, ECCOMAS Composite Materials 2017, Eindhoven)

Important innovation drivers in the aerospace industry

- Highly optimized composite structures, non-conventional materials, simulation across the scales.

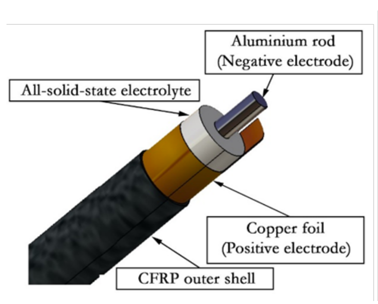


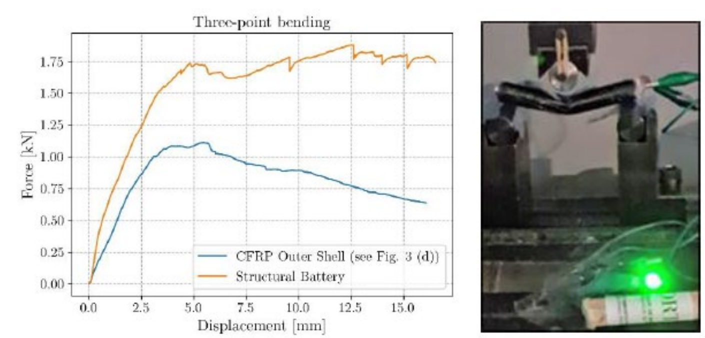
(Waypoint 2050, Air Transport Action Group, 2nd ed., Sept. 2021).



(Picture courtesy of Dr. Stéphane Mahdi, Airbus).

- Multidisciplinary & multifunctional (hydrogen, electrification, batteries, SHM, self-healing).





(a) (b)

(Danzi, Camanho et al., **Molecules**, 2012, *Coaxial energy harvesting and storage*, patent pending).

"Alcoa announced its intention to reduce the cost and weight of its products by 20% in order to defend the position of metallic aerospace structures against composites." J. Hinrichsen, "Alcoa Aerospace – Optimized Solutions Meeting Mission Requirements", Aeromat Plenary Session Address, Orlando, Florida, 6 June, 2005.

General guidelines to design aeronautical composite parts (Baker et al., Composite Materials for Aircraft Structures, AIAA, 2004):

- Use balanced and symmetric laminates to avoid unwanted warping.
- Use a minimum of 10% of plies in each of the 0°, 90°, ±45° directions.
- Use a maximum of four adjacent plies in any one direction.
- Place ±45° plies on the outside surfaces of shear loaded panels to increase buckling loads.
- Avoid highly directional laminates in regions around holes and notches.

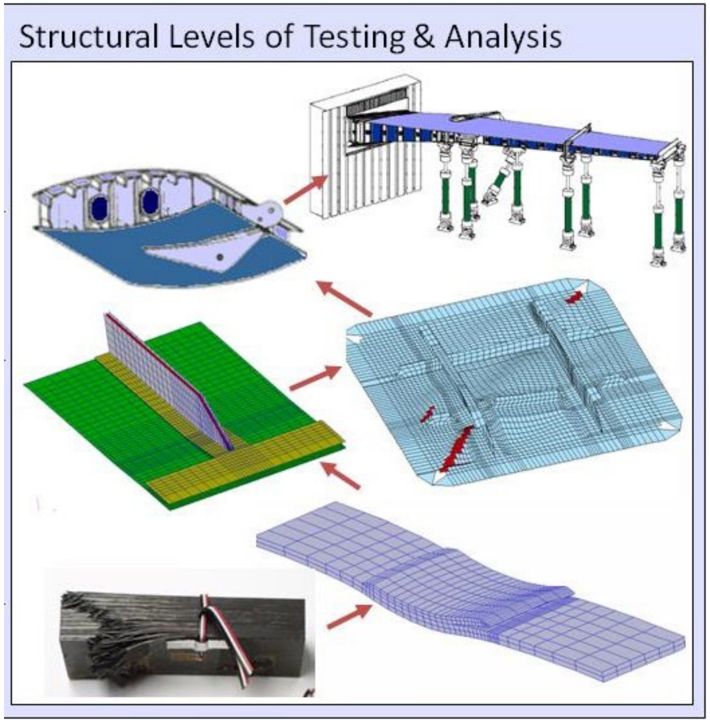
Typical laminates used in the industry based on standard-grade materials:

- Quasi–isotropic: [±45n/0n/90n]ms
- Directional: [±45/0n/90]ms

- The weight/fuel savings enabled by these configurations are relatively low (10%-20%).
- The costs of engineering are higher when compared to metals.
- Extra systems must be added (e.g. copper outer layer for lightning strike protection).

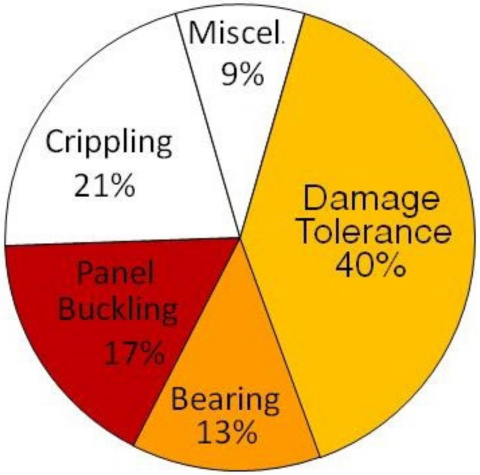
Can we do better?

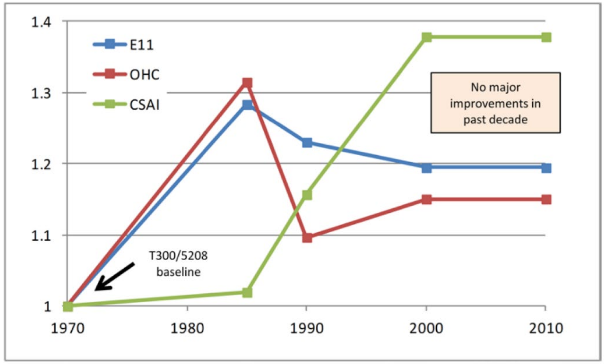
1. Analysis models to reduce recurring and non-recurring costs.



2. Improvement of the mechanical response of composite structures with respect to the main design drivers.

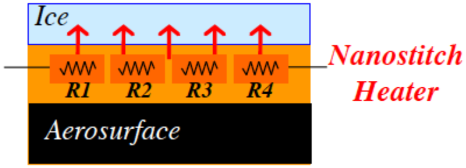
Airframe structure breakdown by failure mode designing the structure:

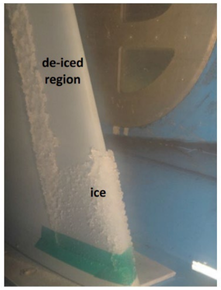




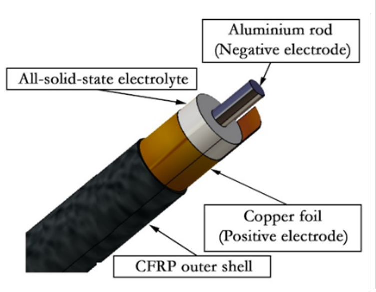
(C. Rosseau, S. Engelstad, S. Owens, 53rd AIAA SDM Conference, 2012).

3. Explore the potential of composite materials as the basis of multifunctional structures.

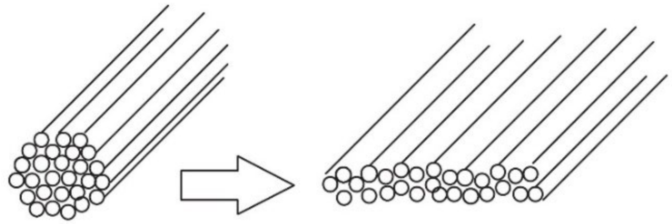


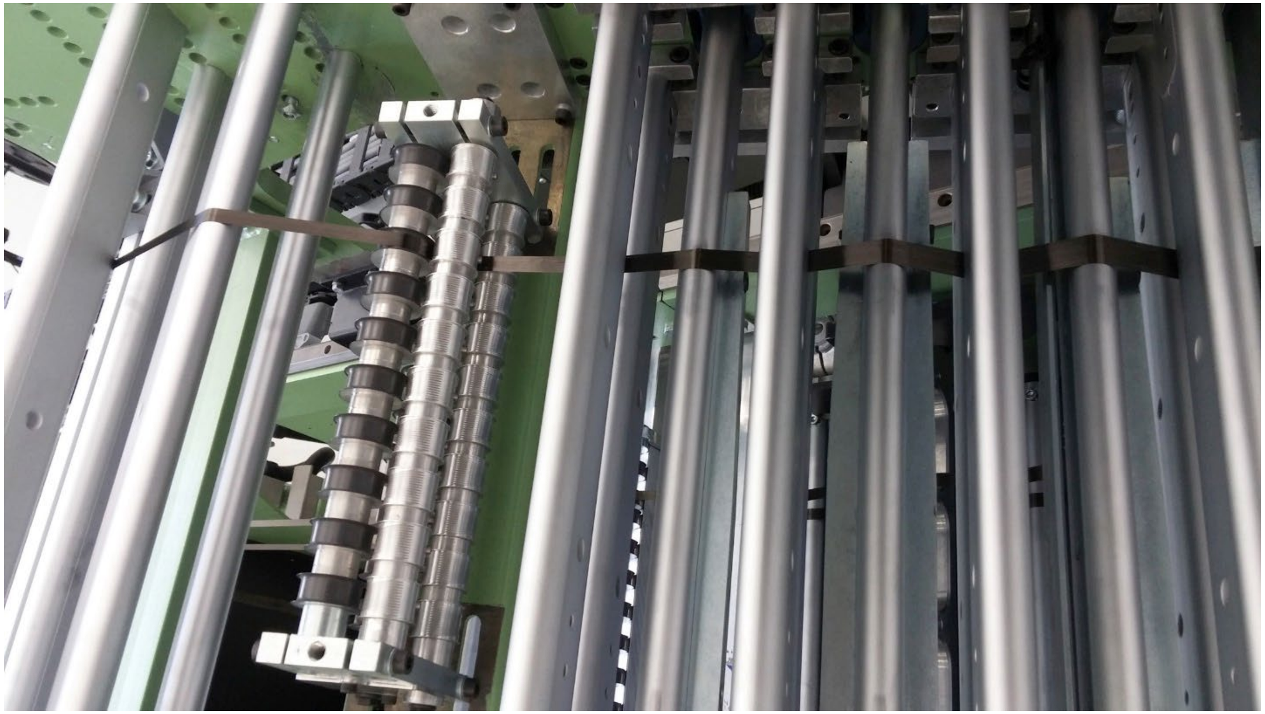


De-icing during ice-tunnel testing



Manufacturing - tow-spreading





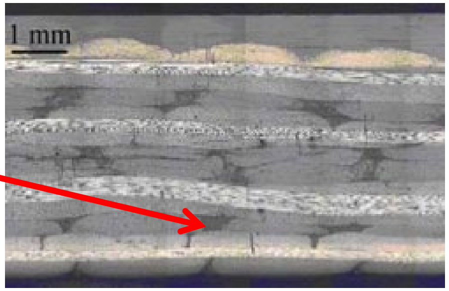
- Ply thickness as low as 20µm.
- 18gsm (UD) – 75gsm (fabrics).

Potential benefits

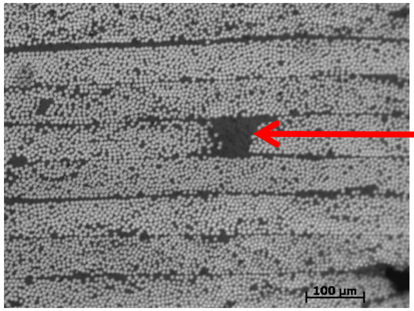
1. Improved fibre dispersion and reduced crimp angle.

Normal NCF

~500μm x 500μm resin pocket



75gsm NCF



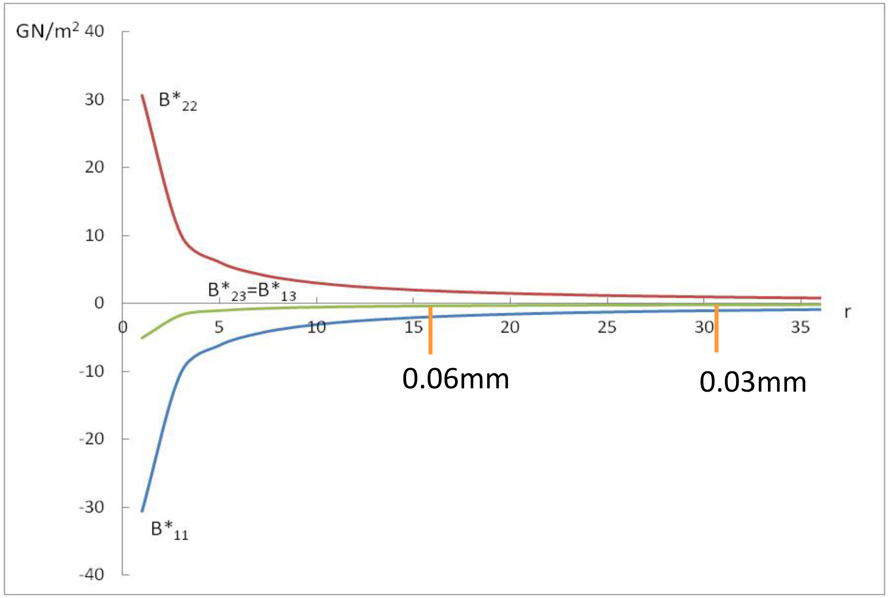
~50μm x 50μm resin pocket

2. Possibility of using continuous lay-up: mid-plane symmetry no longer required.

IM7-8552 CFRP

$[0/+45/-45/90]_{rT}$

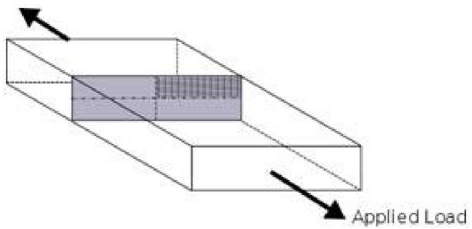
$$[B^*(r)] = \frac{1}{r}\begin{bmatrix} -30.6 & 0 & -5.1 \\ 0 & 30.6 & -5.1 \\ -5.1 & -5.1 & 10.1 \end{bmatrix} \times 10^9 \quad \mathrm{N/m^2}$$



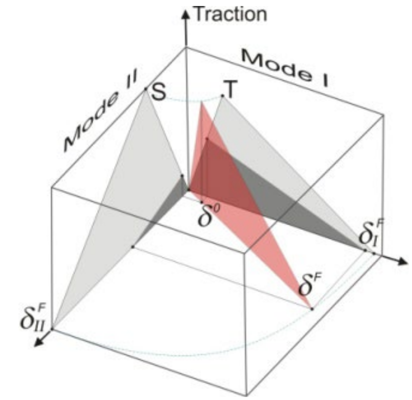
Potential benefits

3. Improved resistance to delamination.

3.1 Free-edge delamination



T700/M21, t_{ply}=0.04mm
$[+45_r/-45_r/0_r/90_r]_{nS}$

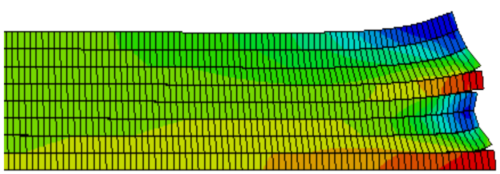


(Turon, Dávila, Camanho, Costa, Engineering Fracture Mechanics, 74, 1665-1682, 2007).

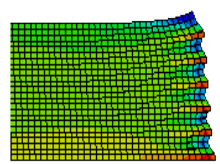
Thick, r=3, n=2

Thin, r=1, n=6

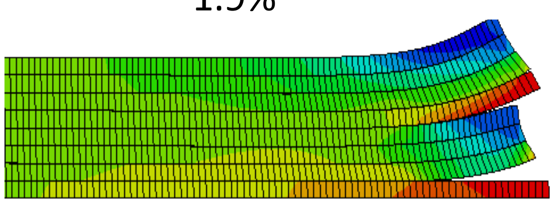
1%



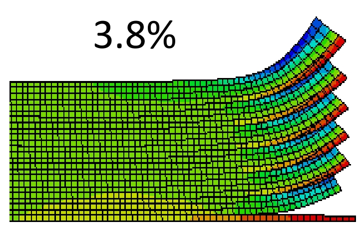
1%

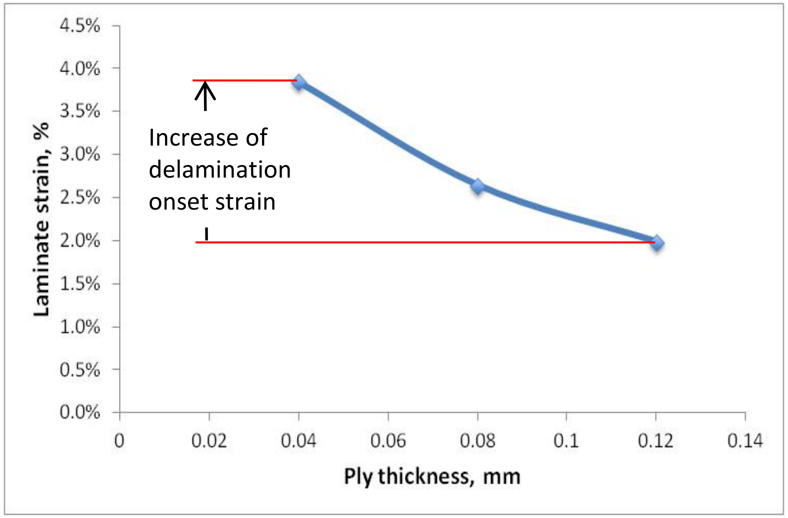


1.9%



3.8%

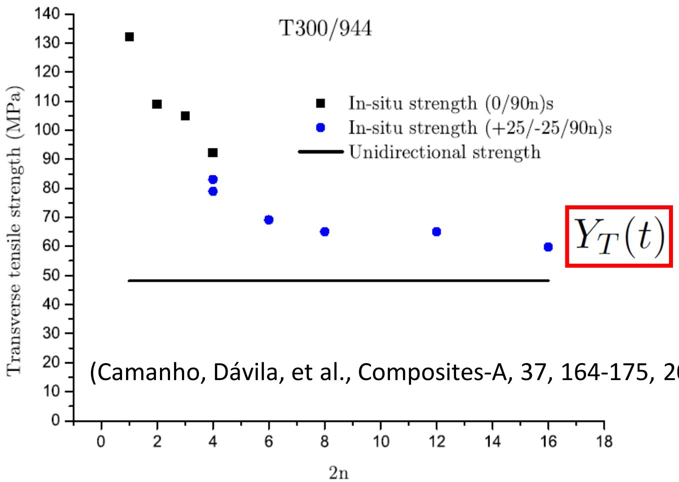




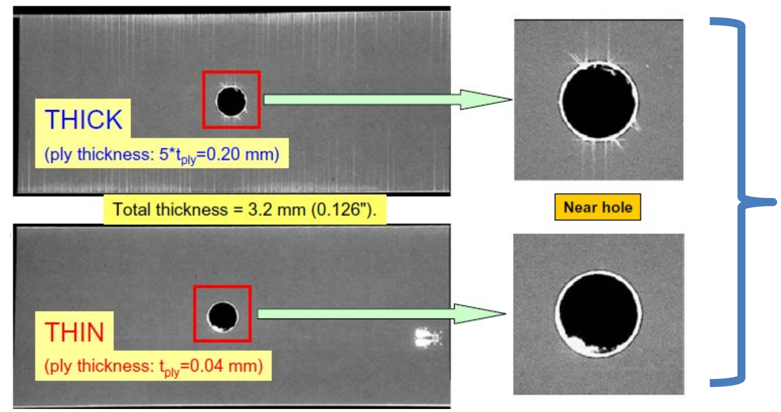
Potential benefits

4. Improved resistance to ply cracking.

4.1 In-situ effect

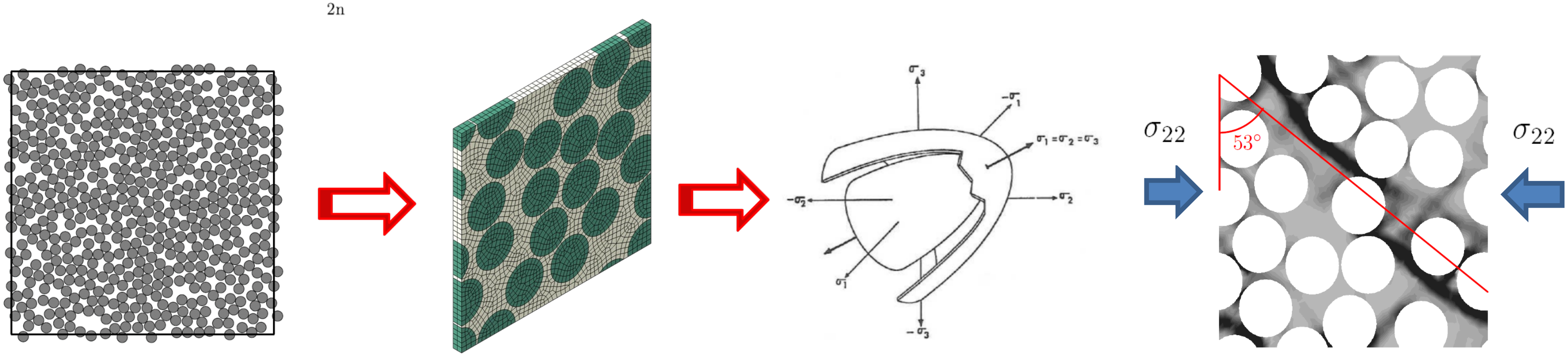


(Camanho, Dávila, et al., Composites-A, 37, 164-175, 2006).



Same applied (remote) stress

(SW Tsai, Stanford University, private communication, 2011).



Generation of random RVEs

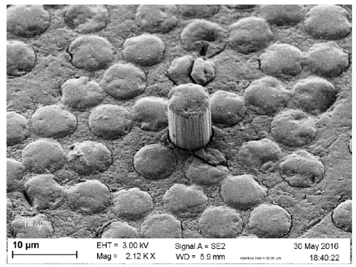
Mesh generation

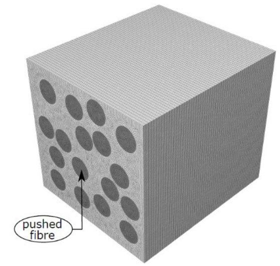
Material models for the constituents

Analysis

(Melro, Camanho, Composites Science and Technology, Vol. 68, 2092-2102, 2008).

Models for the constituents





Resin: plastic damage model based on paroboloidal yield surface and non-associated flow.

(A.R. Melro, P.P. Camanho et al, International J. Solids and Structures, 55, 92-107, 2015).

Fibre-matrix interface: frictional cohesive zone model.

(G. Catalanotti, P.P. Camanho, et al, Composite Structures, 182, 153-163, 2017).

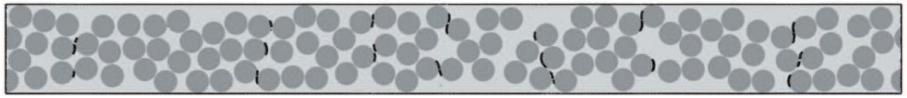
Fibre: Non-linear elastic damage model based on stochastic fibre strengths.

(R.P. Tavares, P.P. Camanho, W.K. Liu, et al, Computational Mechanics, 57, 405-421, 2016).

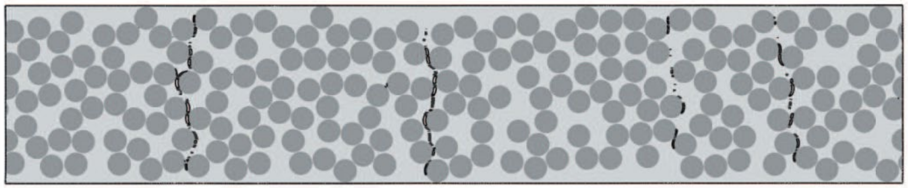
Simulation of in-situ effects

(A. Arteiro, P.P. Camanho et al, Composite Structures, 116, 2014).

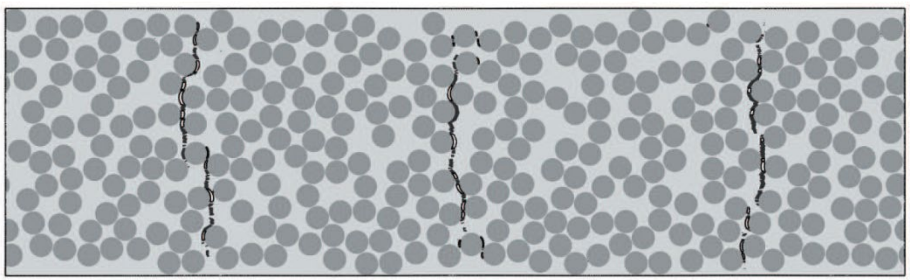
Simulation of in-situ effects



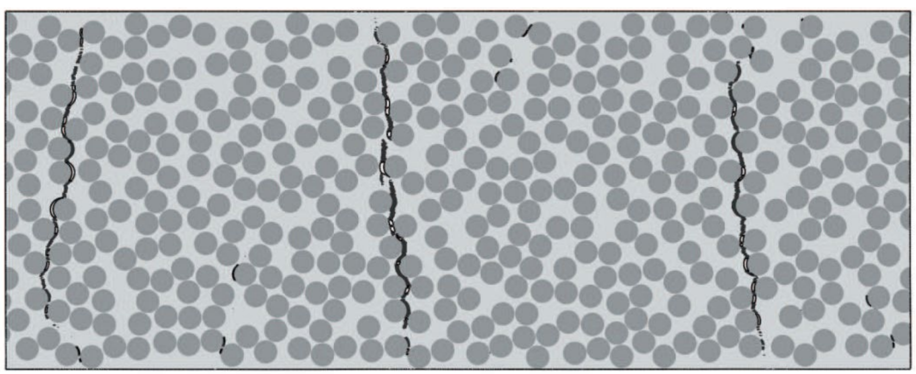
0.02mm



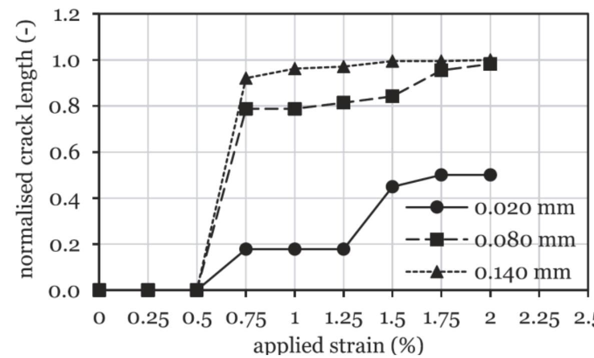
0.04mm

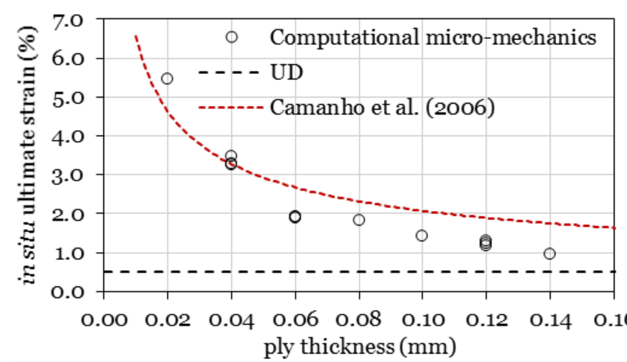


0.06mm



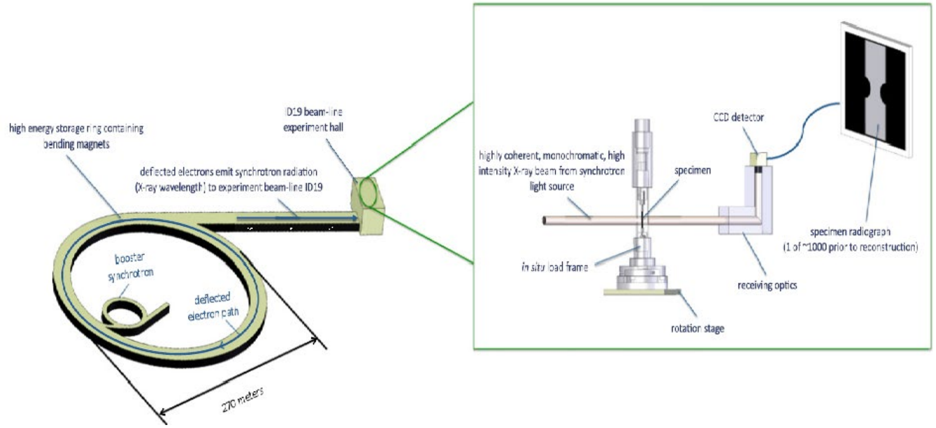
0.08mm

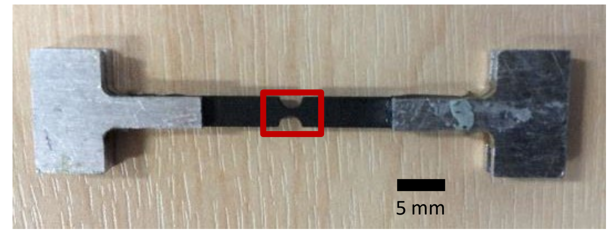




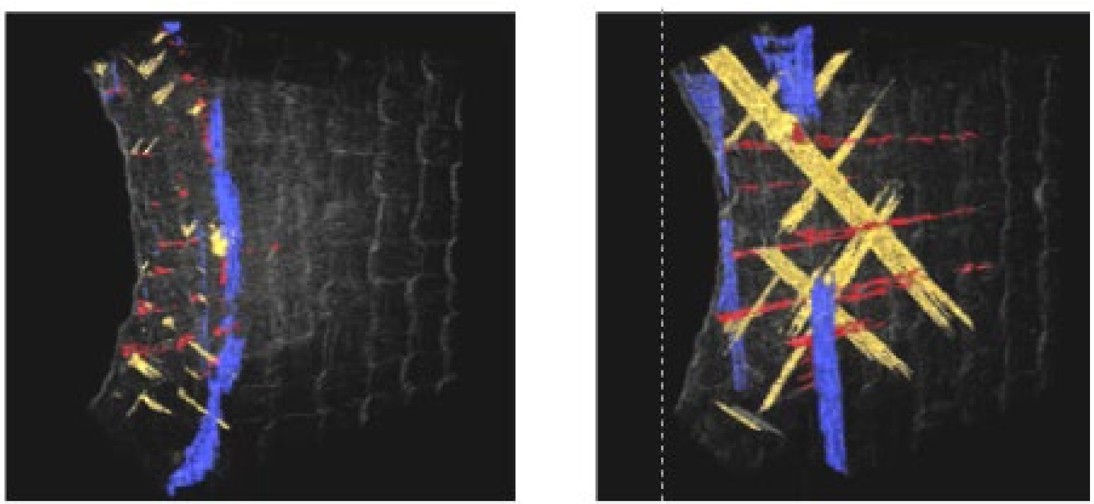
(A. Arteiro, P.P. Camanho et al, Composite Structures, 116, 2014).

European Synchrotron Radiation Facility (Grenoble)





70% UTS thin ply and standard grade CFRP

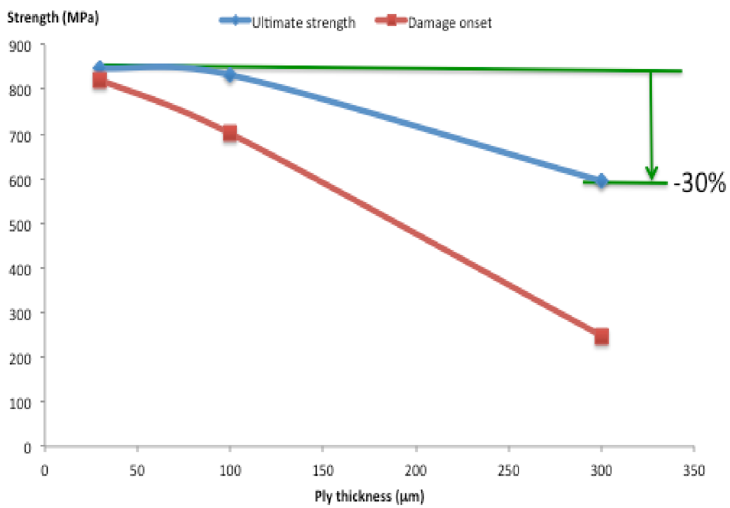


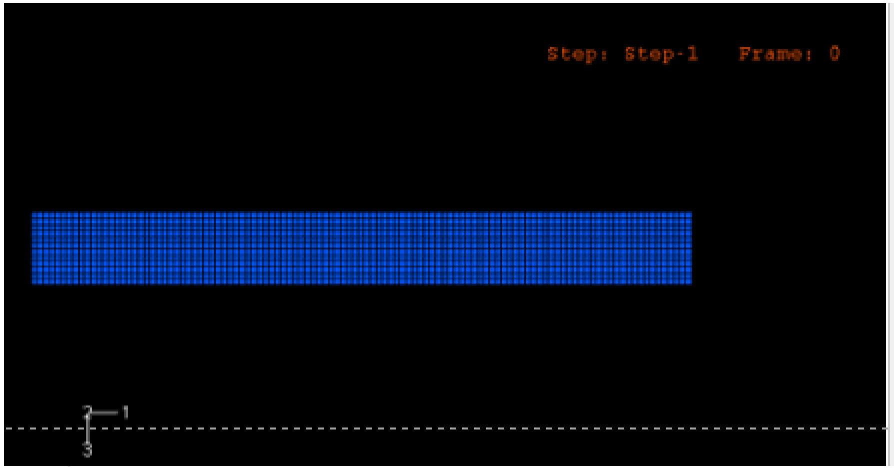
(R. Kopp, PhD thesis, MIT)

M40JB/ThinPreg80EP t_{ply}=0.03mm, 0.100mm and 0.300mm.

Lay-ups: $[(+45/90/-45/0)]_{ns}$, n=10, 3, 1; Total laminate thickness 2.4mm

Unnotched strength

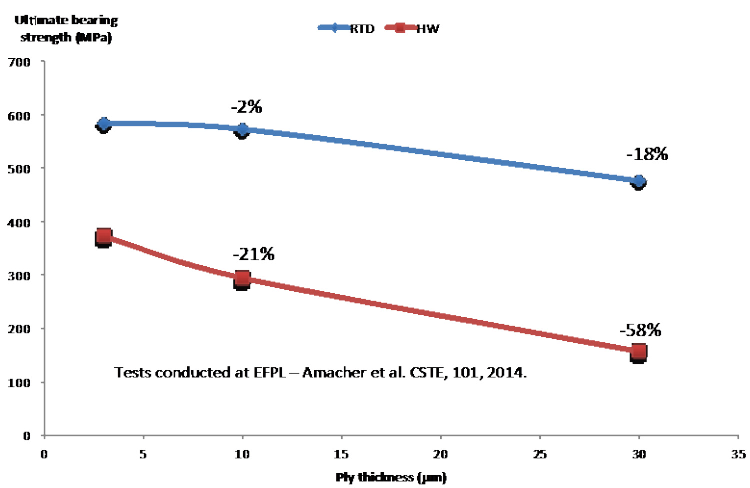




(Mollenhauer et al., Composites – A, 43, 2012).

(Maimí, Camanho, et al., Journal of Composite Materials, 42,,2008).

Bolted joint strength (single-lap shear)

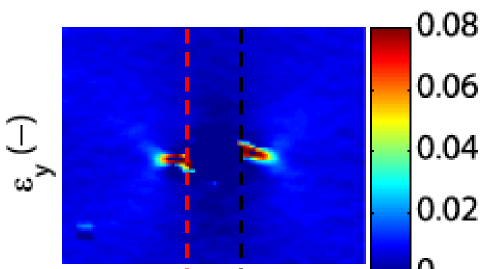


M40JB/ThinPreg80EP

Lay-ups: $[(+45/90/-45/0)]_{ns}$, n=10, 3, 1; Total laminate thickness 2.4mm

Open-hole tensile strength (w/d=6).

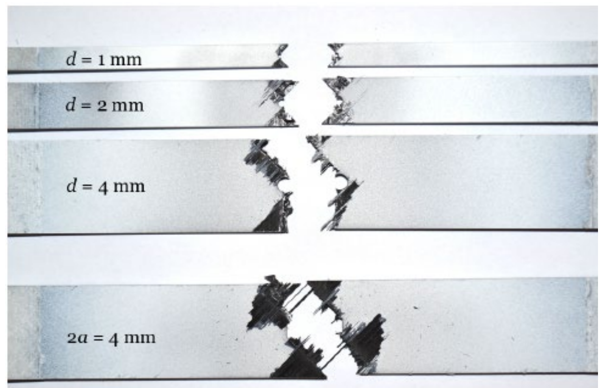
t=0.03mm

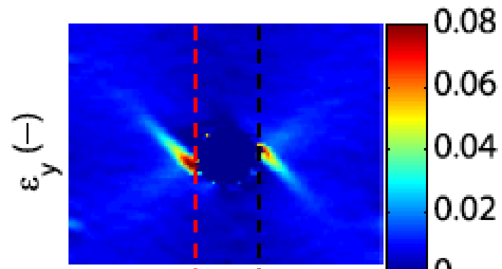


d=2mm

470MPa

t=0.10mm

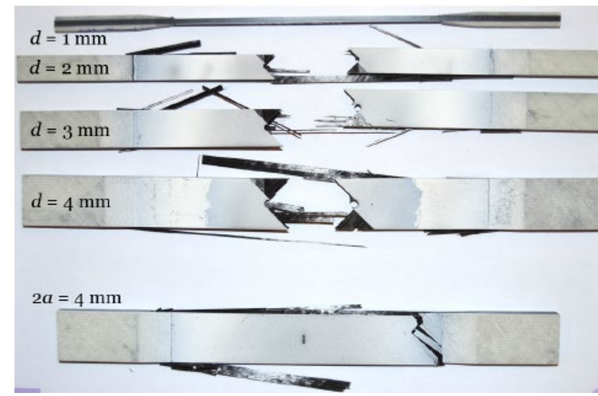


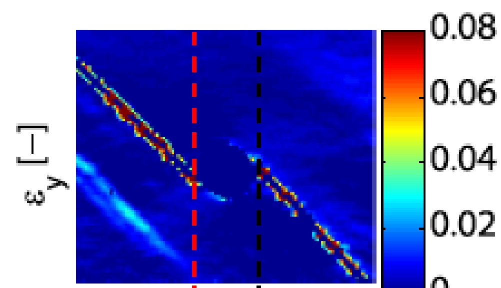


d=2mm

524MPa

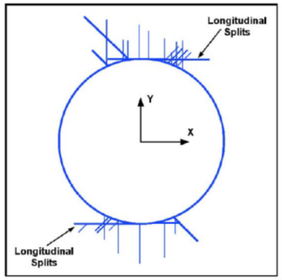
t=0.30mm



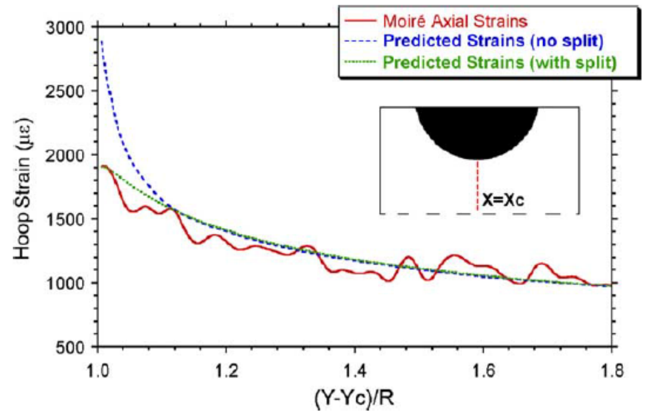


d=2mm

388MPa



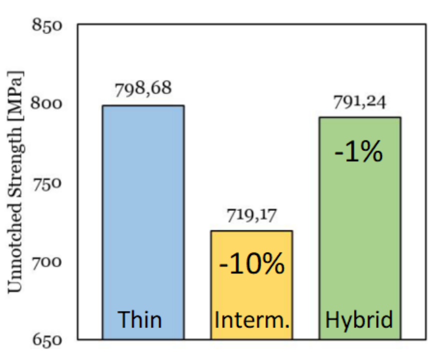
(Iarve et al, Composites - A, 36, 2005).



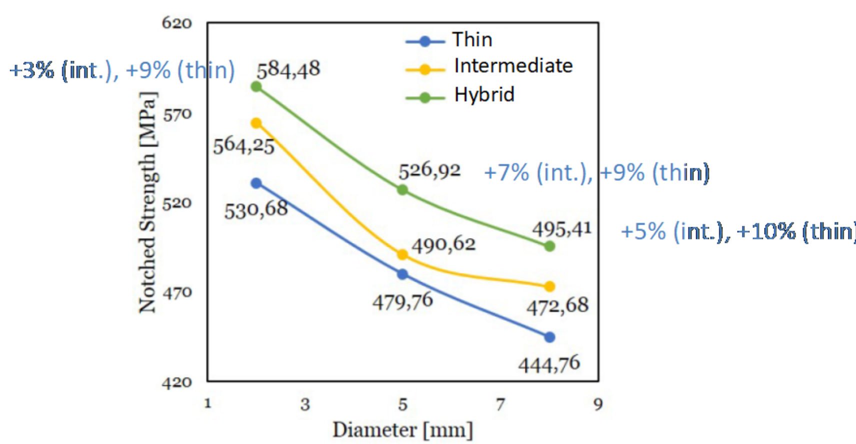
How can we increase both the unnotched and notched strength of baseline composites?

Hybrid grades – ultra thin grades used in the off axis plies.

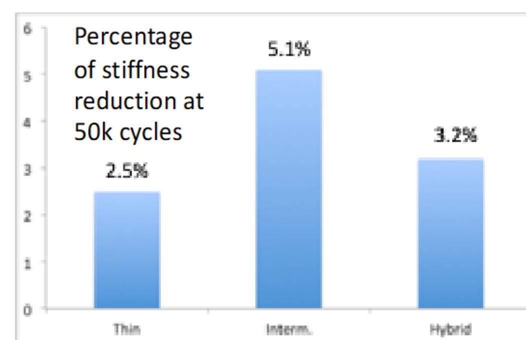
Unnotched strength



Open-hole tensile strength

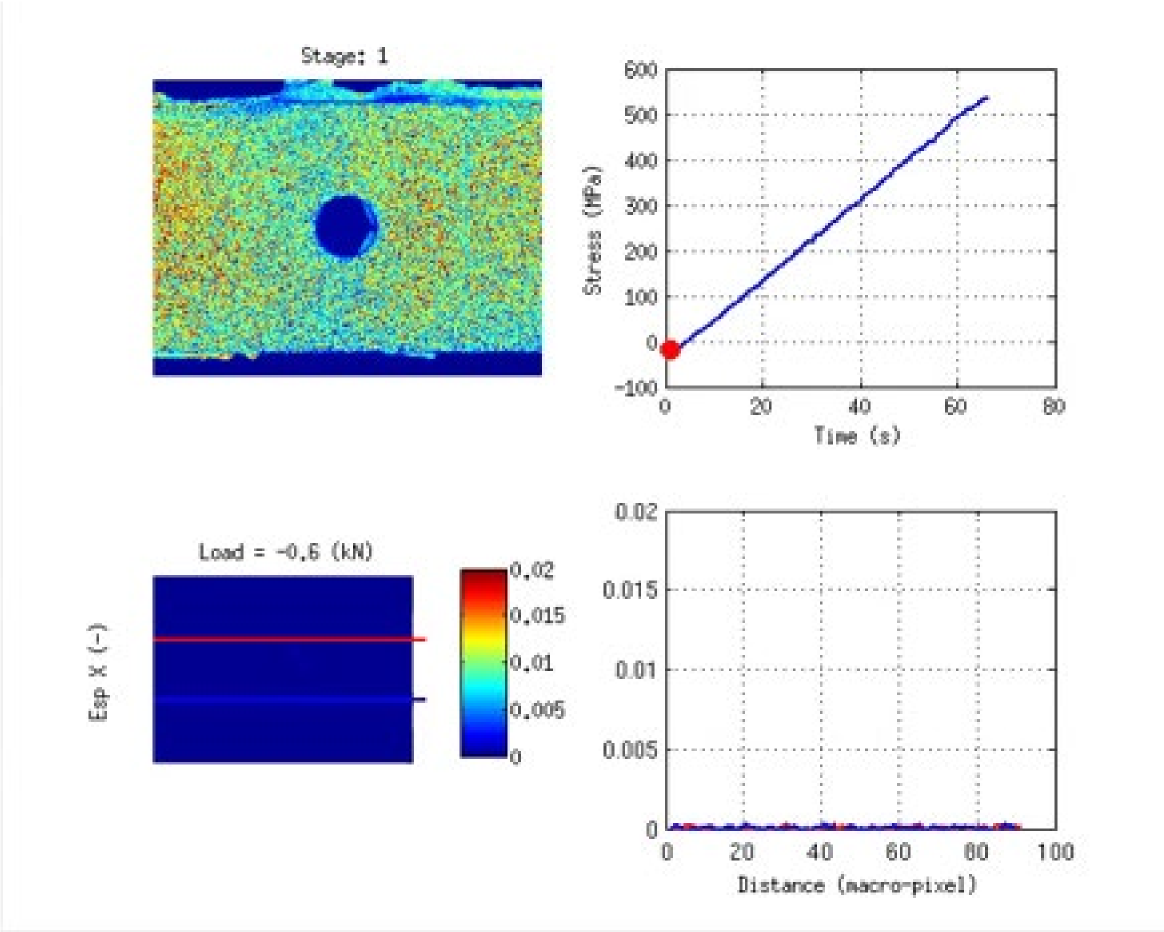


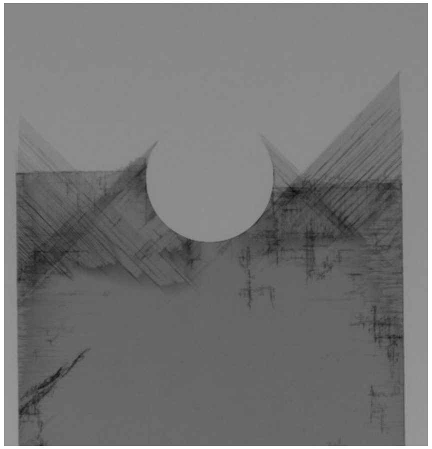
Open-hole fatigue (70% strength, R=0.1)

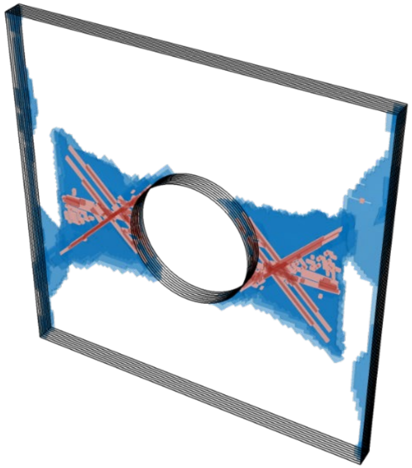


(Furtado, Camanho et al., Composite Structures, 145, 2016).

Implications in the design of composite structures







(Maimí, Camanho et al., Mechanics of Materials, 39, 909-919, 2007).

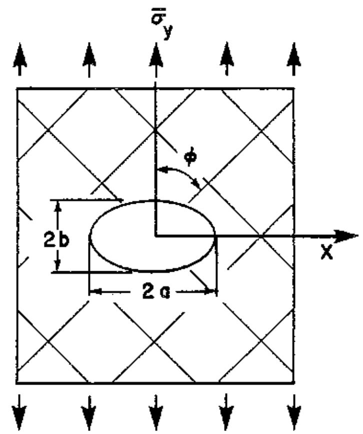
Finite Fracture Mechanics

"Both energy and stress criteria are necessary conditions for fracture but neither one nor the other are sufficient".

"The incremental form of the energy criterion $\left(-\frac{\Delta\Pi}{\Delta A} \geq \mathcal{G}_c\right)$ is the foundation of FFMs".

(Leguillon, European J. of Mechanics A, 21, 61-72, 2002).

$$\begin{cases} \frac{1}{l}\int_a^{a+l} \sigma_{yy}(x)dx = X_T^L \\ \int_a^{a+l} \mathcal{K}_I^2(a)da = \int_0^l \mathcal{K}_C^2(\Delta a)d(\Delta a) \end{cases}$$



$$\gamma = x/a$$

$$\lambda = b/a$$

$$\sigma_{yy}(x,0) = \sigma^{\infty}\mathcal{S}\left(\lambda,\gamma,K_T^{\infty}\right)\frac{K_T}{K_T^{\infty}}$$

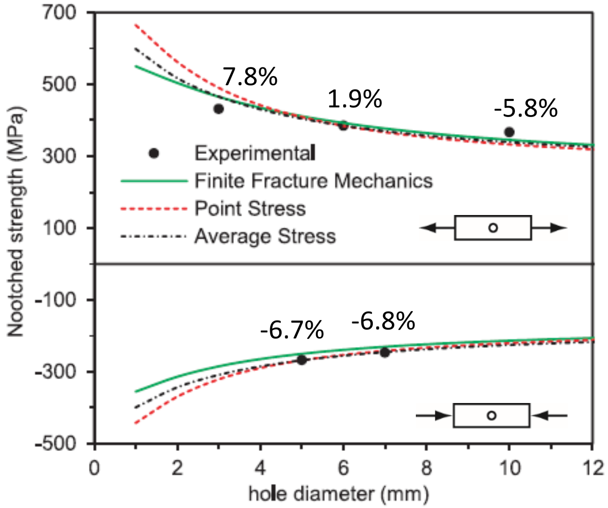
Complex Variable Theory (Lekhnitskii)

Finite width correction factor

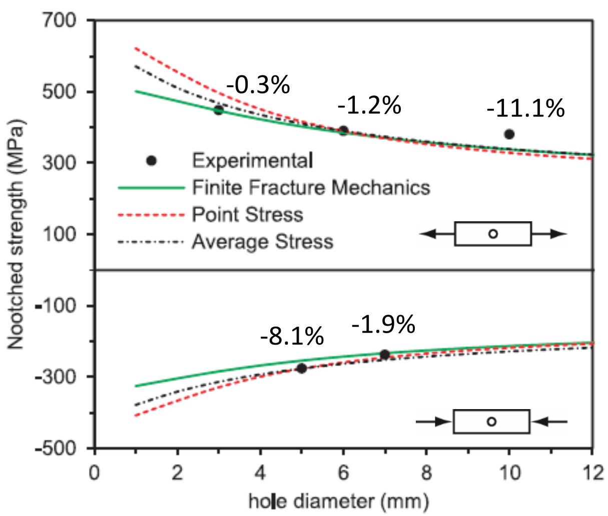
$$\mathcal{K}_I = \frac{1}{\sqrt{1-\left(\frac{2a}{w}\right)^2}}\sigma^{\infty}\sqrt{\pi a} \quad , \lambda \to 0$$

$$\mathcal{K}_I = \sigma^{\infty}F_hF_w\sqrt{\pi a} \quad , \lambda = 1$$

C-Ply T700/AR-2527 (75 gsm)

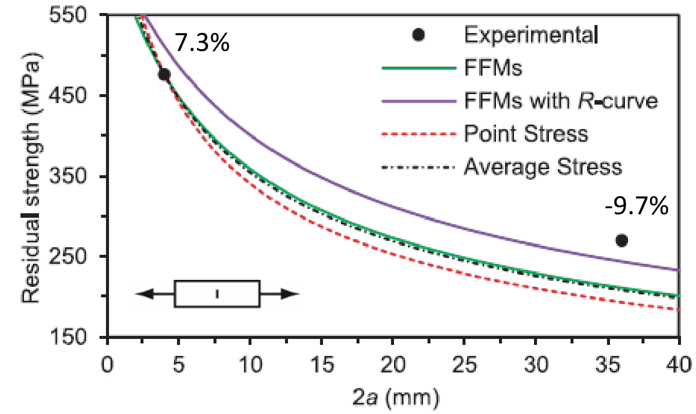


(a) $[(0/-45)/(90/45)]_{6T}$ lay-up.



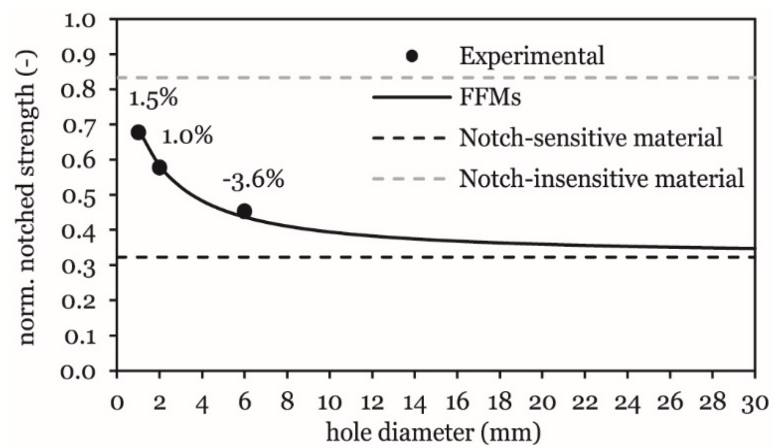
(b) $[(0/-45)/(45/0)/(90/45)/(-45/90)]_S$ lay-up.

C-Ply T700/AR-2527 (75 gsm)

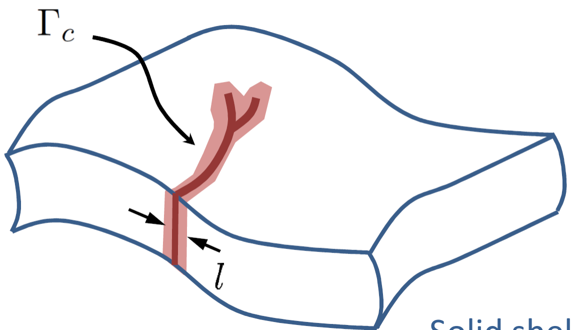


M40JB/ThinPreg™ 80EP/CF (30 gsm)

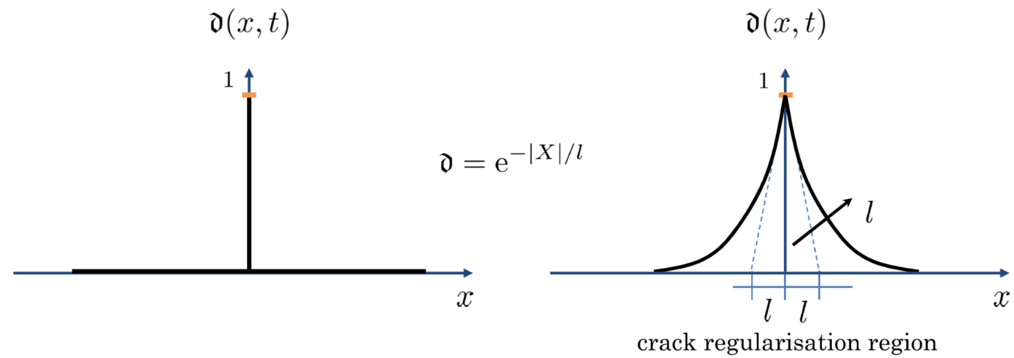
$[45/90/-45/0]_{nS}$



Phase Field models



Solid shell discretisation



$$\int_{\Gamma_c} \mathcal{G}_c \, d\Gamma \approx \int_{\mathcal{B}_0} \mathcal{G}_c \gamma(\mathfrak{d}, \nabla_{\mathbf{X}} \mathfrak{d}) \, d\Omega$$

Positive-negative decomposition of the free energy:

$$\psi(\boldsymbol{\varepsilon}, \mathfrak{d}) = \mathfrak{g}(\mathfrak{d}) \psi_+^e(\boldsymbol{\varepsilon}) + \psi_-^e(\boldsymbol{\varepsilon})$$

with:

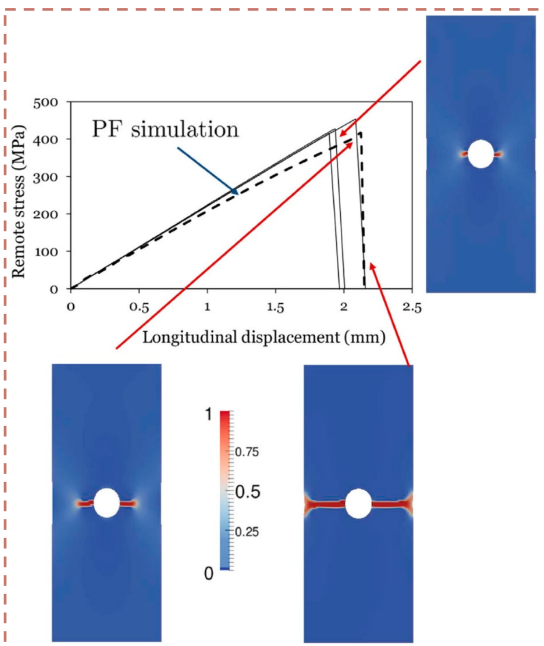
$$\psi_+^e(\boldsymbol{\varepsilon}) = \frac{\lambda}{2}\left(\langle \mathrm{tr}[\boldsymbol{\varepsilon}] \rangle_+\right)^2 + \mu \mathrm{tr}[\boldsymbol{\varepsilon}_+^2]$$

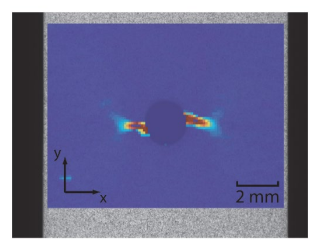
$$\psi_-^e(\boldsymbol{\varepsilon}) = \frac{\lambda}{2}\left(\langle \mathrm{tr}[\boldsymbol{\varepsilon}] \rangle_-\right)^2 + \mu \mathrm{tr}[\boldsymbol{\varepsilon}_-^2]$$

Degradation function:

$$\mathfrak{g}(\mathfrak{d}) = [1 - \mathfrak{d}]^2 + \mathcal{K}$$

$$\mathcal{K} \approx 0$$



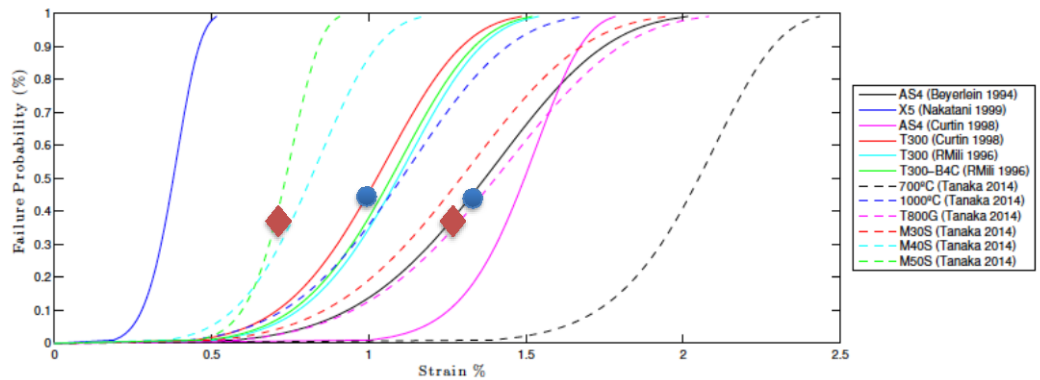


(J Reinoso, PP Camanho, et al, Compos Science & Technology, 150:205-216, 2017)

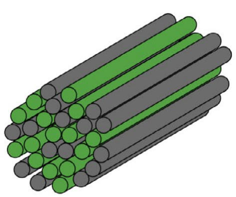
Fibre-hybrid composites

The main objective is to is to prevent catastrophic failure of composite materials by increasing their ductility.

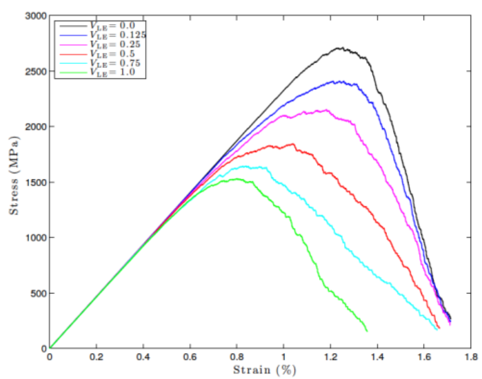
Cumulative distribution function for different fibres



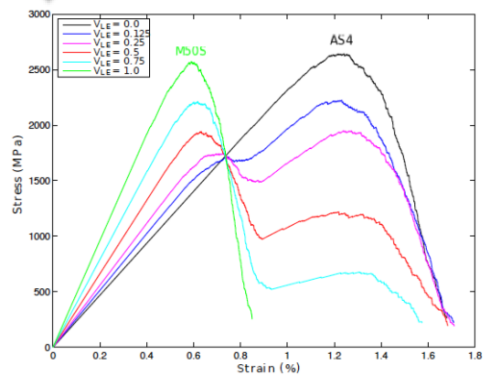
Dry tows



AS4/T300



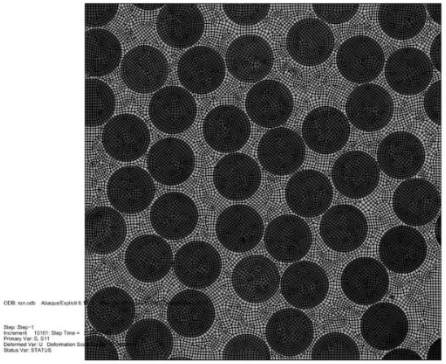
AS4/M50S

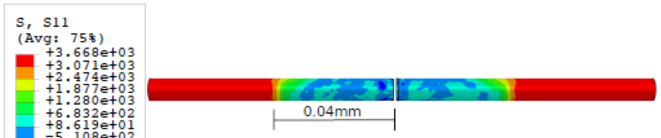


What are the main parameters of the microstructure of hybrid composites that influence strength and toughness?

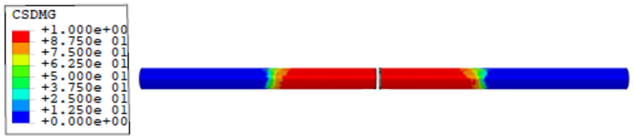
Computational micromechanical model

Longitudinal tensile failure of composite material

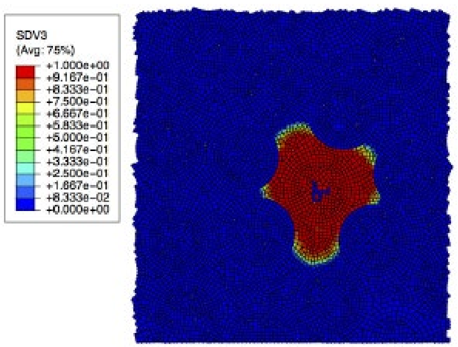




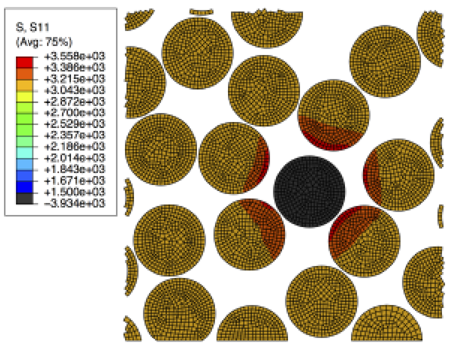
(c) Stress profile after fibre failure



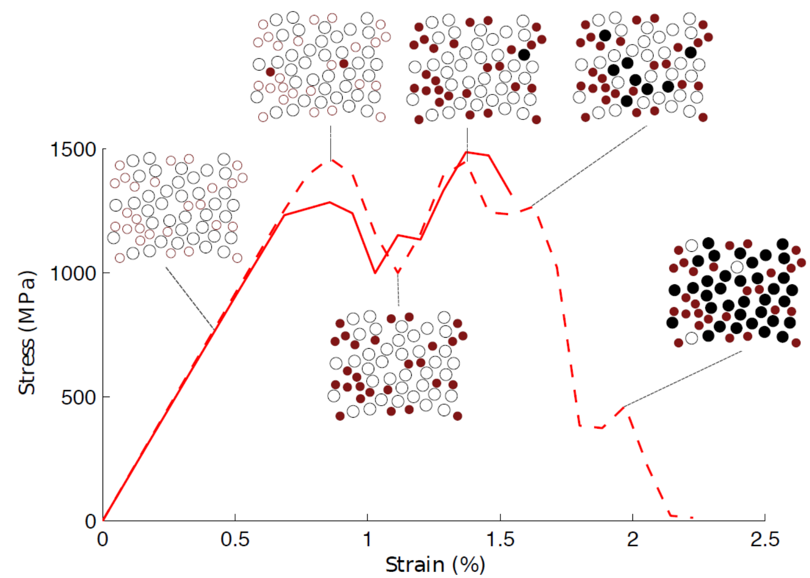
(d) Interfacial damage after fibre failure



(e) Matrix crack around a broken fibre



(f) Stress concentration in intact fibres

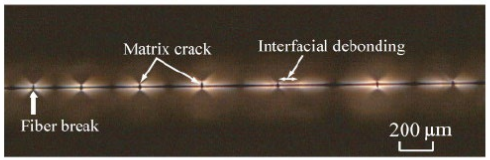


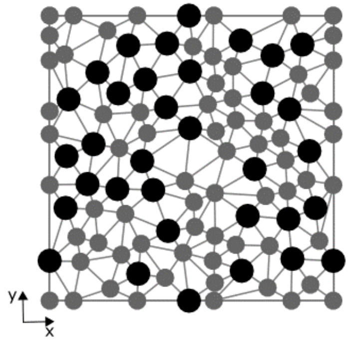
50 Fibres, 3 million elements, 6 days (cluster)

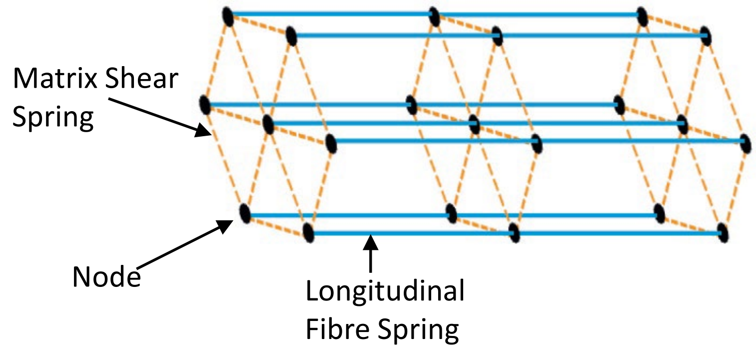
(RP Tavares, PP Camanho, MA Bessa, WK Liu, et al, Computational Mechanics, Vol. 57, 405-421, 2016).

Spring element model

- Simplified 1D micromechanical model.
- The main mechanisms of longitudinal failure are represented.



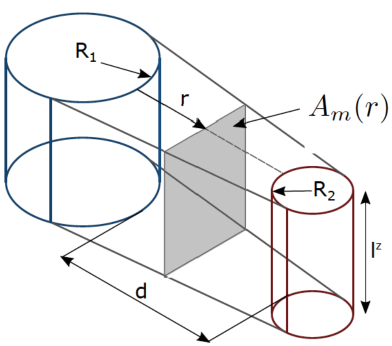




$$f_m(r) = G A_m(r) \frac{du}{dr}$$

$$\frac{d}{dr}\left(G A_m(r) \frac{du}{dr}\right) = 0$$

$$A_m^{(1)} = \frac{2\pi R_1}{n_1} l^z$$



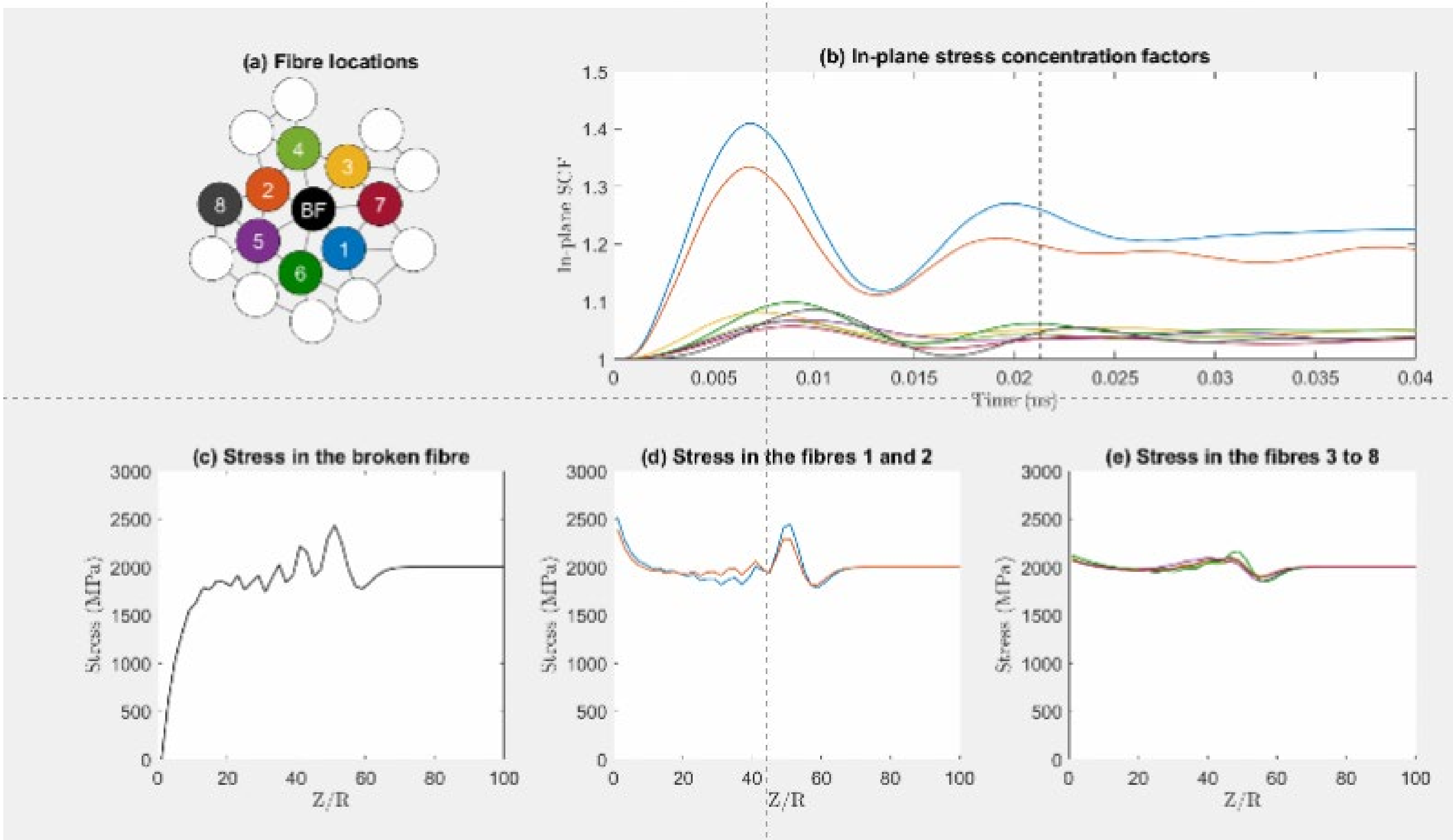
$$A_m(r) = A_m^{(1)} + \frac{\left(A_m^{(2)} - A_m^{(1)}\right)}{d} r$$

$$A_m^{(2)} = \frac{2\pi R_2}{n_2} l^z$$

$$\mathbf{K}_m = \frac{G\left(A_m^{(2)} - A_m^{(1)}\right)}{d \ln\left(A_m^{(2)}/A_m^{(1)}\right)} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$

$$\mathbf{K} = \sum_{e=1}^{N_f - N_f^b} \mathbf{K}_f^e + \sum_{e=1}^{N_m - N_m^b} \mathbf{K}_m^e.$$

Spring element model



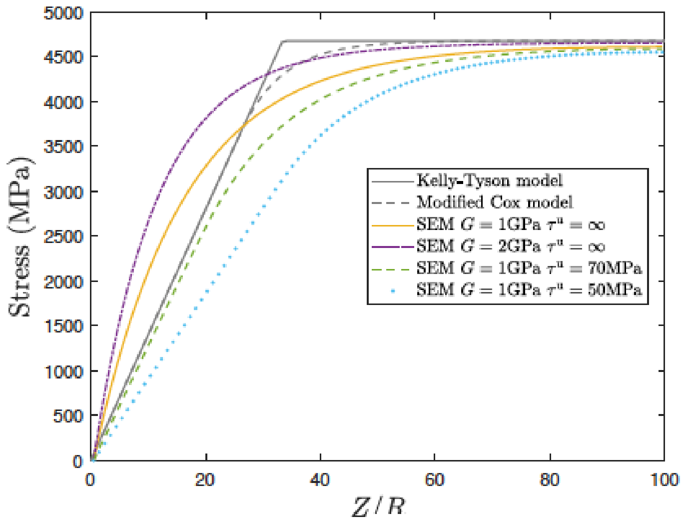
(RP Tavares, PP Camanho, et al., Int. Journal of Fracture, 208, 269-285, 2017).

Simulations

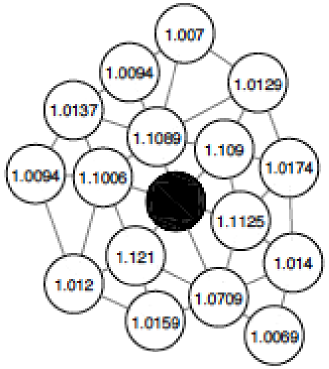
Local fields around a broken fibre

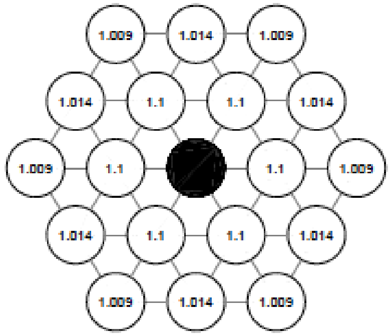
AS4 fibres characterized by Curtin and Takeda.

Recovery region



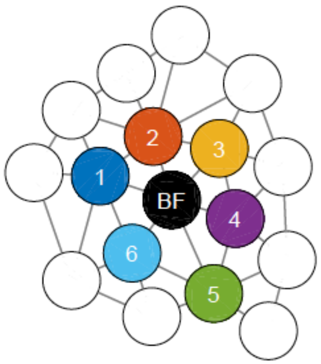
Stress concentration on intact fibres surrounding a fibre break

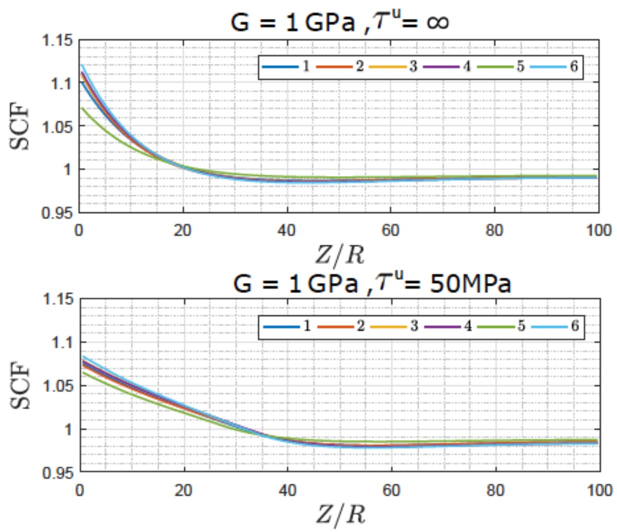


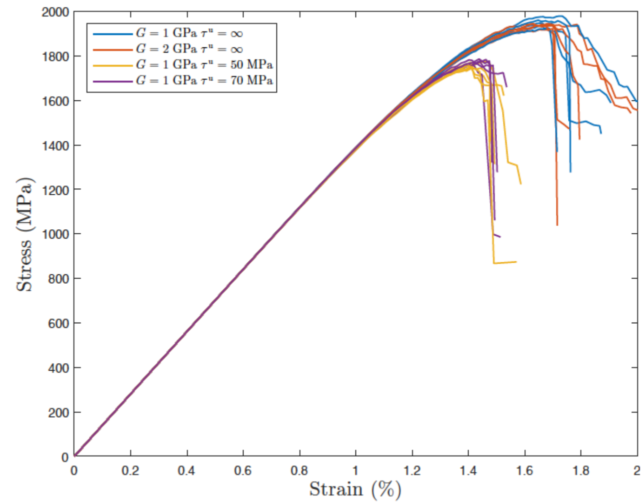


(RP Tavares, PP Camanho, et al., Int. Journal of Fracture, 208, 269-285, 2017).

Stress concentration along the axis of the intact fibres surrounding a fibre break



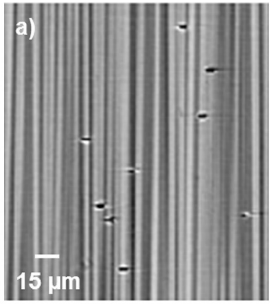




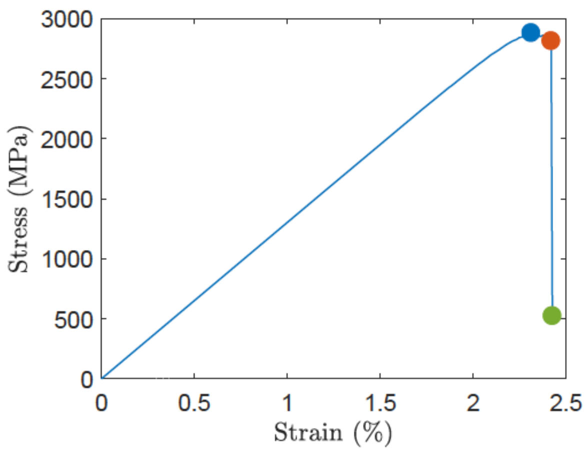
Cluster formation

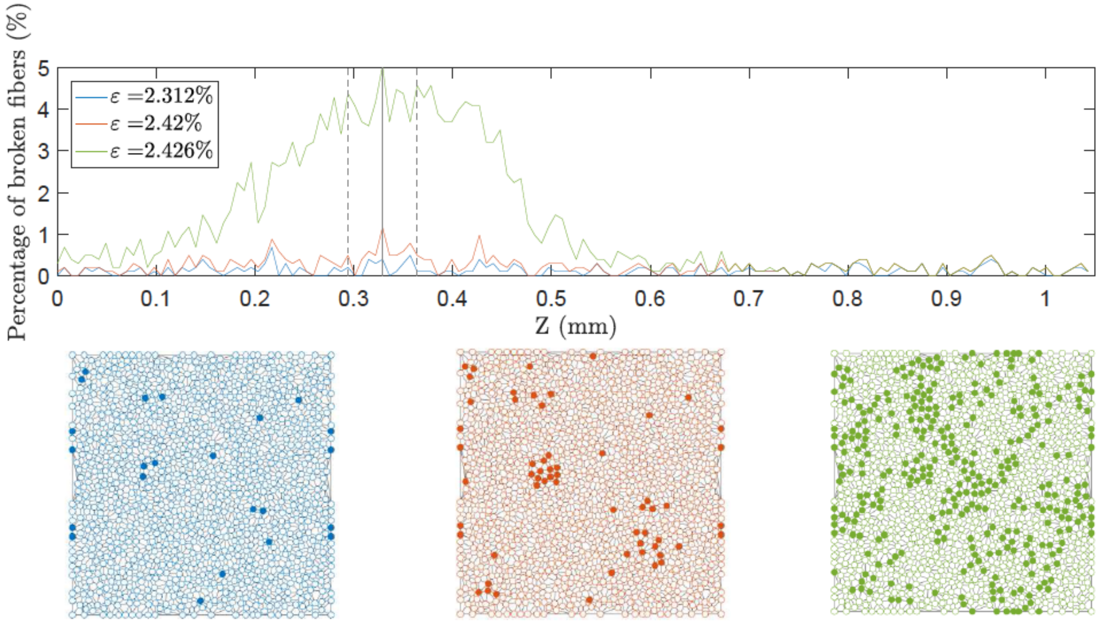
Cluster: “distance between the centre of 2 fibres is lower than 4 times the fibre radius, and the axial distance between break planes less than 10 times the fiber radius.”

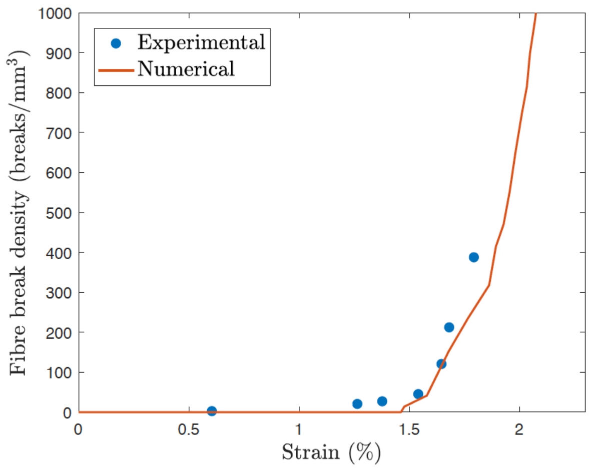
(Swolfs et al, Composites-A, 2015).



T700 carbon fibres

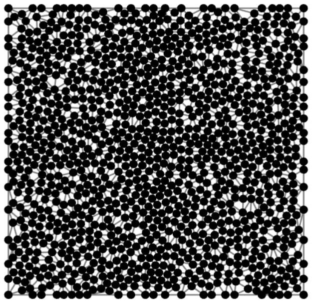




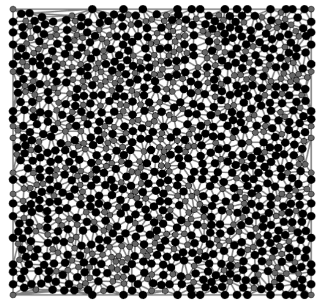


Predicted mean value of the critical cluster size: 12.6 fibres
T700 (Scott 2011): 14 fibres.

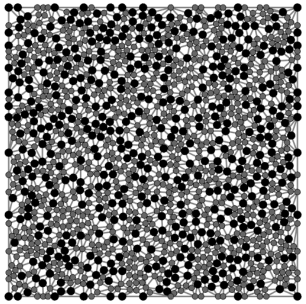
(RP Tavares, PP Camanho, et al., Int. Journal of Fracture, 208, 269-285, 2017).



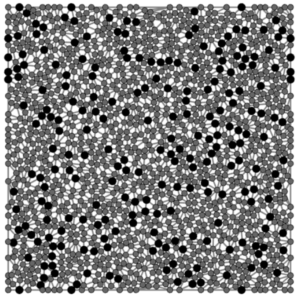
AS4 100%



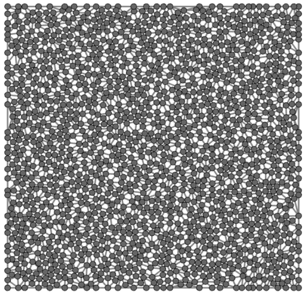
AS4 80% M50 20%



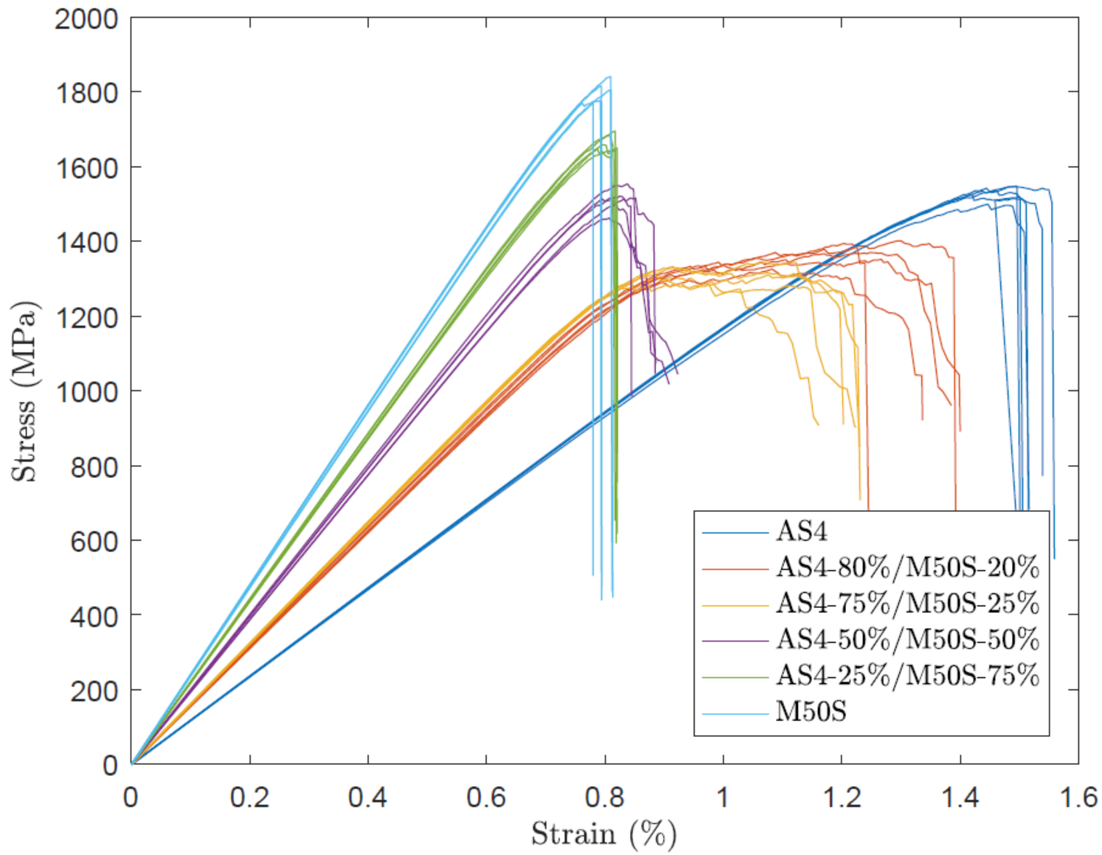
AS4 50% M50 50%



AS4 25% M50 75%

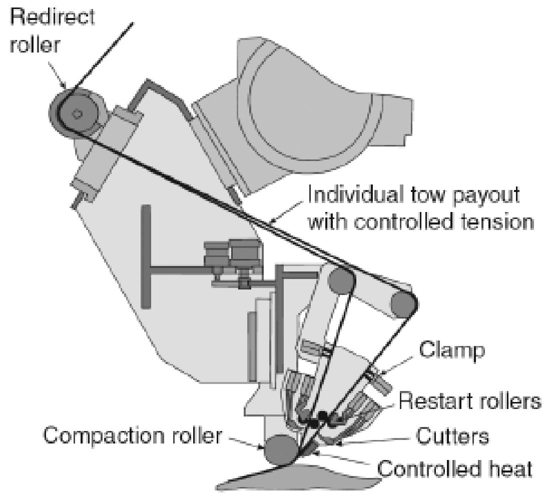


M50 100%



	AS4	AS4-80%/ M50S-20%	AS4-50%/ M50S-50%	AS4-25%/ M50S-75%	M50S
X_T(Mpa)	1774	1344	1504	1678	1811
ε_f (%)	1.42	1.226	0.826	0.806	0.796
Max. Cluster size	16	36	7.8	8	8.4

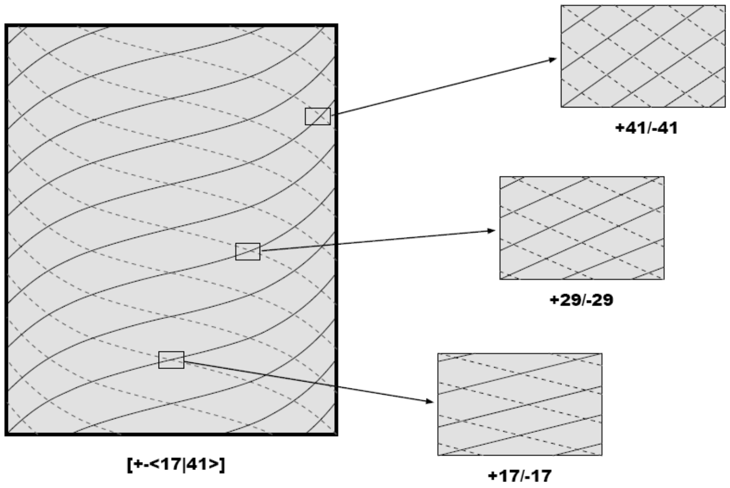
How can we increase the buckling load of composite structures?



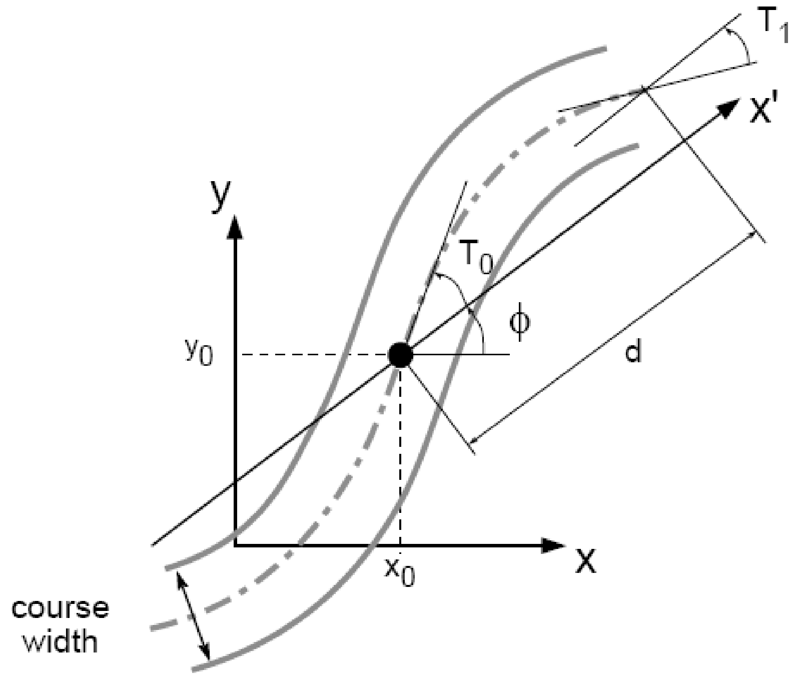
Nose section of Boeing 787

Laminates with steered fibres

Variable-Stiffness Panels (VSP).



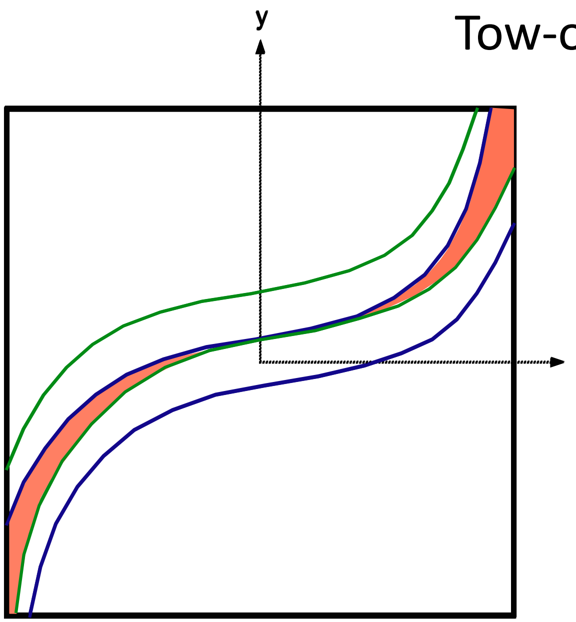
Linear fibre orientation variation: $\theta(x') = \phi + (T_1 + T_0)\frac{|x'|}{d} - T_0$



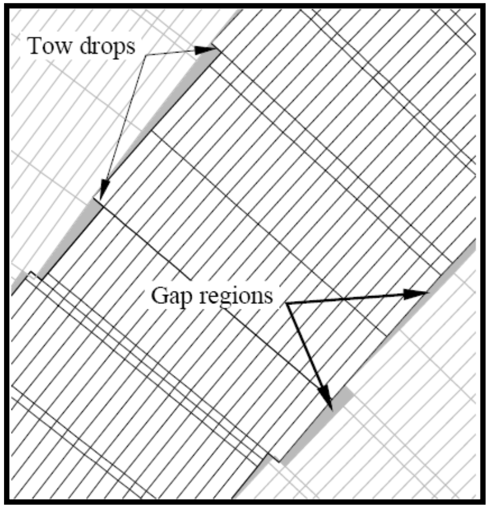
Notation: [ϕ <T_0|T_1>]

Examples: [± <30|60>], [90± <15|45>], [±45/± <17|54>]$_s$.

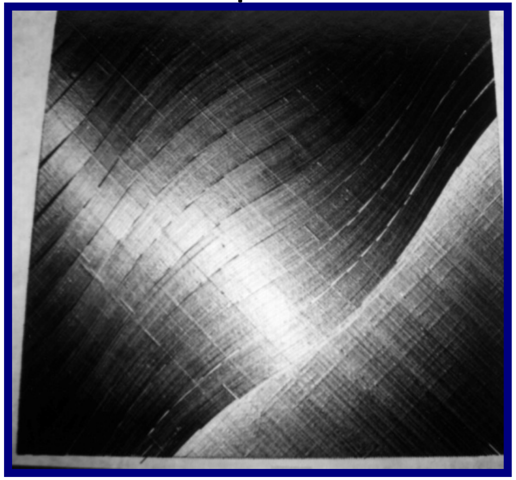
Tow-overlapping and tow-dropping



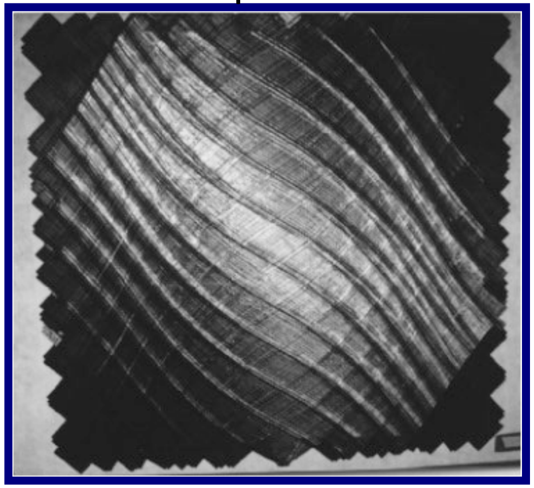
thickness build-up or constant thickness with two-drops



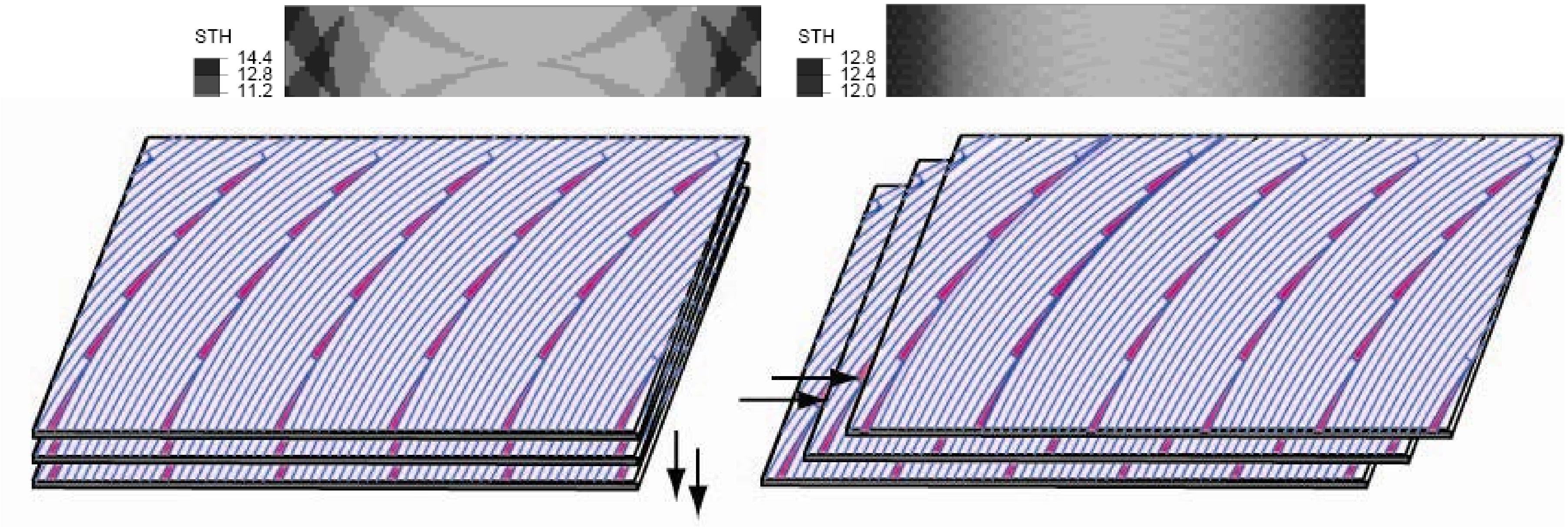
Tow-Drop Method



Overlap Method



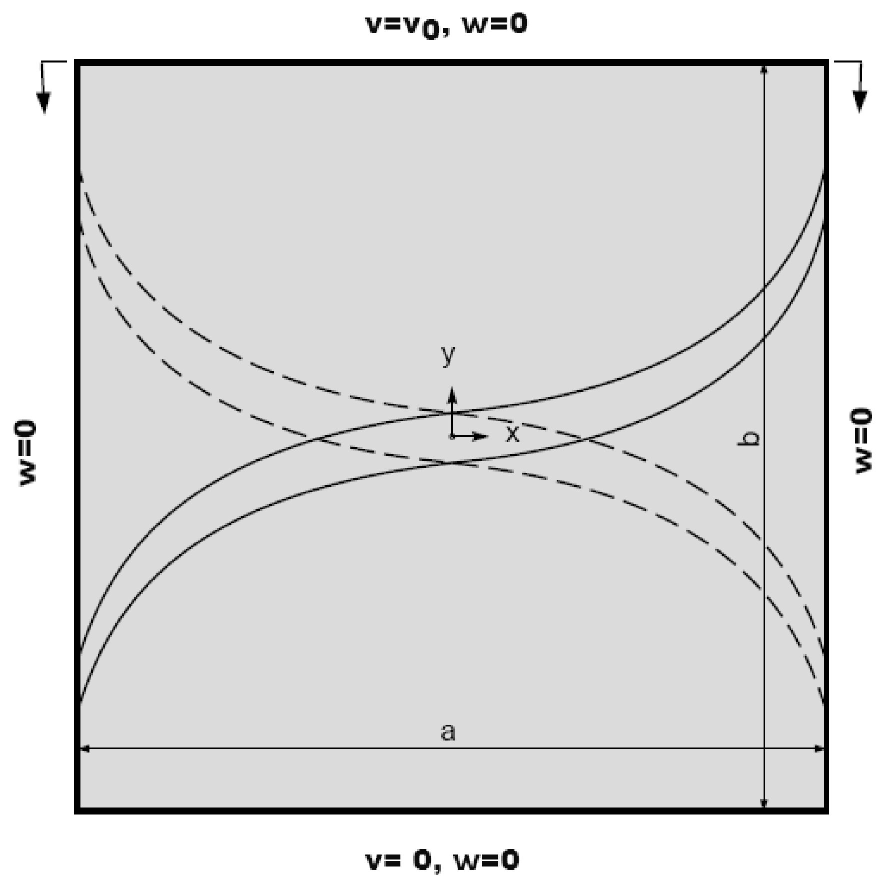
Ply staggering: shifting of plies with the same orientation with respect to each other



Staggering smoothes the thickness build-up and may avoid the need for tow-drops

Variable stiffness panels

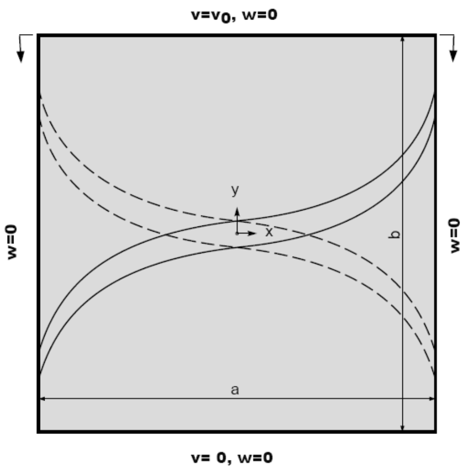
Problem statement



Family of configurations : [± <T_0|T_1>]$_{6s}$

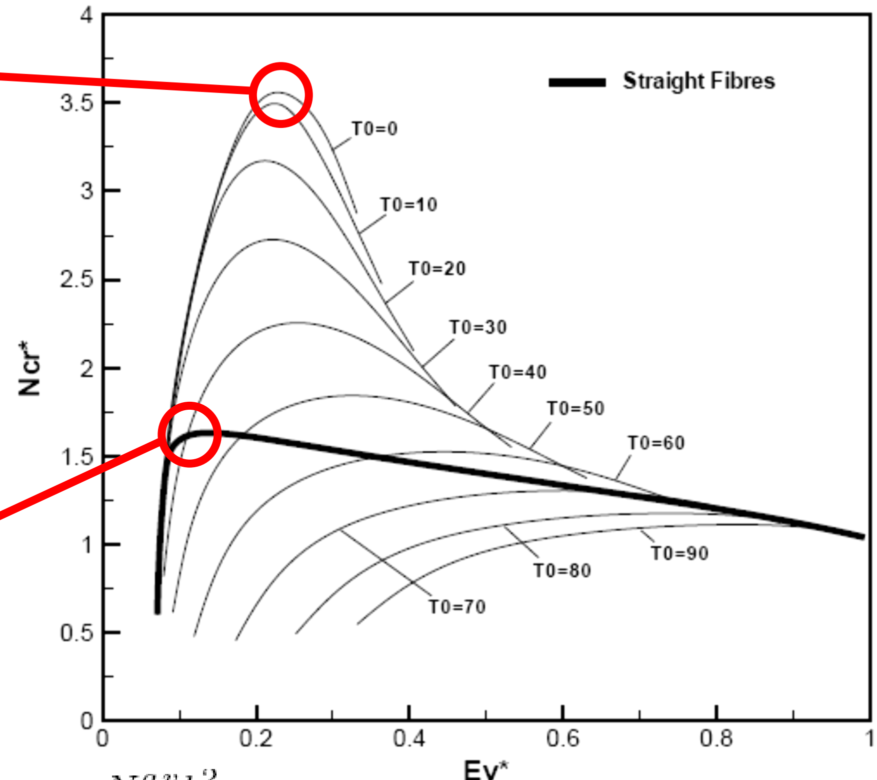
AS4/8773 CFRP, t_{ply}=0.2mm, $t_{laminate}$=4.8mm

Buckling characteristics



$[\pm \langle 0|75\rangle]_{6s}$

$[\pm 45]_{6s}$



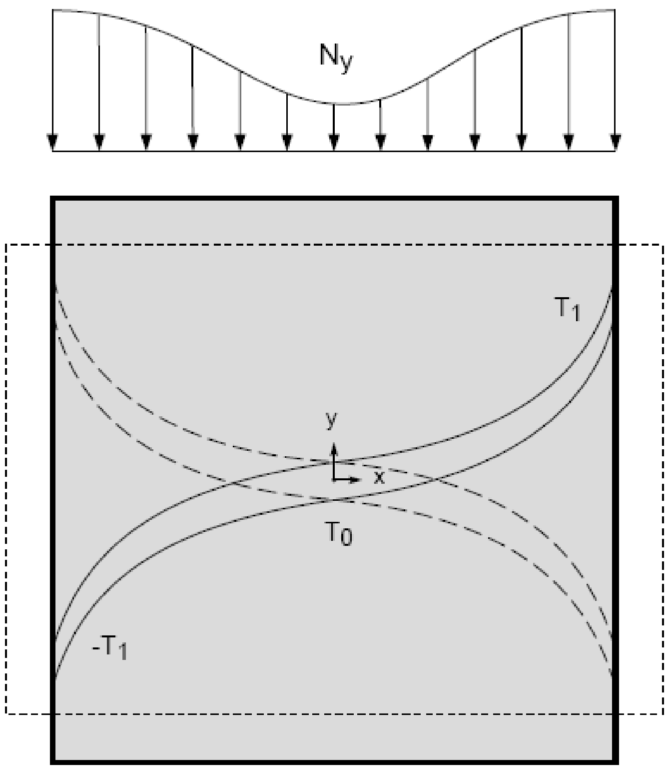
$$N_{cr}^{av} = \frac{1}{a}\int_{-a/2}^{a/2} N_{y,cr}(x, b/2)\,dx \qquad N_{cr}^{*} = \frac{N_{cr}^{av} b^2}{E_1 h_l^3}$$

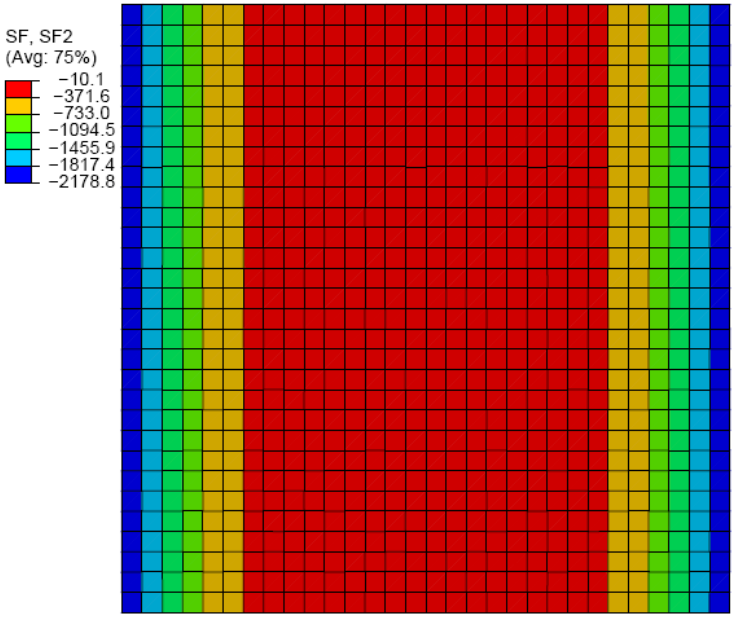
$$E_y^{eq} = \frac{b\int_{-a/2}^{a/2} N_y(x, b/2)\,dx}{h_l a v_0} \qquad E_y^{*} = \frac{E_y^{eq}}{E_1}$$

(Lopes, Camanho, et al., Composites – Part A, Vol. 41, 1760-1767, 2010).

Buckling characteristics

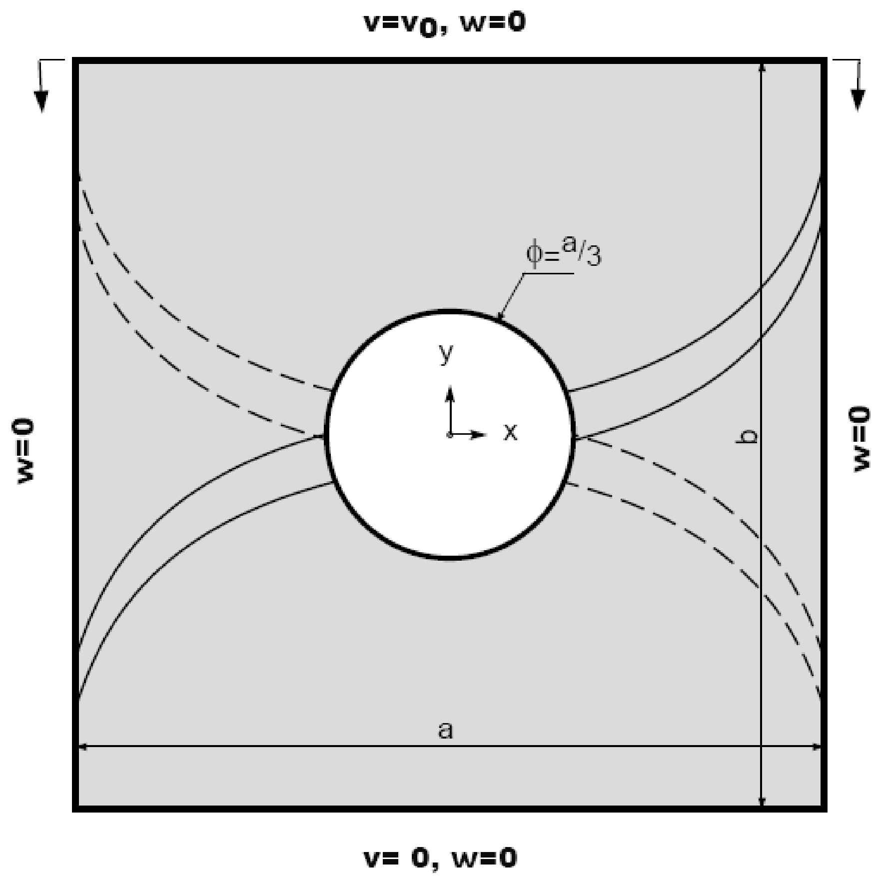
$[\pm <0|75>]_{6s}$





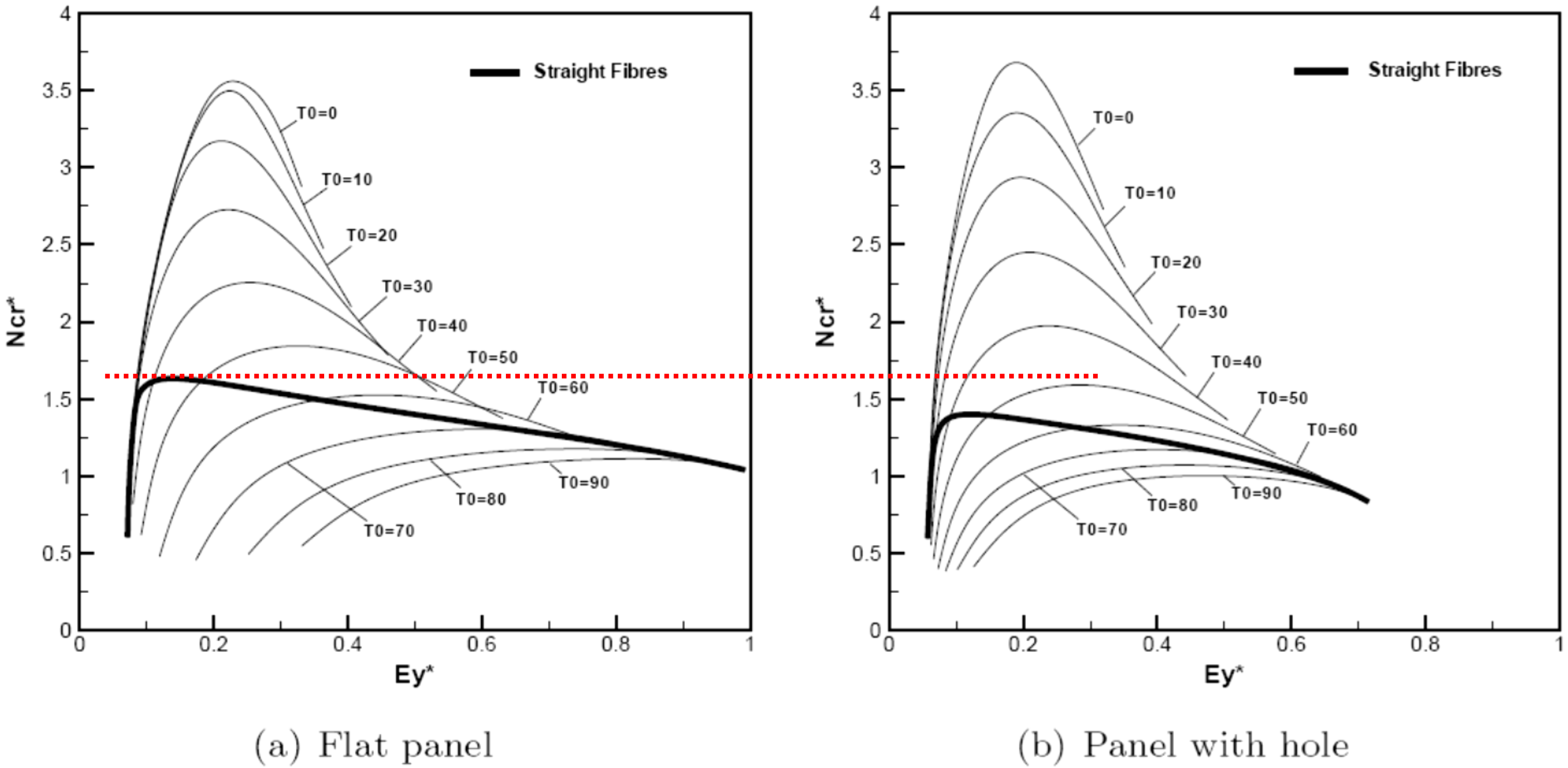
The load is transferred to the supported edges

Effect of a central hole



(Lopes, Camanho, et al., Composites – Part A, Vol. 41, 1760-1767, 2010).

Effect of a central hole

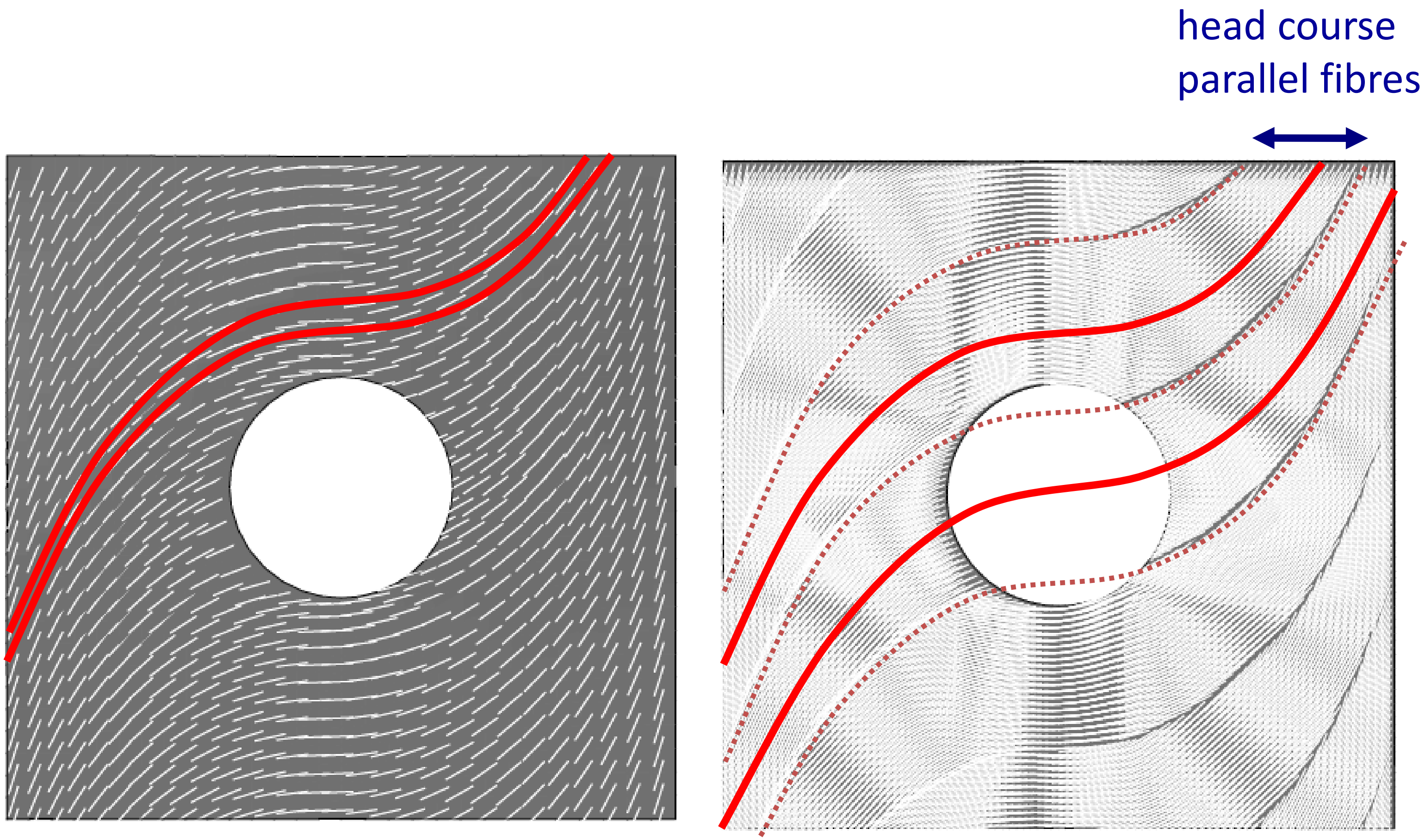


(a) Flat panel

(b) Panel with hole

(Lopes, Camanho, et al., Composites – Part A, Vol. 41, 1760-1767, 2010).

Performance of manufacturable VSP's



(a) Ideal ply (b) Manufacturable ply

(Lopes, Camanho, et al., Composites – Part A, Vol. 41, 1760-1767, 2010).

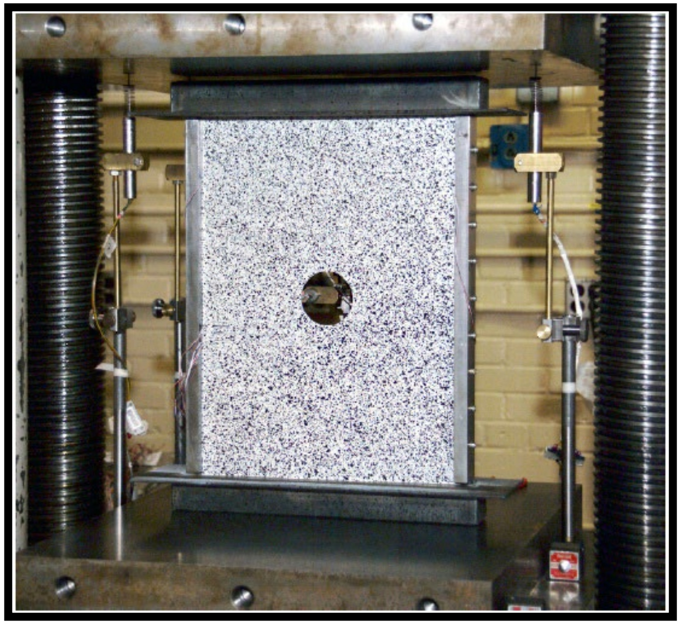
Buckling and first ply failure of "manufacturable" VSP

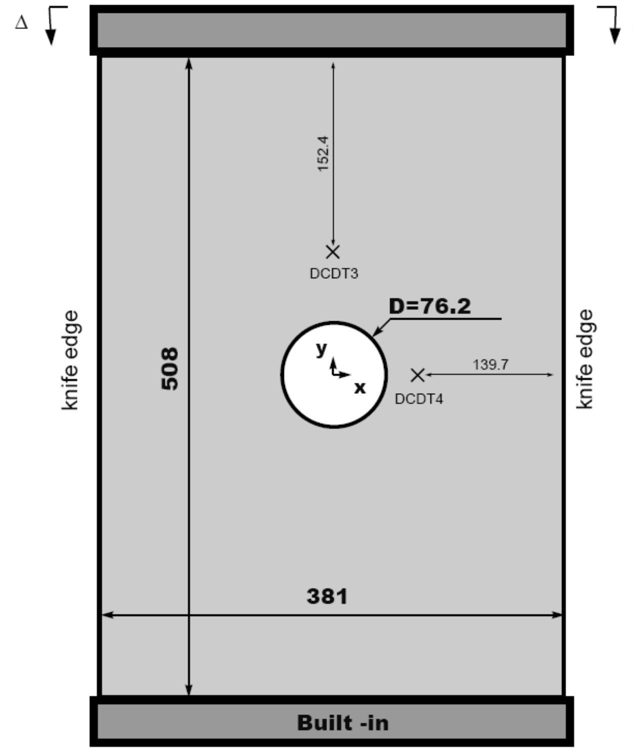
Design	N_{cr}^{av} [N/mm]	N_{fpf}^{av} [N/mm]	*vs.* $[\pm 80]_{6s}$ [%]	*vs.* $[\pm 45]_{6s}$ [%]
Straight fibres ($[\pm 45]_{6s}$)	232.7	244.7	-47.2	-
Straight fibres ($[\pm 80]_{6s}$)	148.8	464.1	-	89.7
Ideal VSP	555.8	559.6	20.0	120.5
Manufacturable VSP	548.6	469.5	1.2	91.9
Manufacturable VSP (staggered plies)	543.9	523.4	12.8	113.9

little influence on buckling

higher influence on first-ply failure

Test cases





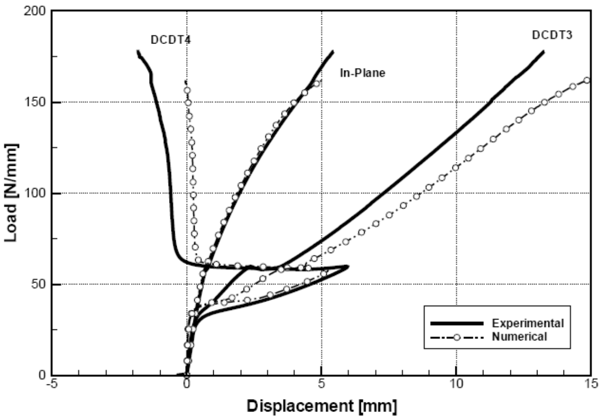
Configurations:

Straight-fibres - $[\pm 45_2/\pm 30/\pm 45/\pm 15]_s$

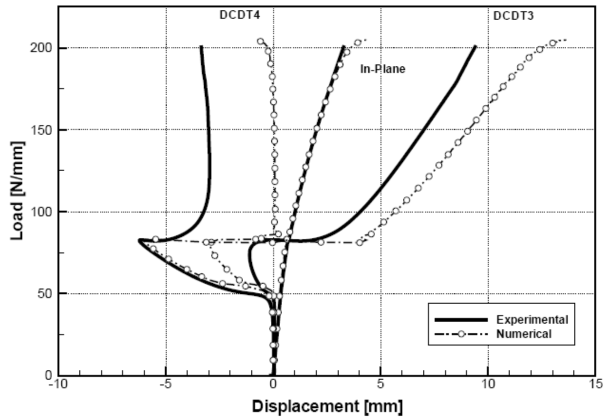
Steered-fibres - $[\pm 45/\pm < 45|60 >_2 /\pm < 30|15 > /\pm < 45|60 >]_s$

1 - Tow-drop method (staggered plies) 2 - Tow-overlap method

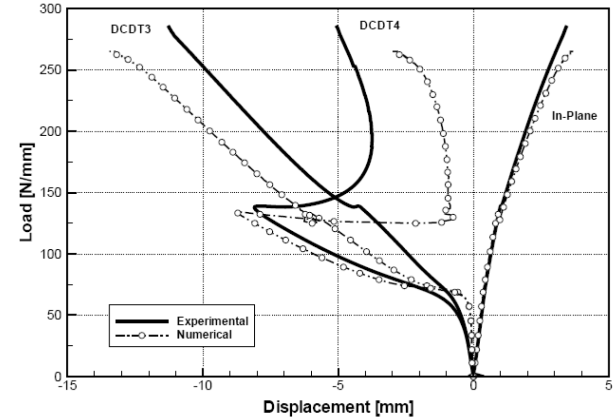
Test cases



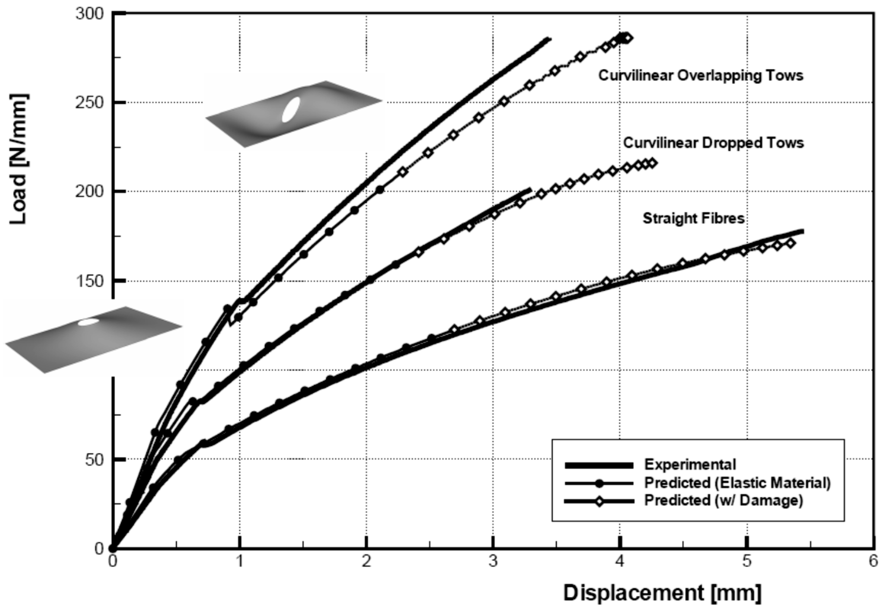
(a) Straight fibres

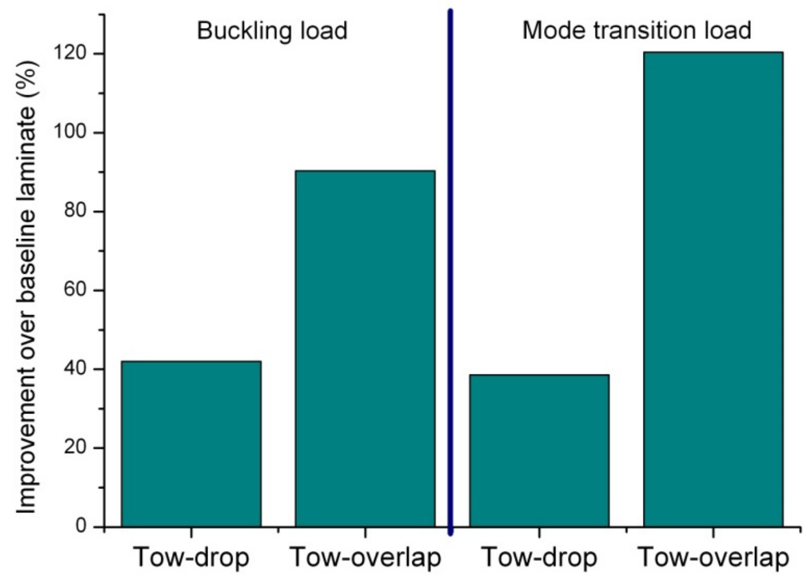


(b) Curvilinear dropped tows



(c) Curvilinear overlapping tows





(Lopes, Camanho, et al., Int. J. of Solids and Structures, Vol. 44, 8493-8516, 2007).

Conclusions

- ✓ Thin-ply laminates result in improved fibre dispersion and reduced crimp angles. In addition, continuous lay-up without mid-plane symmetry is possible.

- ✓ Thin-ply laminates increase delamination onset loads and the in-situ transverse tensile, compressive and shear strengths. The tensile strength of unnotched specimens increases when thinner plies are used. Finite Fracture Mechanics and phase-field methods are well-suited to predict the strength of thin-ply laminates.

- ✓ Selective hybridization, with inner 0° plies of intermediate thickness and thin off-axis plies, results in improved open hole strengths. In addition, the unnotched and fatigue strengths are equivalent to those of the thin ply laminate.

- ✓ Judicious fibre hybridization increases the strain to failure of a baseline CFRP.

- ✓ The computational micromechanical models proposed are able to capture the mechanics of longitudinal tensile failure of hybrid composites.

Conclusions

- ✓ Variable-stiffness panels are currently straightforward to manufacture. Their capacity for load redistribution allows for marked improvements on the buckling and failure performances of composite laminates.
- ✓ It is possible to design variable-stiffness panels that are notch insensitive in terms of buckling failure.
- ✓ Manufacturability issues, such as tow-dropping, impose restrictions to the performance of variable-stiffness panels. These can be mitigated by ply staggering.
- ✓ The critical bucking load of optimized 'traditional' laminates can be increased by ~90% using variable-stiffness panels (for roughly the same mass).

Acknowledgements

AIRBUS AN EADS COMPANY
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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Sesión de Sostenibilidad

CFRC based on sustainable epoxy thermosets with potential applications in the aerospace and space sector

Prof. Alice Mija
University Côte d'Azur, Institute of Chemistry of Nice. European Space Agency, ESTEC, Thales Alenia Space

CFRC based on sustainable epoxy thermosets with potential applications in the aerospace and space sectors

Prof. Alice Mija[a*]

Dr. Roxana Dinu[a], Dr. Ugo Lafont[b], Dr. Olivier Damiano[c]

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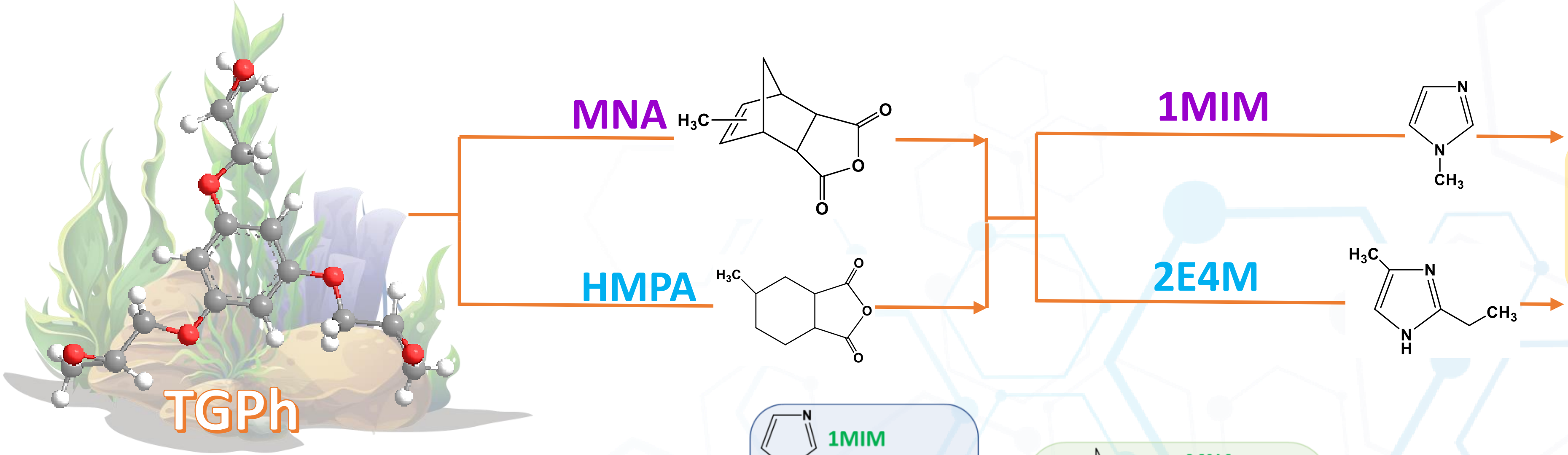
COMPOSIFORUM 2022 - The International Industrial Forum on Composite Materials

2022

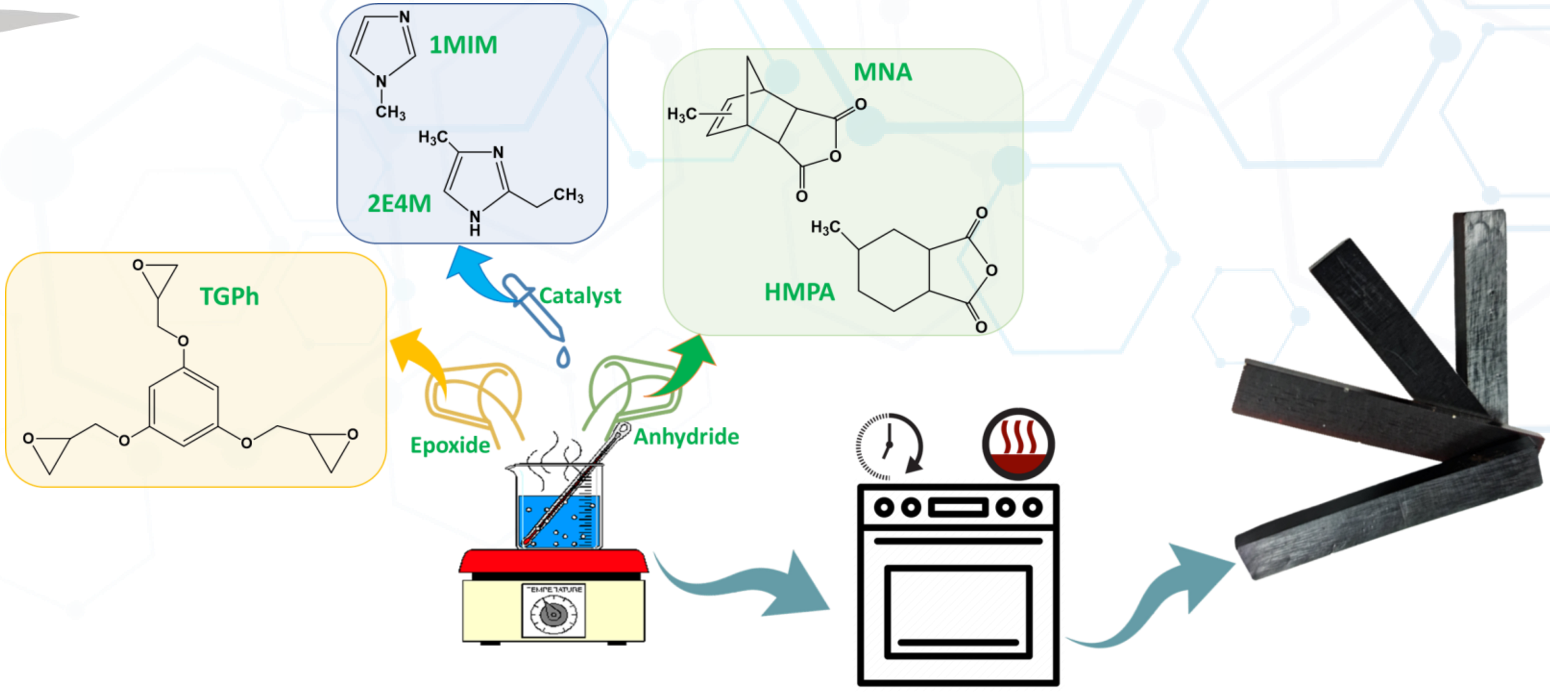
17 November 2022
ZARAGOZA, SPAIN

A/ Design of sustainable & biobased epoxy thermosets with high BOC content & performances

Design of Sustainable Epoxy Thermosets

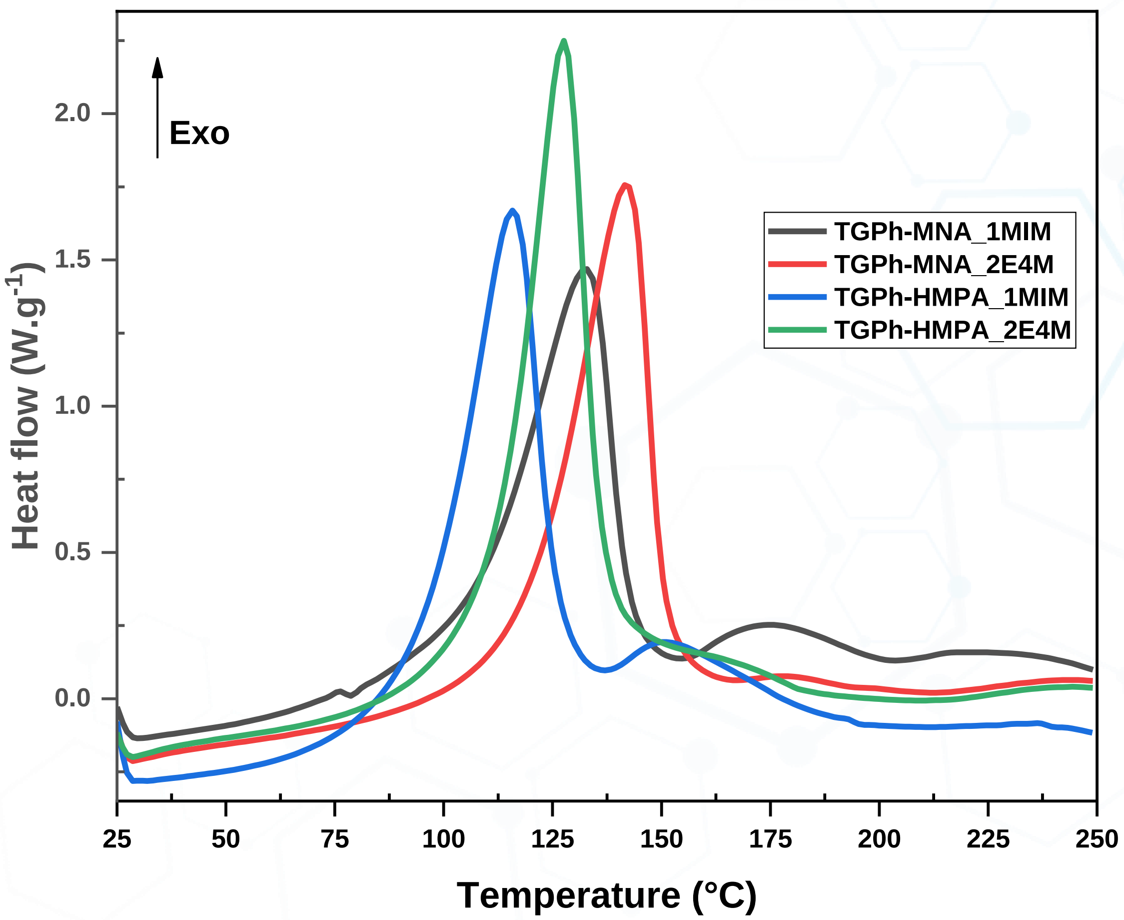


Elaboration of various formulations



Dinu, R.; Lafont, U.; Damiano, O.; Mija, A.; High Glass Transition Materials from Sustainable Epoxy Resins with Potential Applications in the Aerospace and Space Sectors, *ACS Applied Polymer Materials*, **2022**, 4, 5, 3636–3646

Reactivity study of thermoset resins by DSC

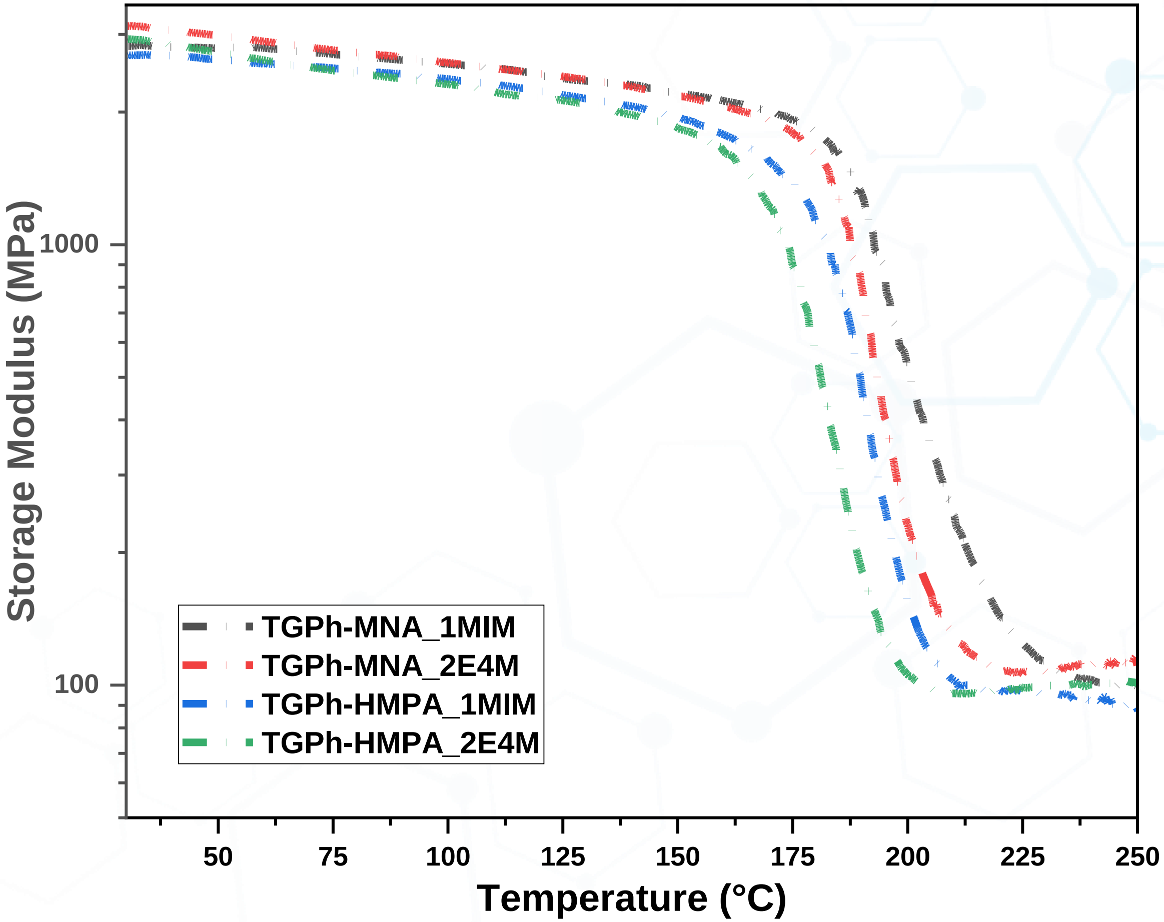


Formulations	T_{onset} - T_{end} (°C)	T_{peak} (°C)	ΔH (J.g^{-1})
TGPh-MNA_1MIM	45–205	132; 173	257
TGPh-MNA_2E4M	58–212	141	258
TGPh-HMPA_1MIM	36–200	115; 151	315
TGPh-HMPA_2E4M	58–201	127	292

- ✓ crosslinking reactions start at : T_{onset}= 36-58 °C
- ✓ T_{max} >> suitable at industrial scale : T_{max}= 115-149 °C
- ✓ good reactivity: ΔH = 257-315 J.g^{-1}

Properties of synthesized thermosets – DMA

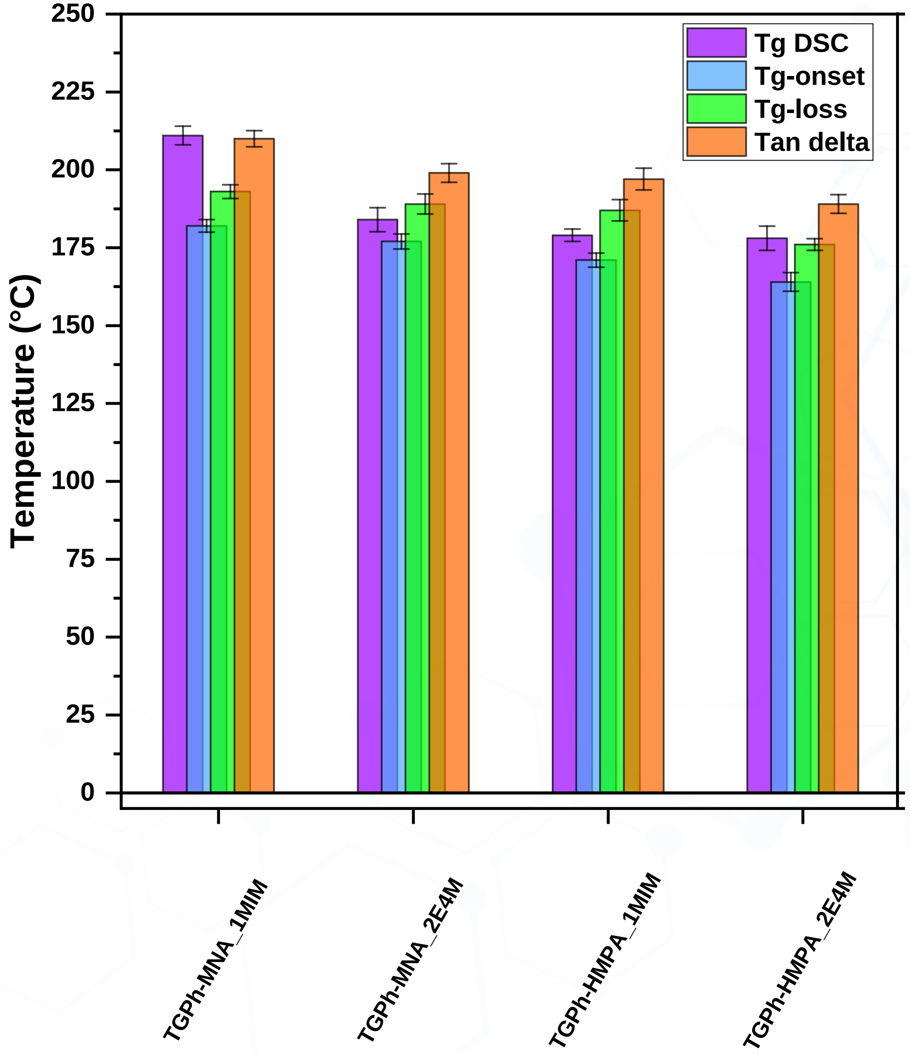
- 3 Points Bending, 3 °C/min heating rate, 1.0 Hz



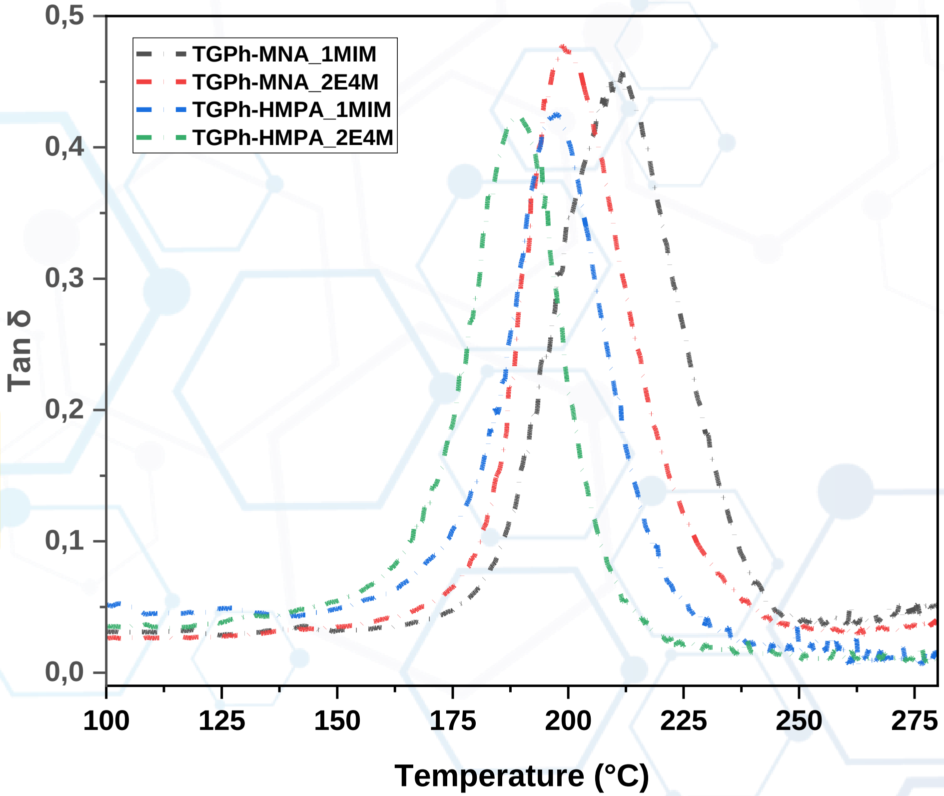
Thermosets	*E'* at 30 °C (GPa)	*υ* (mmol·cm^{-3})	M_c (g/mol)
TGPh-MNA_1MIM	2.8	7.3	165
TGPh-MNA_2E4M	3.1	8.0	144
TGPh-HMPA_1MIM	2.7	6.7	175
TGPh-HMPA_2E4M	2.9	7.6	152

✓ high storage moduli (*E'*) & crosslink densities (ν) ⇒ rigid materials

Properties of synthesized thermosets – Glass transition & tan δ



✓ $T_g \approx$ 190-210 °C



Commercial e.g.:

- Park Aerospace Nelco® N5000-30/32 BT : T_g = 205 °C
- Dow VORAFORCE™ TW 103/TW 158 : T_g = 175-185 °C
- Hexcel® HexPly® 108 : T_g = 190-210 °C

Properties of synthesized thermosets – Glass transition, tan δ & SD values

≤ 1,3 g/cm³ – in accordance with industrial criteria

Thermosets	Density (g/cm³)	Hardness Shore D tests	Glass transition (°C)	
			T_g (DSC)	tan δ (DMA)
TGPh-MNA_1MIM	1.20	89	211 ± 1	210
TGPh-MNA_2E4M	1.22	88	184 ± 1	199
TGPh-HMPA_1MIM	1.17	88	179 ± 1	197
TGPh-HMPA_2E4M	1.16	87	178 ± 1	189

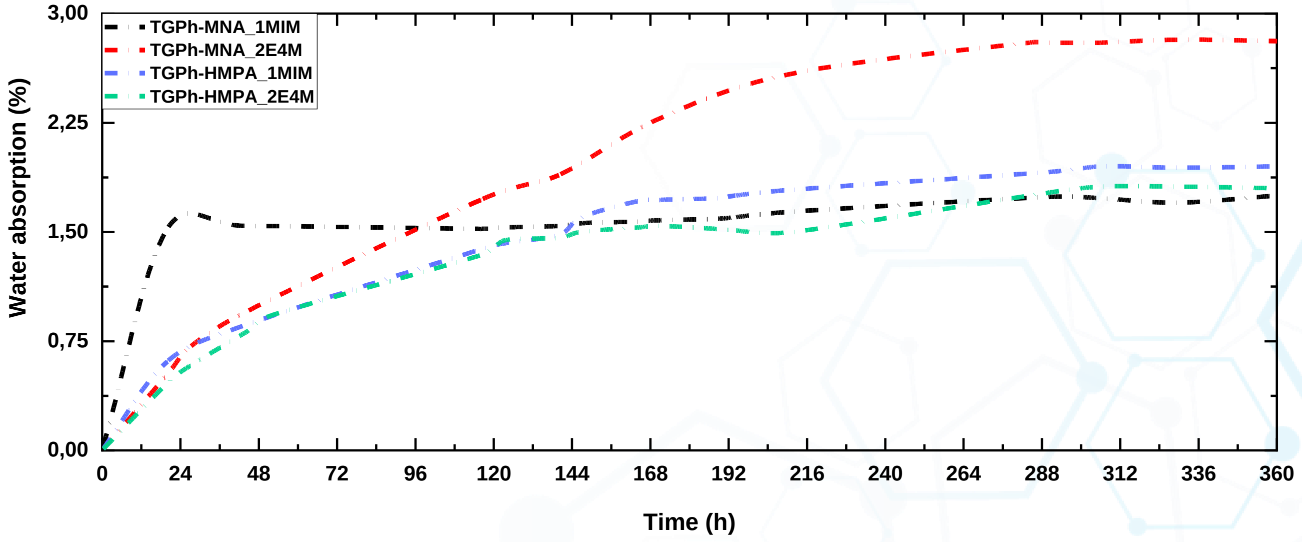
⇒ suitable for industrial hard material applications : construction, automotive and naval industry, materials for structural aerospace components

<< Extra hard material category >>

Commercial e.g.:

- Kohesi Bond KB 1427 HT-3 : 85SD
- Henkel Loctite® Stycast® EO 1058 : 90SD
- Master Bond EP45HTND-2 : 70SD

Properties of synthesized thermosets – Water Absorption & Gel Content



- ✓ Low hydrophilicity
- ✓ ↗↗ GC% = highly crosslinked systems

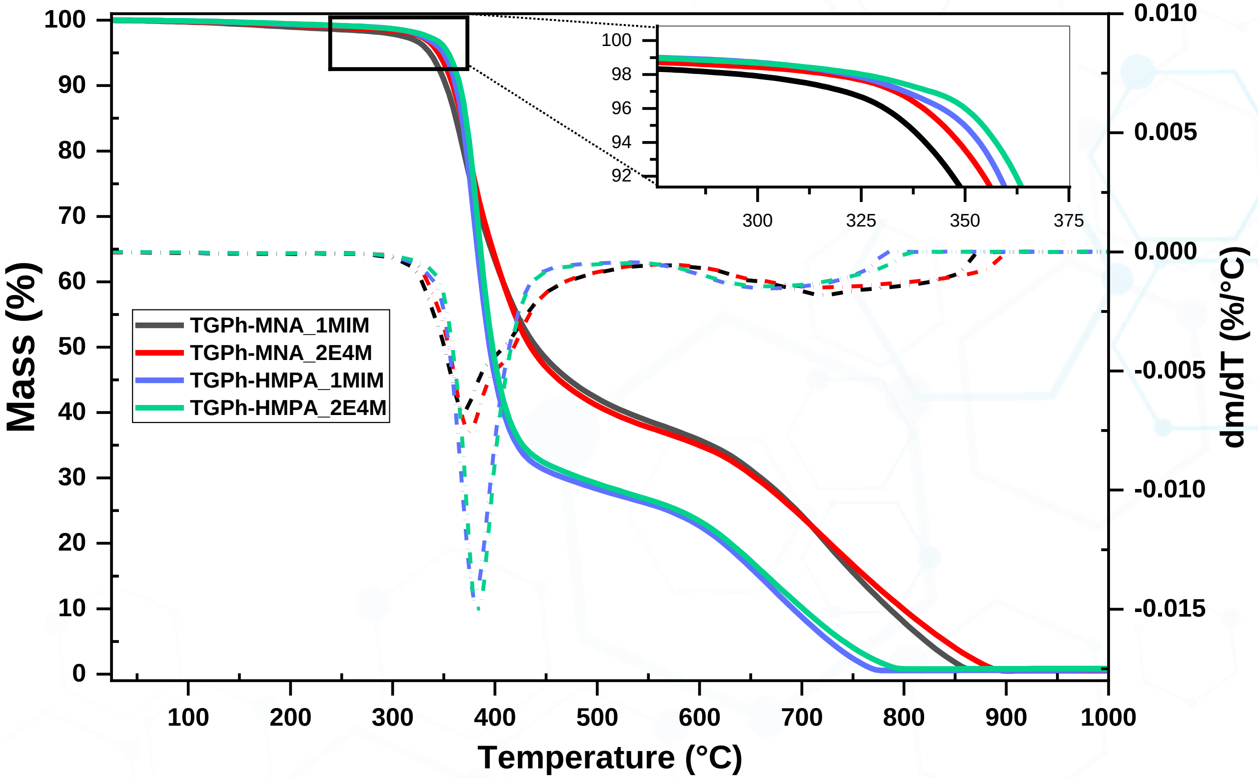
⇒ saturation stage after ~ 15 days >> WA ≈ 1.5 – 1.95 %

Samples	WA at 24h (%)	Gel Content (%)
TGPh-MNA_1MIM	1.5	99.88
TGPh-MNA_2E4M	0.52	99.72
TGPh-HMPA_1MIM	0.61	99.80
TGPh-HMPA_2E4M	0.46	99.62

Commercial e.g.:
- Cookson Group STAYCHIP® 3105: WA% = 1.5%
- Cookson Group STAYCHIP® 3100: WA% = 1.14%
- Henkel Loctite® ABLESTIK 2053S Epoxy: WA% = 1%
- Hexcel® F161 Epoxy Resin: WA% = 28%

Properties of synthesized thermosets – Thermal Stability

➢ **TGA under air; heating at 10 °C/min**



→ **2-steps thermal degradation**

→ T_{dmax} = 369-379 °C

➢ T_s (heat resistance index) → physical heat-tolerance

$$T_s = 0.49[T_{5\%} + 0.6(T_{30\%} - T_{5\%})]$$

✓ T_s = 180-182 °C

Classified as heat resistant materials
T_s = 100-200 °C
$T_{s\ Epoxy\ \&\ Phenolic\ resins}$ ≈ 200 °C

✓ $T_{5\%}$ = 335-352 °C

Commercial e.g.:
- Park Aerospace Nelco® N4000-6 FC : $T_{5\%}$ = 325 °C
- Park Aerospace Nelco® N4350-13 RF : $T_{5\%}$ = 350 °C

Properties of synthesized thermosets – BOC & BCC

- **Bio-based Carbon Content (BCC)**

$$\mathrm{BCC} = \frac{\sum(\mathrm{W}_{100\%} \cdot \mathrm{TC}_{100\%})}{\sum(\mathrm{W}_{100\%} \cdot \mathrm{TC}_{100\%}) + \sum(\mathrm{W}_{0\%} \cdot \mathrm{TC}_{0\%})} \cdot 100$$

- **Bio-based Organic Carbon (BOC)**

$$\mathrm{BOC} = \frac{\sum bio - based\ carbon}{\sum \mathrm{bio-based\ carbon} + \sum \mathrm{petro-based\ carbon}} \cdot 100$$

Thermoset	BCC (%)	BOC (%)
TGPh-MNA_1MIM	56	74
TGPh-MNA_2E4M	55	74
TGPh-HMPA_1MIM	58	77
TGPh-HMPA_2E4M	58	77

30% biobased

OK biobased
TÜV AUSTRIA
★ ★

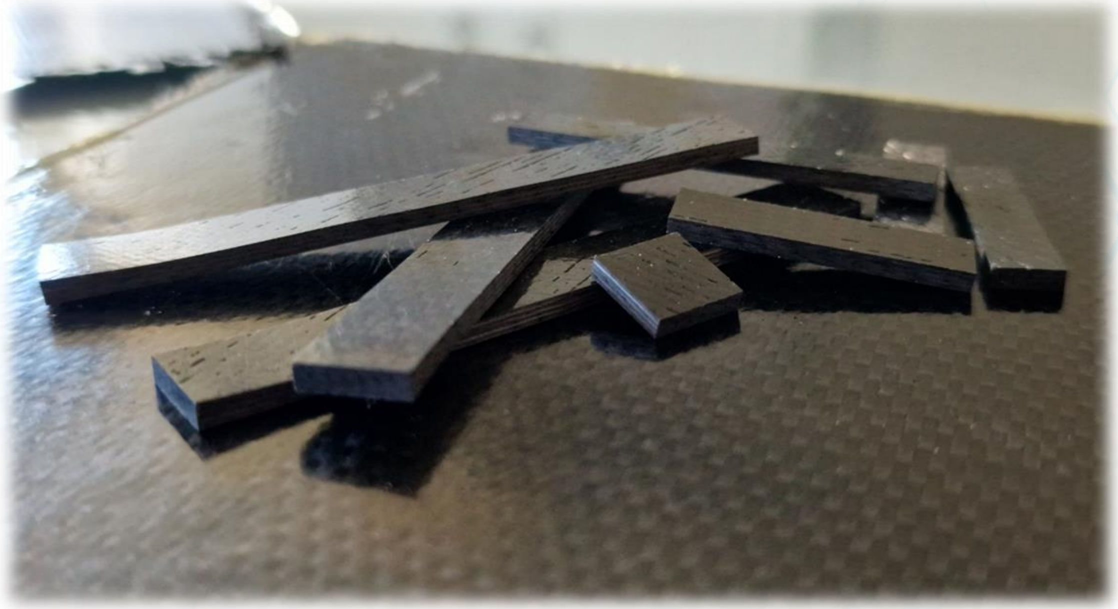
BCC ≈ 40 – 60 %

Concluding remarks – Thermosets Resins

System			DSC			DMA				Shore Hardness (SD)	Density (g/cm³)	TGA	WA % at 24h		BCC (%)	BOC (%)
Comp. A	Comp. B	Comp. C	T_{max} (°C)	ΔH ($J.g^{-1}$)	T_g (°C)	Tan δ (°C)	E' at 25°C (GPa)	υ ($mmol \cdot cm^{-3}$)	Mc (g/mol)			$T_{5\%}$ (°C)	24h	15 days		
TGPh	MNA	1MIM (1 wt.%)	132	257	211	210	2.8	7.3	165	89	1.20	335	0.30	1.75	56	74
		2E4M (1 wt.%)	141	258	184	199	3.1	8.0	144	88	1.22	340	0.39	2.81	55	74
	HMPA	1MIM (1 wt.%)	115	315	179	197	2.7	6.7	175	88	1.17	350	0.40	1.95	58	77
		2E4M (1 wt.%)	127	292	178	189	2.9	7.6	152	87	1.16	352	0.21	1.80	58	77

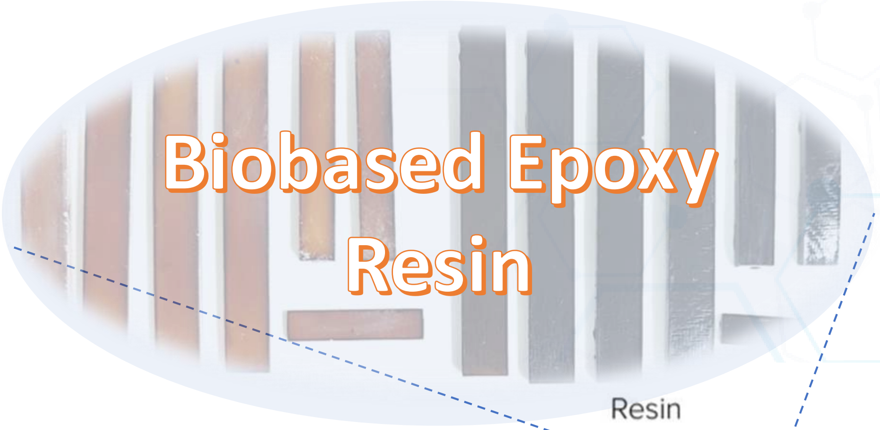
- ✓ Synthesized biobased epoxy monomers
- ✓ Feasible industrial protocol for thermosets production
- ✓ High T_g → Rigid materials; T_g ≈ 190-210 °C
- ✓ ↗↗ GC≈ 99% - high crosslinked thermosets
- ✓ Thermal stability $T_{5\%}$ = 335-352 °C
- ✓ Low hydrophilicity
- ✓ BOC >74%

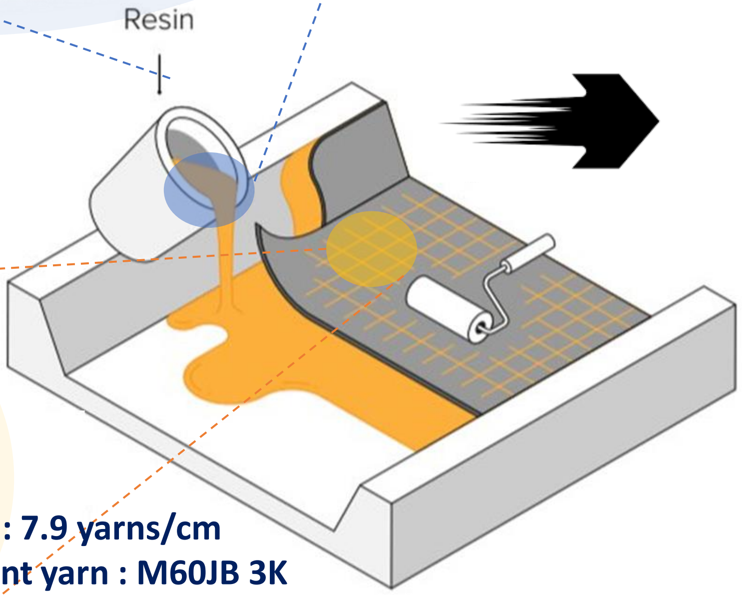
Dinu, R.; Lafont, U.; Damiano, O.; Mija, *ACS Applied Polymer Materials*, **2022**, 4, 3636–3646

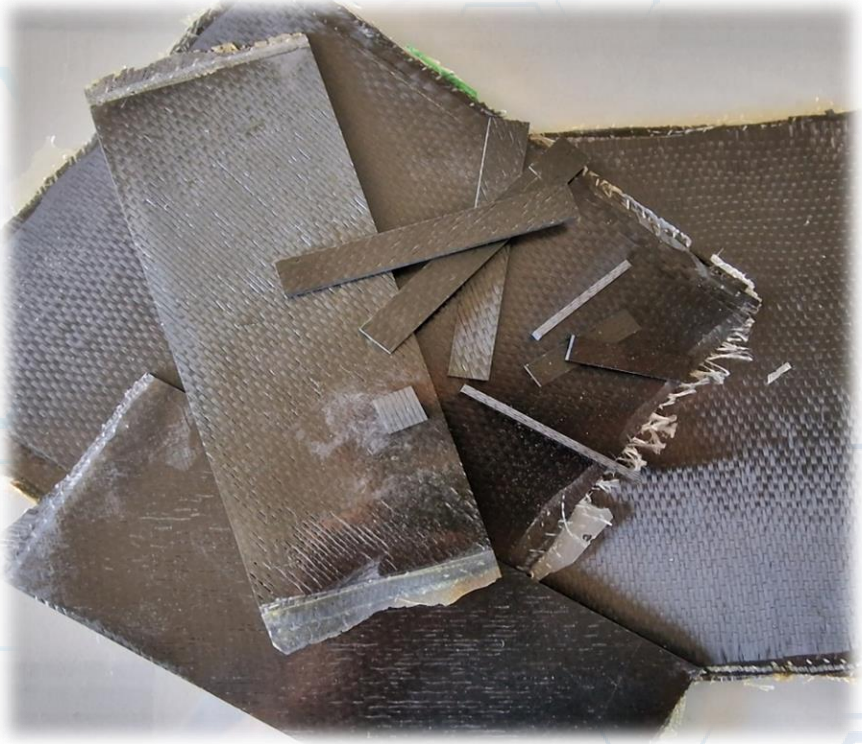


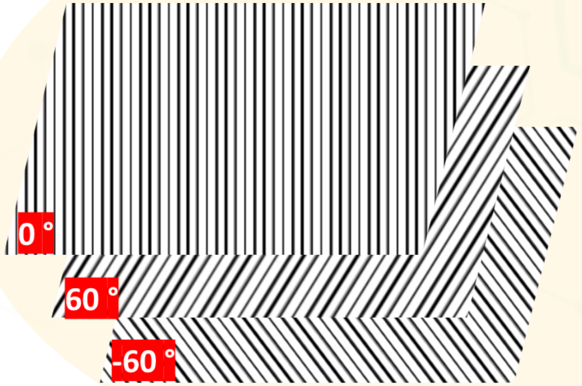
B/ Carbon Fibers Biobased Epoxy Composites

CF Biobased Epoxy Composites Manufacturing









12 layers
Fibres count : 7.9 yarns/cm
Reinforcement yarn : M60JB 3K (Warp) & M60JB 3K (Waft)

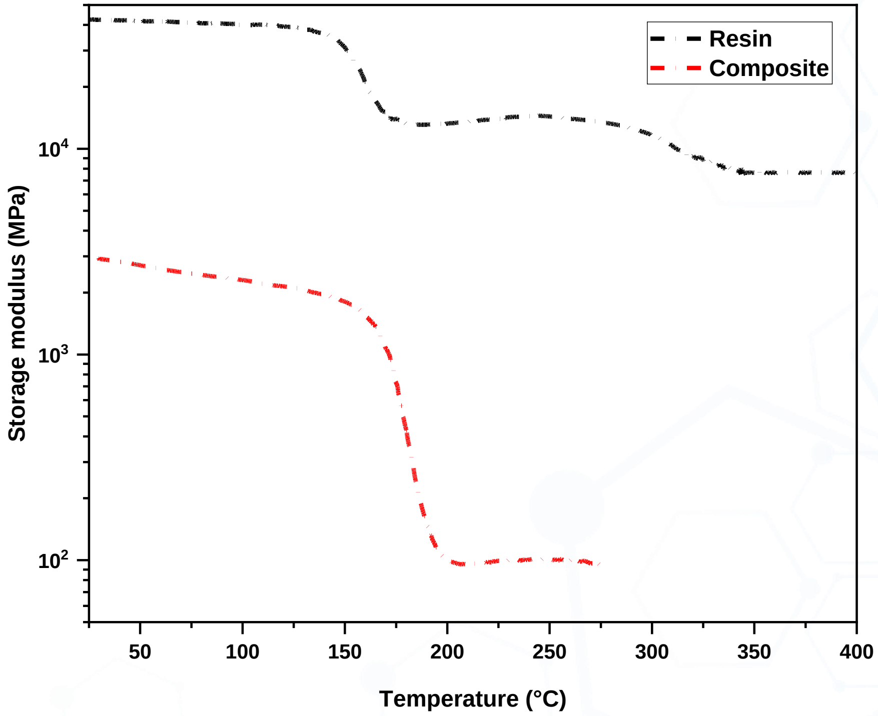
HexForce G0947 Carbon Fabrics - HEXCEL

Biobased epoxy resin// HexForce G0947 CF

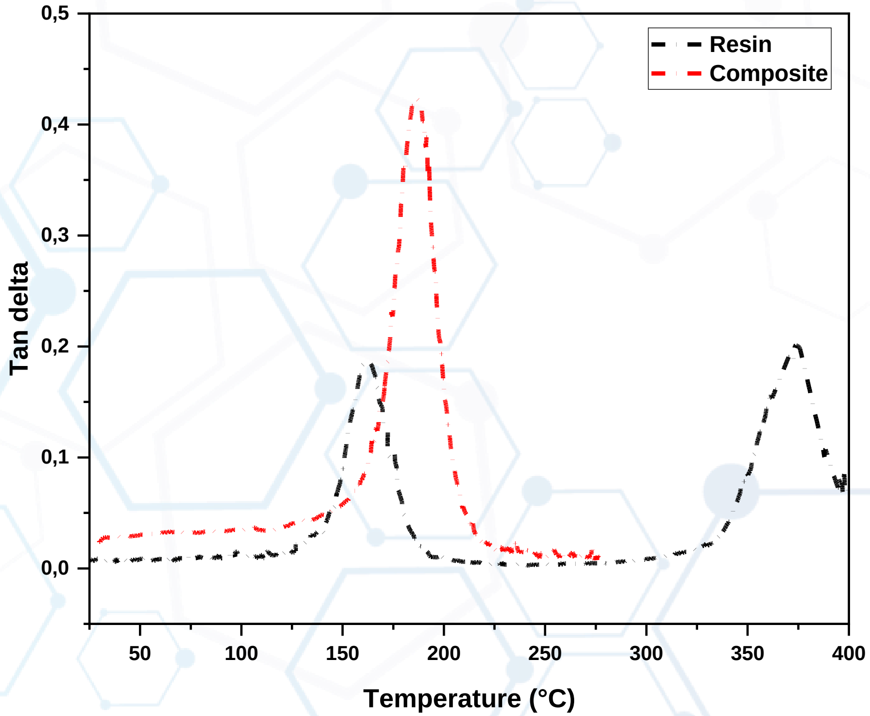
M_f = 0.62 - fiber mass fraction
V_f = 0.83 - fiber volum fraction

Properties of CF Biobased Epoxy Composites – DMA

3 Points Bending, 3 °C/min heating rate, 1.0 Hz



Samples	*E'*, at 30 °C (GPa)	Tan *δ* (°C)
Resin	2.9	189
Composite	42.4	163 & 374



- **Increase of mechanical properties :**
  E' **: - glassy region ~ 3 to 43 GPa**
  - rubbery region ~ 0.1 to 14 GPa

- **2 tan *δ* : 163 & 374 °C**

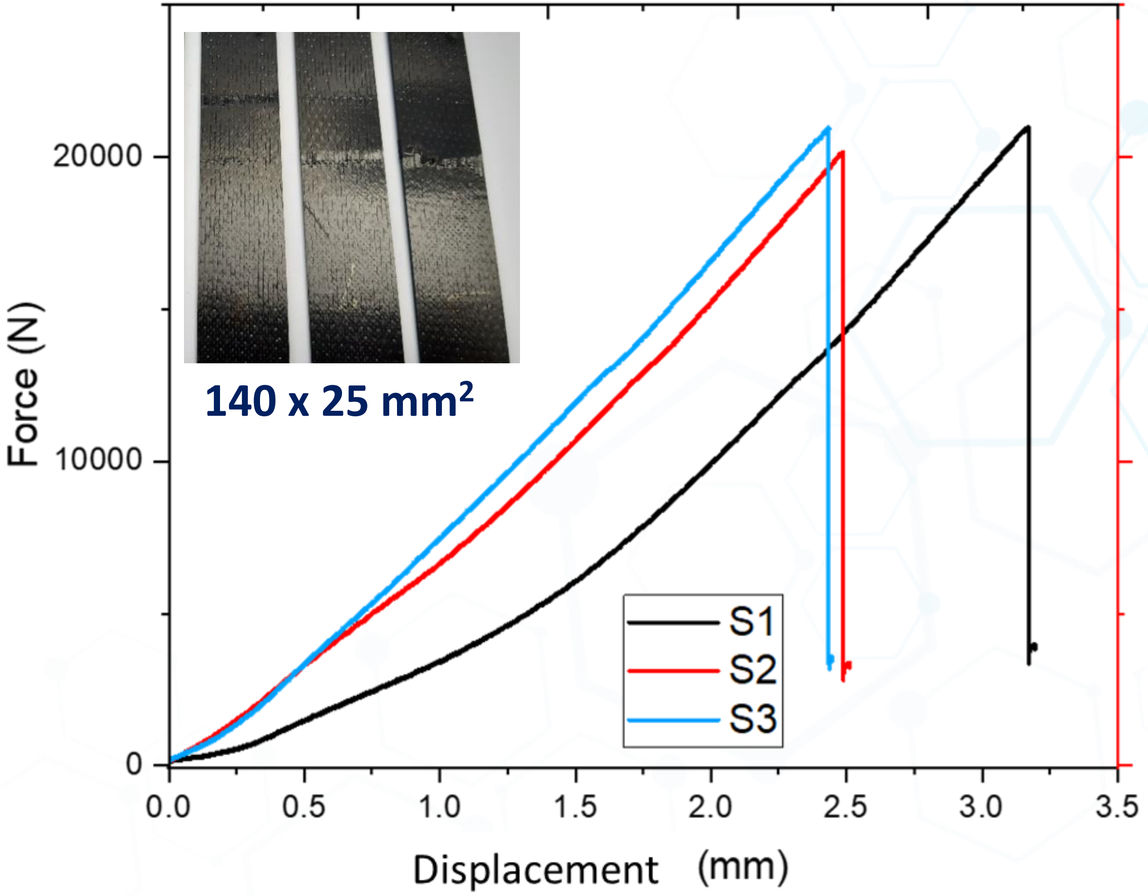
Commercial e.g.:

- Solvay CYCOM® 890 RTM Resin - Woven Carbon Fabric Composite: T_g = 169-210 °C
- Polynt 90 CF40-400g Carbon Fiber Epoxy Fleece: T_g = 150-200 °C
- Solvay CYCOM® 934 Epoxy-Carbon Fiber Reinforced Laminate: T_g = 160-194 °C
- Park Aerospace Nelcote® E-746 Epoxy Prepreg, 3k 5HS Carbon Reinforced: T_g = 180-230 °C

Unpublished results

Properties of CF Biobased Epoxy Composites – Compression tests

- at room temperature according with ASTM D3410



	Length (mm)	Thickness (mm)	Max Force (N)	Compressive stress (MPa)
S1	25.07	2.14	20957	390.63
S2	25.05	2.06	20143	390.35
S3	25.08	2.05	20950	407.48
Mean	**25.07**	**2.08**	**20683**	**396.15**
Standard deviation	0.02	0.05	468	9.81
Dispersion	0.06%	2.37%	2.26%	2.48%

- **Maximum compressive strength of ~ 400 MPa**

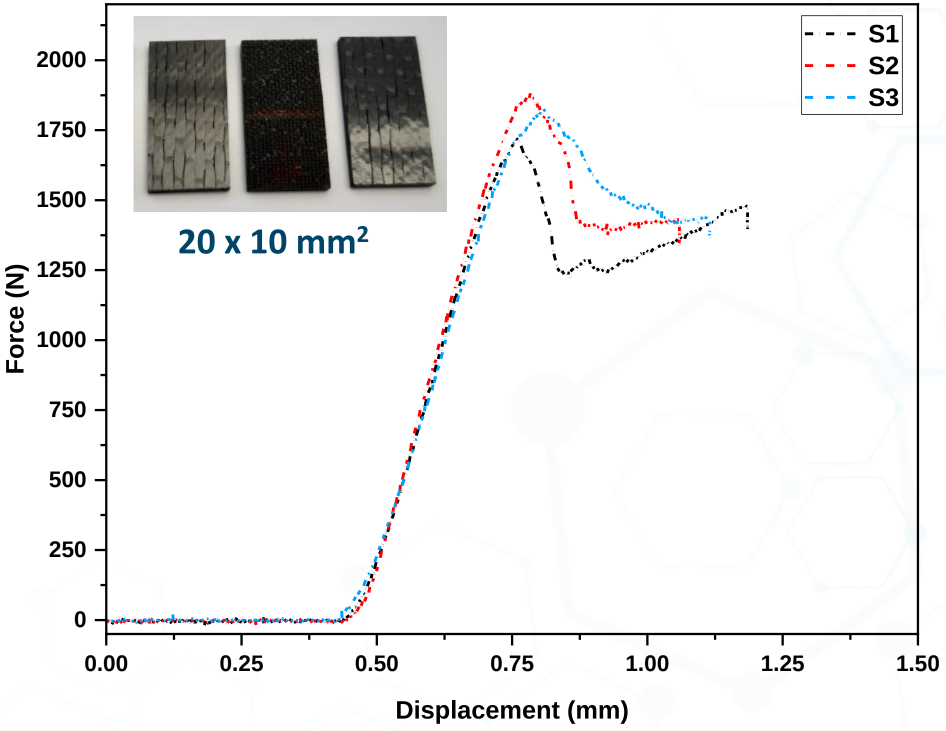
Commercial e.g.:

- Epoxy Novolac 27%, Carbon fabric 73% → 115 MPa
- Solvay LTM® 16 Epoxy with CF0700 Prepreg → 326 MPa
- Hexcel® HexMC® C/2000/R1A Carbon Epoxy Molding Composite → 350 MPa
- Toray 2511 Prepreg Laminate with F4829-11M (M46J-6K PW) Fiber →216 - 484 MPa

Unpublished results

Interlaminar Shear Strength (ILSS) of the Fiber - Matrix Interface

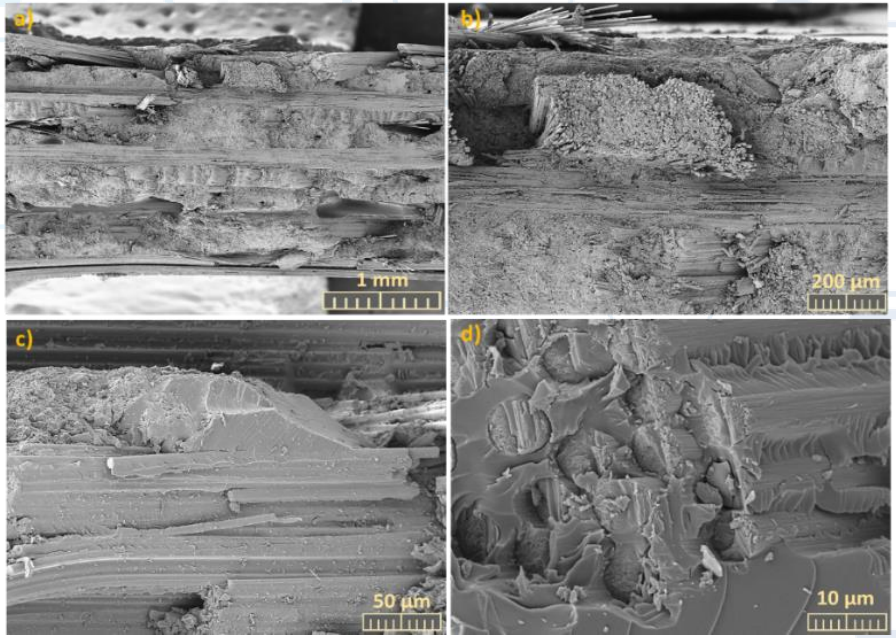
- at room temperature according with IGC 04 26 235
- describes the shear strength between the laminate planes / the quality of the fiber-matrix bonding



	Length (mm)	Thickness (mm)	Max Force (N)	ILSS (MPa)
S1	10.06	2.10	1730	61.42
S2	10.12	2.13	1886	65.62
S3	10.11	2.15	1827	63.04
Mean	**10.10**	**2.13**	**1814**	**63.36**
Standard deviation	0.03	0.03	79	2.12
Dispersion	0.32%	1.18%	4.34%	3.35%

ILSS~ 64 MPa ⇒ very good adhesion matrix/fiber

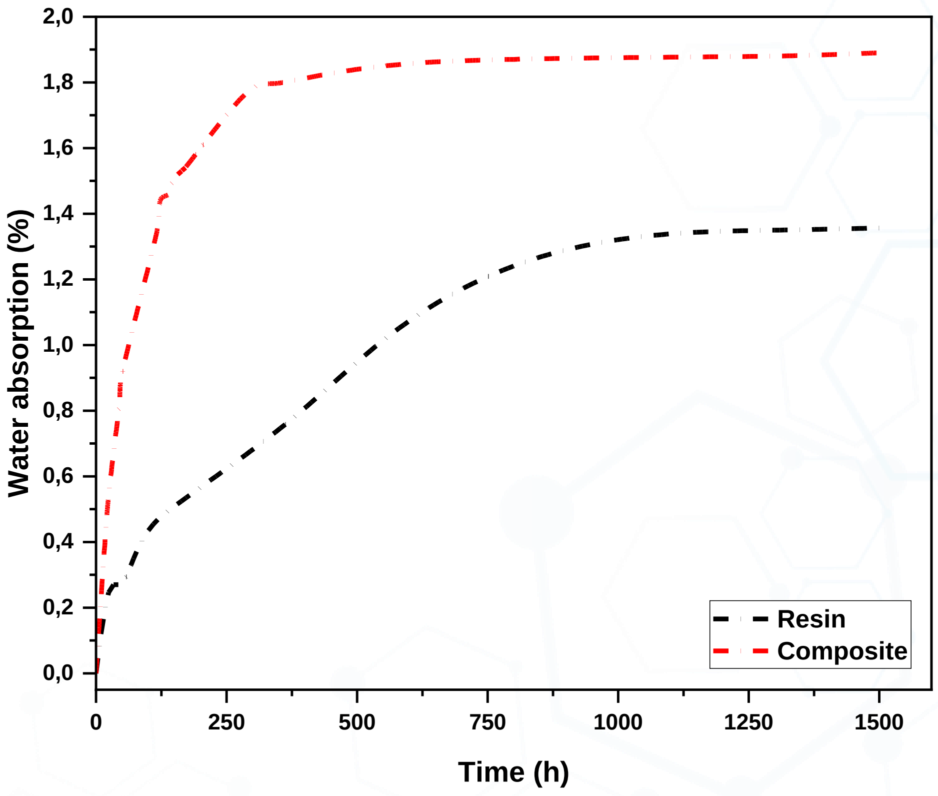
Confirmed by SEM



Commercial e.g.:

- Solvay Thornel® P-55 Carbon Fiber/Epoxy Advanced Composite System → 55 MPa
- Hexcel® HexPly® F522 Epoxy Resin, W3C282 Carbon Fabric → 26-62 MPa
- Hexcel® HexMC® C/2000/R1A Carbon Epoxy Molding Composite → 45 MPa
- Toray 2511 Prepreg Laminate with F4829-11M (M46J-6K PW) Fiber → 46-64 MPa

Properties of CF Biobased Epoxy Composites – SD & WA%



Samples	Density (g/cm³)	SD	WA (%)		GC (%)
			24h	25 days	
Resin	1.16	87	0.46	1.85	99.62
Composite	1.37	97	0.25	1.02	99.94

- SD ↗ ~ 10% ⇒ from 87 to 97 SD
- Decrease WA% : from 0.46 to 0.25 % after 24h
- GC ↗ (99.94%) ⇒ proper crosslinking & interaction matrix - fibers

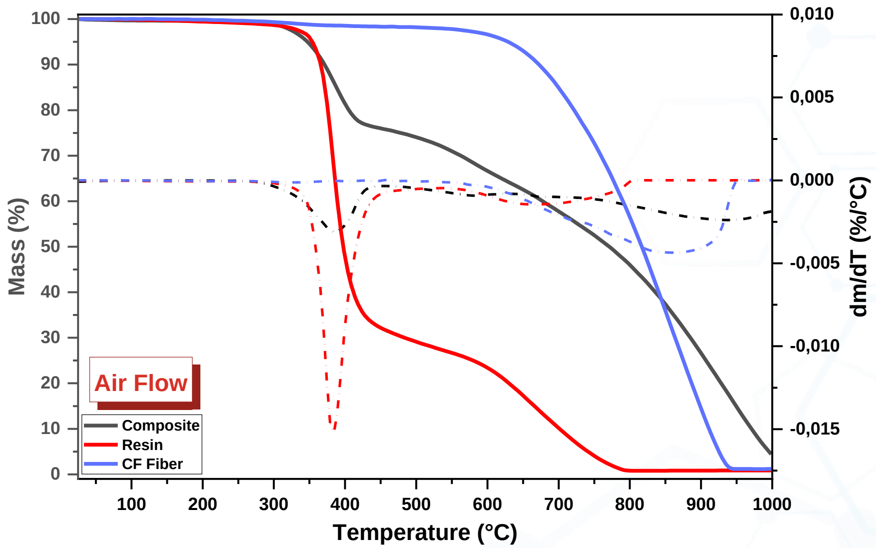
Commercial e.g. for WA% :
- Solvay CYCOM® 5320-1 Epoxy with T40/800B Unidirectional Carbon fiber: WA = 0.55%
- Norplex-Micarta NP185 Carbon Fiber: WA = 1.32 %

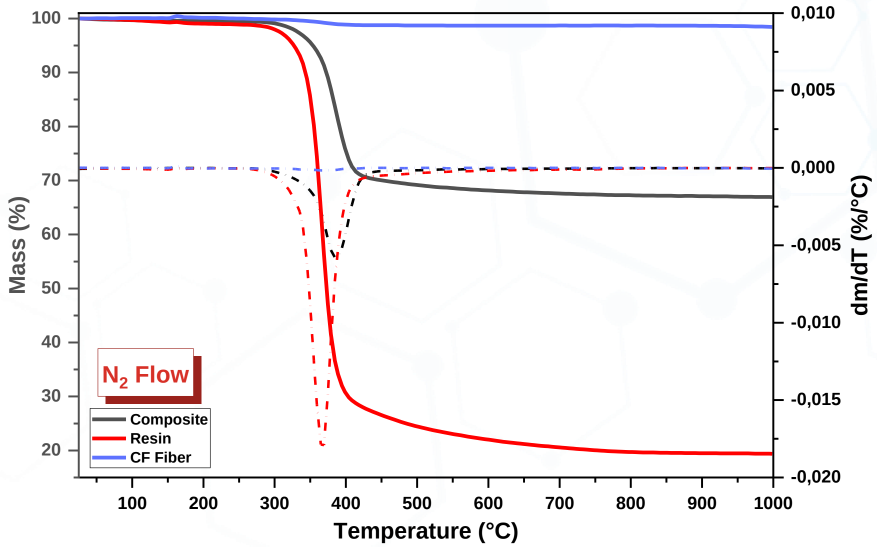
Commercial e.g. for SD:
- NRI Thermo-Wrap™ CF Carbon Fiber Composite - 90 SD
- NRI Trans-Wrap Carbon Fiber Epoxy Composite - 85 SD

Unpublished results

Properties of CF Biobased Epoxy Composites – Thermal Stability

TGA under Air & N_2; heating at 10 °C/min





Samples	$T_{5\%}$ (°C)		T_s	
	Air	N_2	Air	N_2
Resin	350	320	180	169
Composite	350	350	233	197

T_s (heat resistance index) → physical heat-tolerance

$$T_s = 0.49[T_{5\%} + 0.6(T_{30\%} - T_{5\%})]$$

- ✓ T_s improved from "heat resistant materials" to "high heat resistant materials"
- ✓ High thermal stability : $T_{5\%}$ ~ 350 °C

Commercial e.g. :

- Hexcel® HexPly® 8552 Epoxy Matrix, Carbon Fabric Form - $T_{s,air}$ = 121 °C
- Solvay CYCOM® 5250-4 BMI Prepreg System with G40-800 Carbon Fiber - $T_{s,air}$ = 232 °C
- DuPont Performance Polymers Vespel® CP-9800 Carbon Fiber and Epoxy Composite - $T_{s,air}$ = 230 °C

Unpublished results

Properties of CF Biobased Epoxy Composites – Flame Resistance

➢ By TGA : under N_2; heating at 10 °C/min

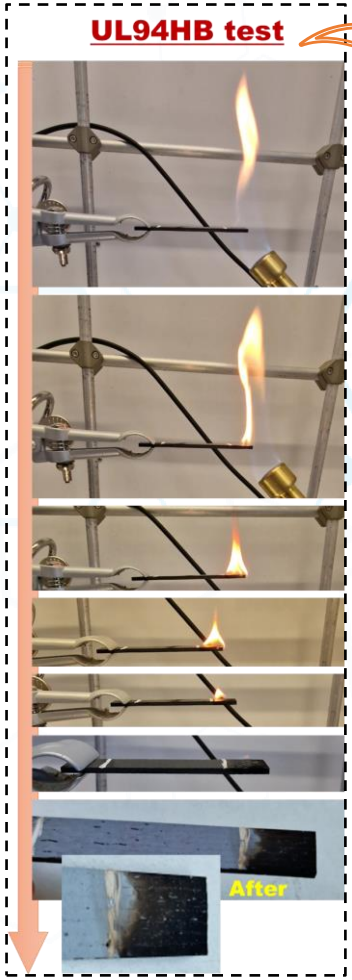
Oxygen Limit Index (*LOI*)

$$LOI = 17.5 + 0.4 \times C_{y800}$$

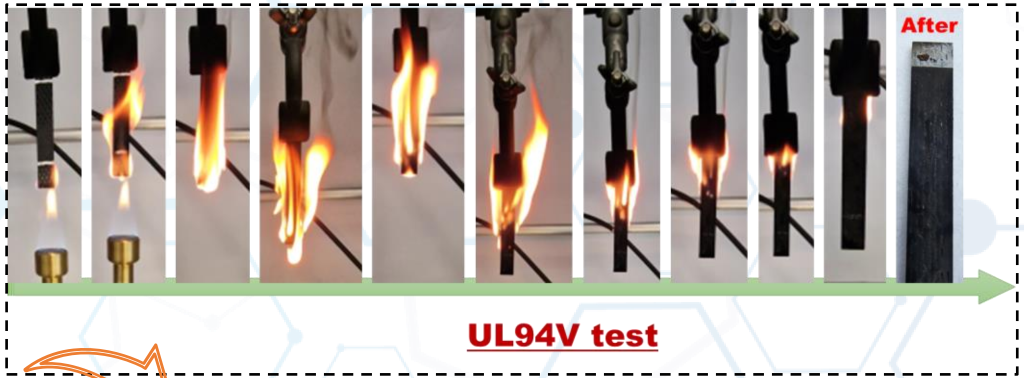
Samples	C_{y800} (%)	*LOI* (%)
	N_2	N_2
Resin	19.7	25.4
Composite	67.3	44.4

- LOI > 28% >> “self-extinguishing” system

➢ By horizontal & vertical combustion tests → UL-94 standard



- CFRC ignite after 10 s → flame persist for another 13 s → the flame front does not pass the 25 mm reference mark ⇒ ⇒ classified as HB



- extinguished in 28 s after the 1st ignition → self-extinguished in 35 s after the 2nd ignition → small amount of smoke & no melting-dripping ⇒ ⇒ classified with V-1 rank

<< Intrinsic flame-retardant character without supplementary addition of any flame retardants >>

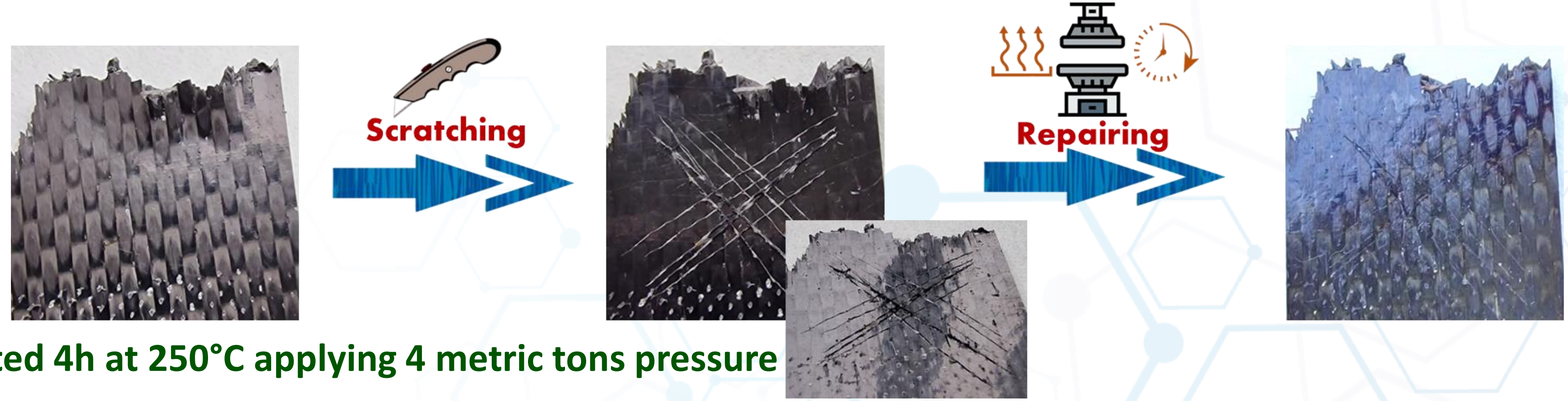
Unpublished results

Properties of CF Biobased Epoxy Composites – Chemical recycling

Polymeric matrix fully disintegrates ⇒ CFRC extracted, dried & reused for new composite development

Unpublished results

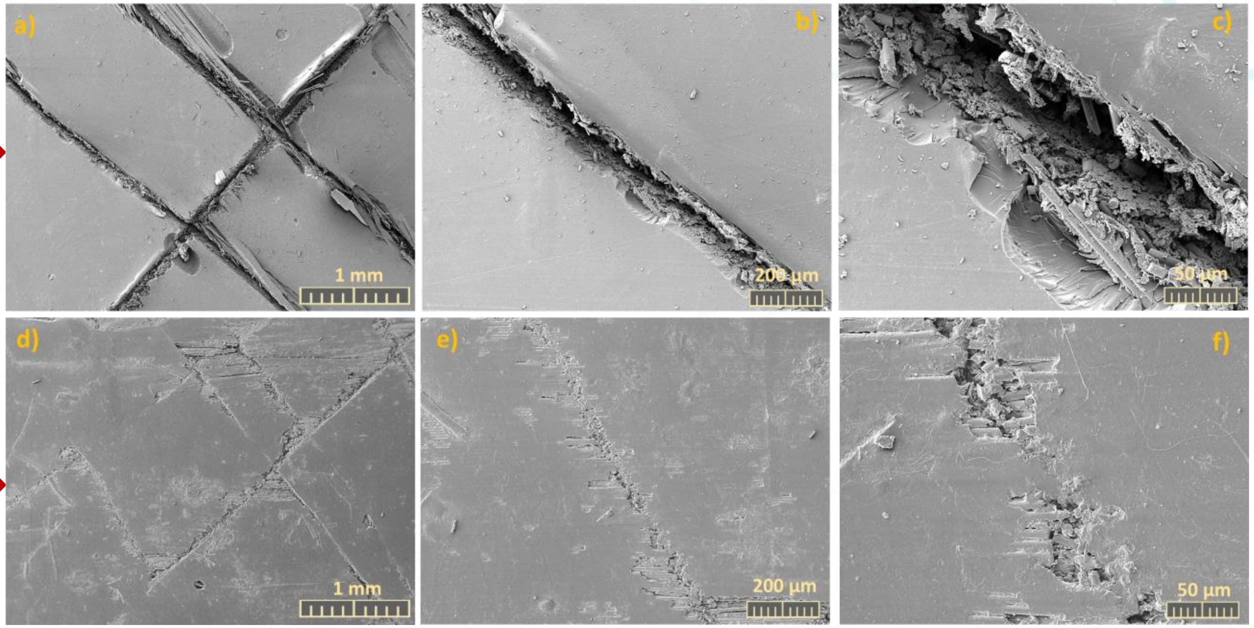
Properties of CF Biobased Epoxy Composites – Chemical recycling & Repairability test



➢ **Heated 4h at 250°C applying 4 metric tons pressure**

Before ⇒

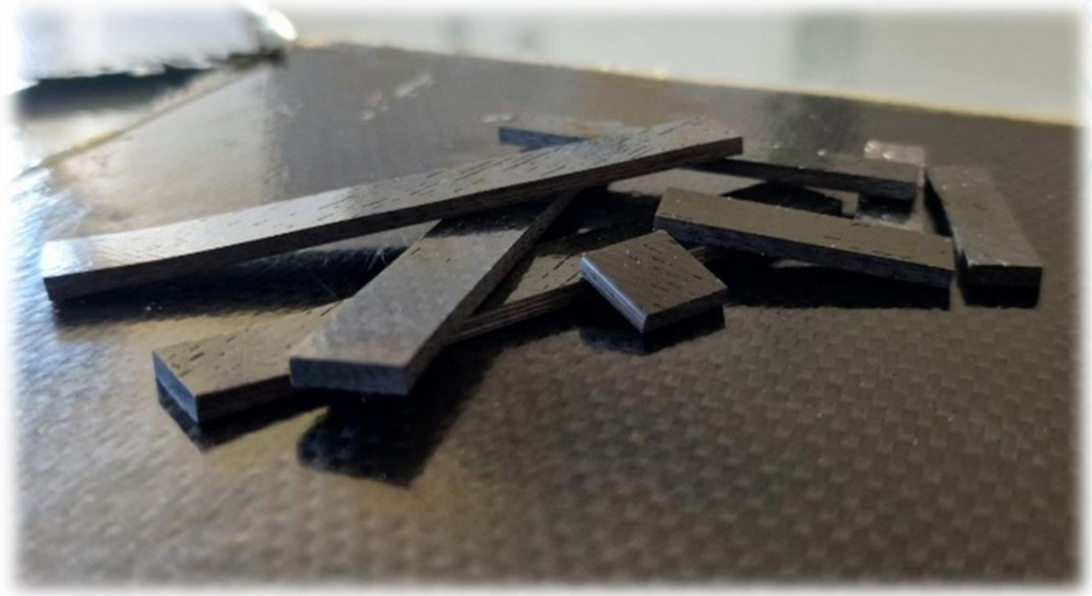
After ⇒



✓ **CFRC biobased epoxy with self-healing ability**

Unpublished results

Concluding remarks – CF Biobased Epoxy Composites



A/ Thermosets with BOC ~ 77%, T_g ~ 189 °C, GC=99%, WA=0.4%

B/ CF Composites with high performances:

- ✓ *E'* = 42 GPa (at RT)
- ✓ T_g ~ 163 & 374 °C
- ✓ ILSS ~ 64 MPa ⇒ very good interaction matrix/fiber
- ✓ compressive strength ~ 400 MPa
- ✓ GC ~ 100%- high crosslinked systems
- ✓ WA ~ 0.25%
- ✓ Extra hard materials ⇒ 95 SD
- ✓ High thermal stability $T_{5\%}$ > 350 °C
- ✓ Flame resistant systems ⇒ *LOI* = 44.4%

  ⇒ classified with - HB rank (UL94HB test)

  - V-1 rank (UL94V test)
- ✓ Chemically recyclable
- ✓ Self-healing ability

Unpublished results

Thank you for your attention !

This work received financial support from the European Space agency under ESA Contract 4000134653 and from the French government, managed by the National Research Agency under the “Investissements d’Avenir UCAJEDI” project with Reference No. ANR-15-IDEX-01

Leading the journey towards more sustainable Carbon Fiber Reinforced plastics

Dr. Caroline Petiot
Central Research & Technology. Composite materials senior scientist - AIRBUS

We pioneer sustainable aerospace for a safe and united world

Leading the journey towards more sustainable Carbon Fiber Reinforced plastics

Dr Caroline Petiot,
Central Research & Technology
Composite materials senior scientist

Zaragoza, Nov. 17th

AIRBUS

Outline

Introduction to the journey towards clean aerospace and targeted ambition

Reduction of our industrial footprint during operations

Towards a Circular economy for Carbon Fiber Reinforced Plastics considering progressive introduction of more Biobased formulations

Conclusions

2022

2035

2050

AIRBUS

Leading the way in the decarbonisation of aviation

Ambition to be the first to offer a zero-emission commercial aircraft by 2035

ZEROe concept aircraft powered by hydrogen

Sustainable growth

Source: Airbus, ATAG

Progress since dawn of the jet age

CO reduced by **50%**

CO_2 reduced by **80%**

NO_x reduced by **90%**

Noise reduced by **75%**

Ambitious aviation industry goals

Cap CO_2 emissions from **2020**

Reach net zero CO_2 emissions by **2050**

Aviation's path towards zero emissions
Emissions per passenger kilometre (%)
-50% achieved
due to:
optimised aerodynamics
advanced materials
next-gen engines
WE ARE HERE
Addressing the remaining 50%
7%
Improved ATM & Aircraft Operations
34%
New Engine & Aircraft Technologies
53%
Sustainable Aviation Fuels
6%
Market-based Measures
1990
2000
2021
2050
AIRBUS

2. REDUCING THE ENVIRONMENTAL FOOTPRINT

OF OUR OPERATIONS

Ambition for 2030 compared to 2015 emissions/consumptions:

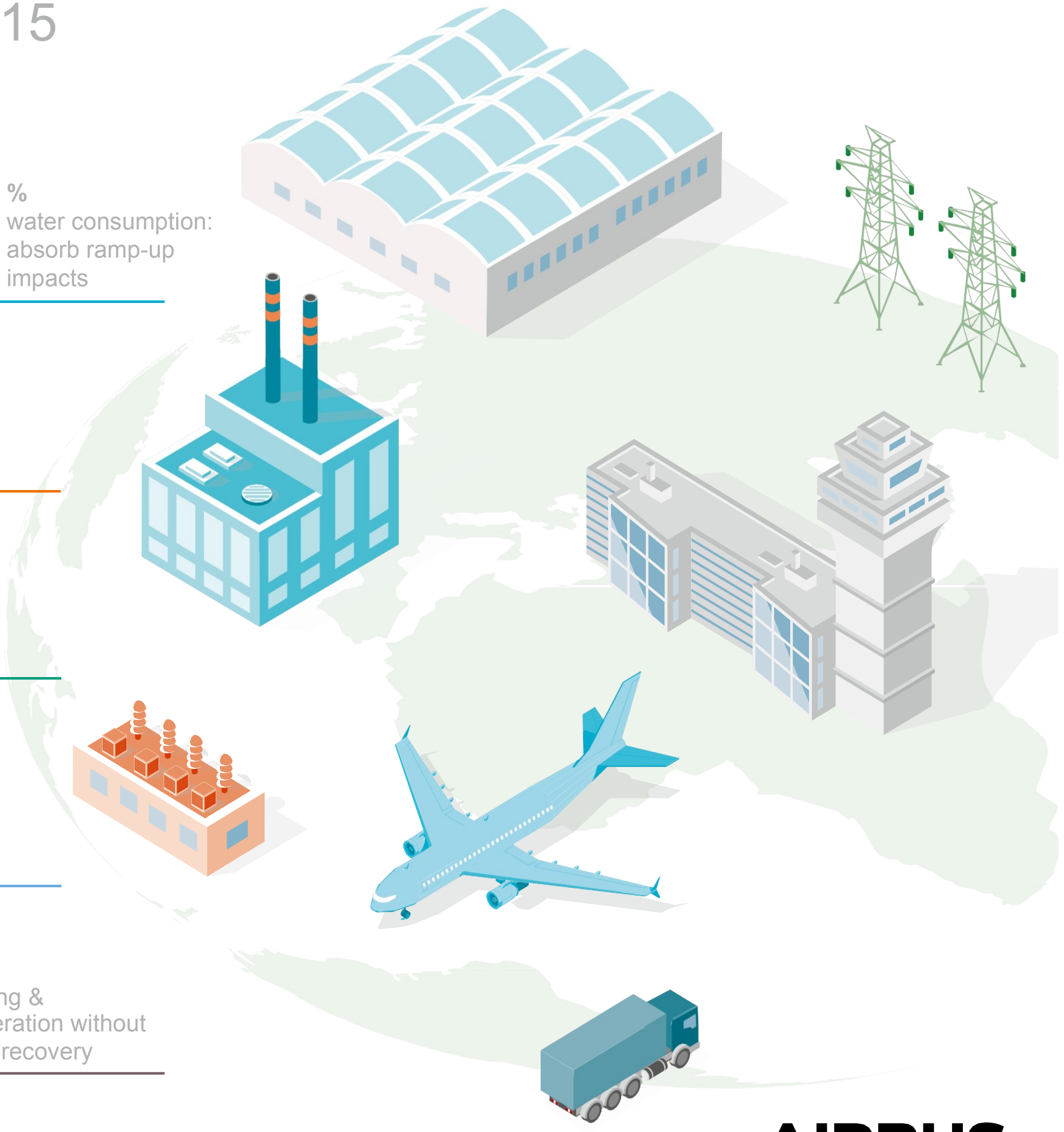
Water — **-50** % water purchasing + **0** % water consumption: absorb ramp-up impacts

Energy — **-20** % energy consumption

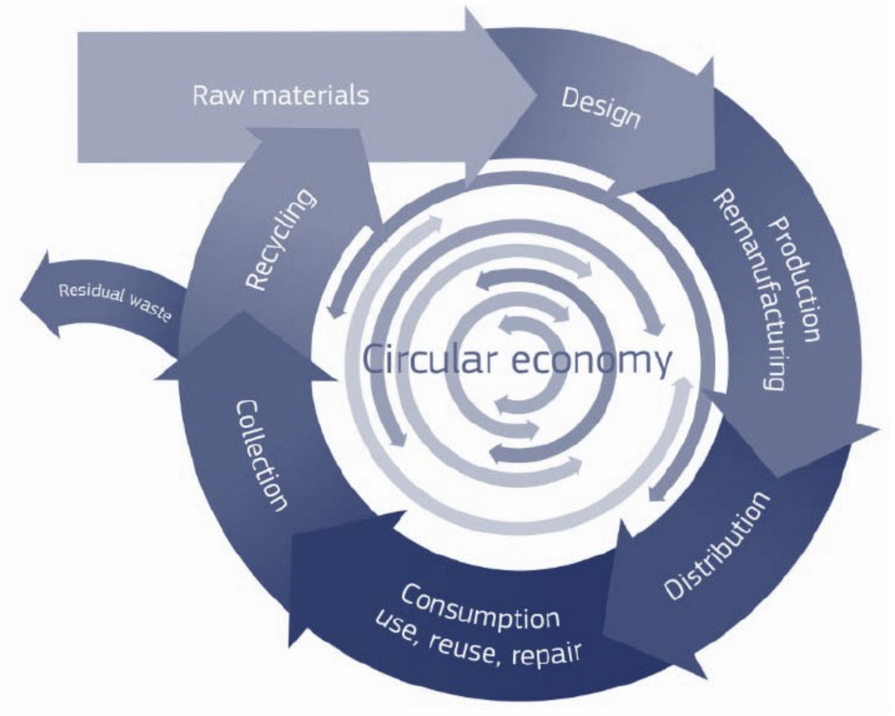
CO_2 — **-63** % CO_2 emissions

VOC and air emissions — **0** % Progressively absorb ramp-up impacts

Waste and raw materials — **-20** % waste production **0** landfilling & 0 incineration without energy recovery

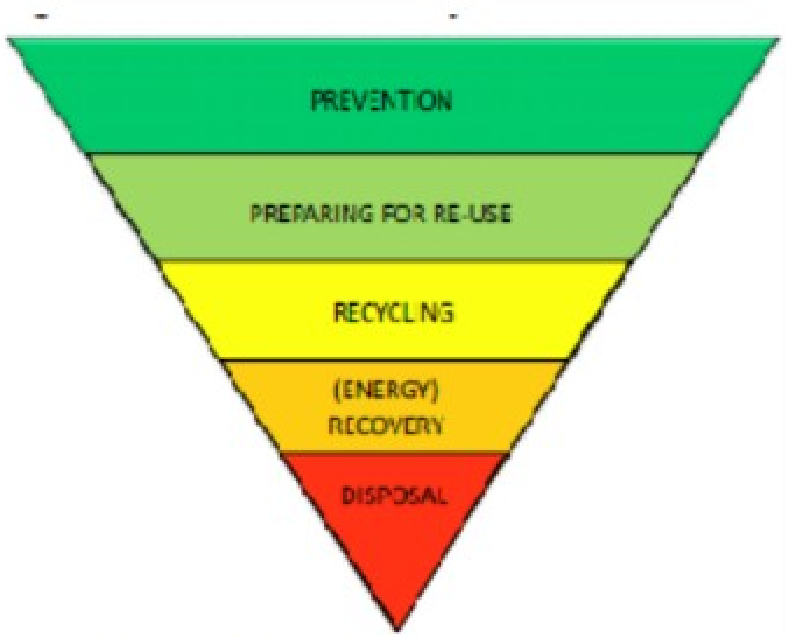


"Towards a circular economy: a zero waste programme for Europe"



Source: EU Commission Communication "Towards a circular economy: a zero waste programme for Europe", Deselnicu & al, ICAMS 2018.

The Waste Hierarchy



Source: European Commission.

Proposal for a Directive of the EU Parliament and of the Council to amend the 6 waste directives

3. TOWARDS A CIRCULAR ECONOMY

A zero waste programme for Europe

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3. TOWARDS A CIRCULAR ECONOMY

AIRBUS ENVIRONMENTAL RESPONSABILITY

INCL. OUR SUPPLY CHAIN

Develop Ecodesign principles

Design

Investing in R&D to design fuel-efficient aircraft that achieve better environmental performance

Supply chain

Working closely with our suppliers to
help them comply with our environmental commitments across the supply chain

Manufacturing

Setting ambitious goals to reduce our manufacturing footprint, promote conservation of resources and better manage our industrial footprint

Operations

Optimising aircraft operations and maintenance to achieve optimal noise and emissions throughout the aircraft's entire service lifespan

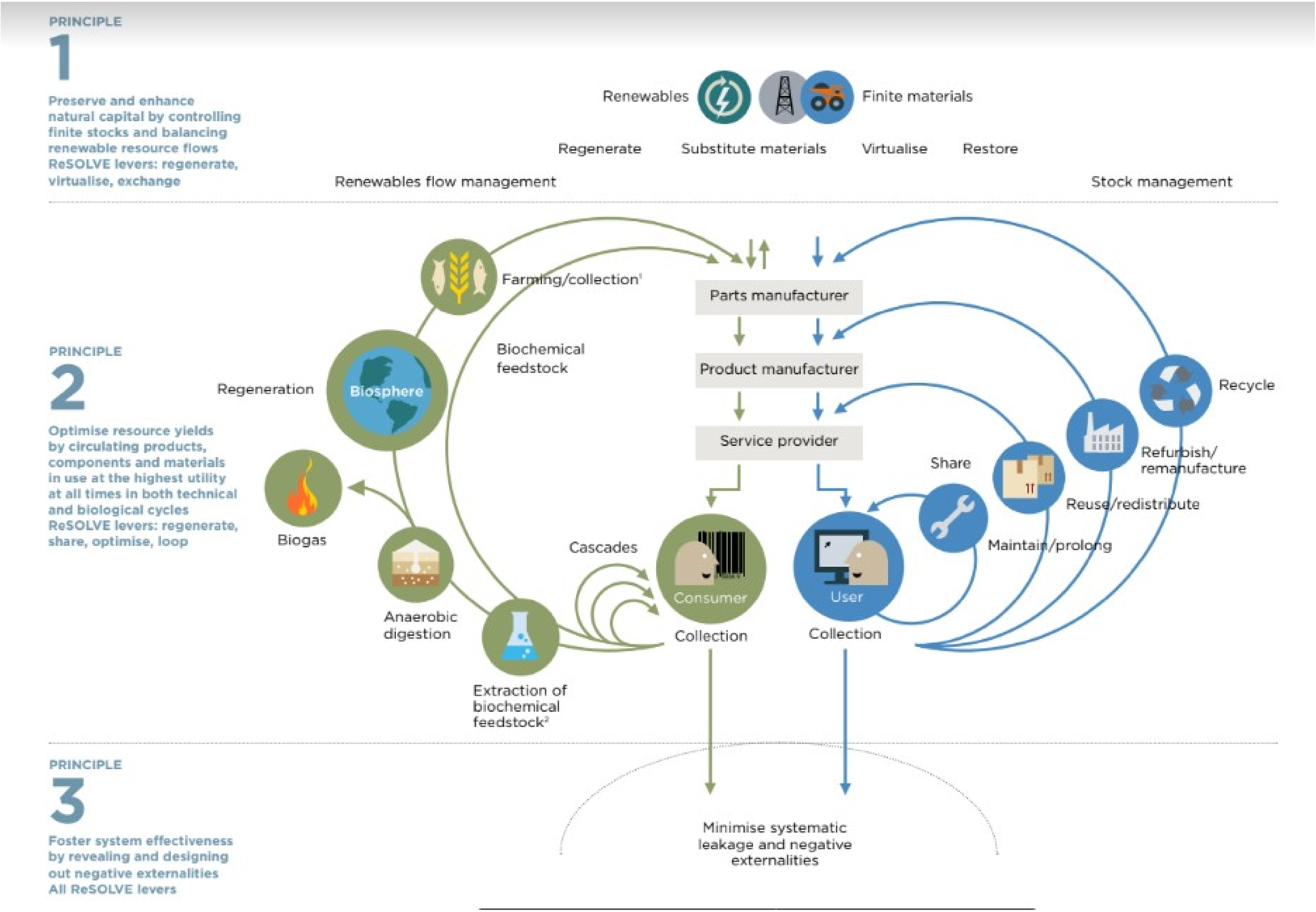
End-of-life recycling

Dismantling aircraft in a manner that maximises reuse and recycling, and focuses on the safe disposal of non-recyclable parts

3. TOWARDS A CIRCULAR ECONOMY

Rethinking the future of plastics 2016, Ellen MacArthur foundation

Renewable flow and plastics stock management



Rethinking the future of plastics 2016, Ellen MacArthur foundation

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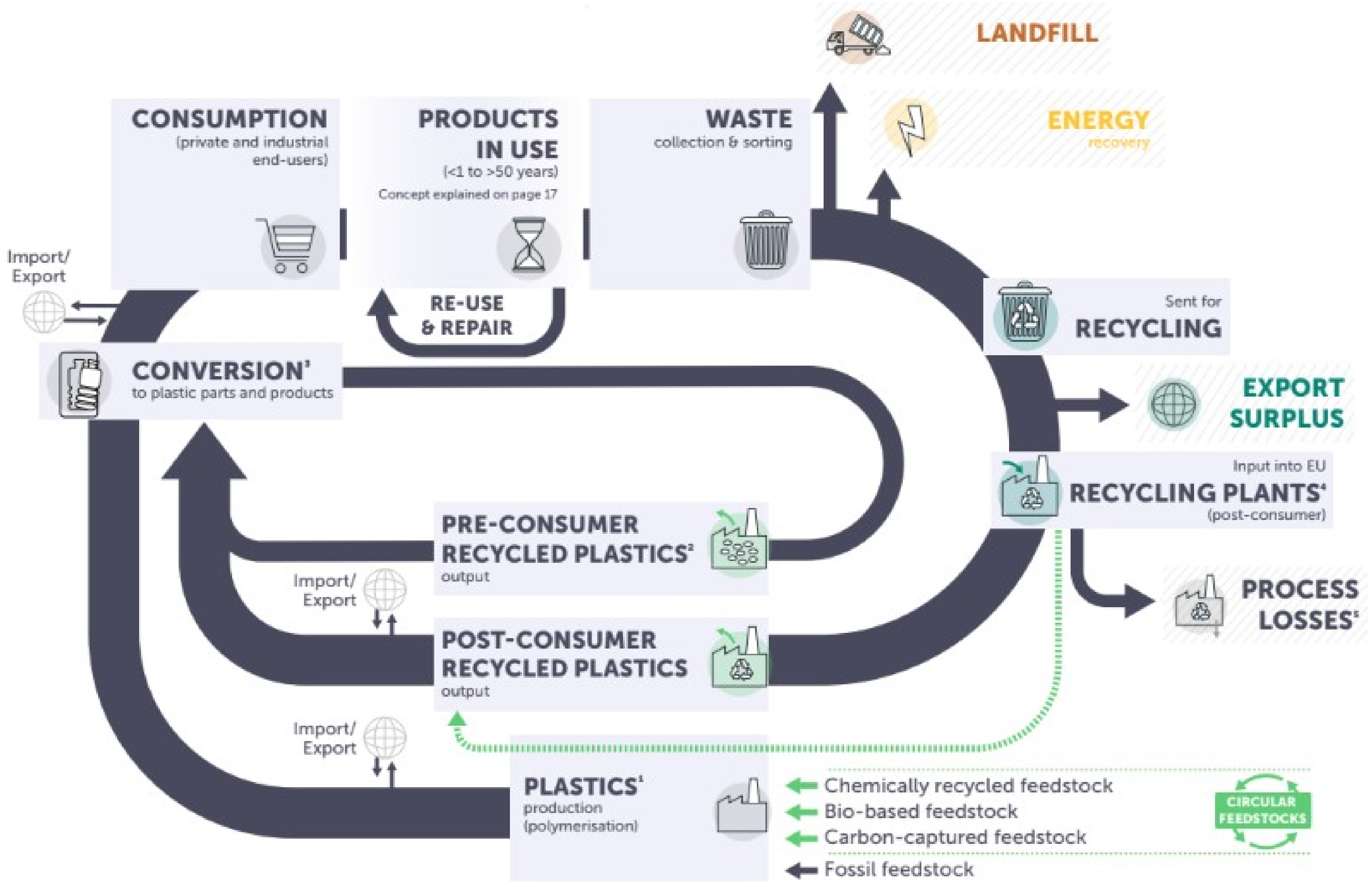

Source: PlasticsEurope-CircularityReport-2022_2804

3. TOWARDS A CIRCULAR ECONOMY

THE NEW MINE

Our feedstock for new classes of high performant CFRPs

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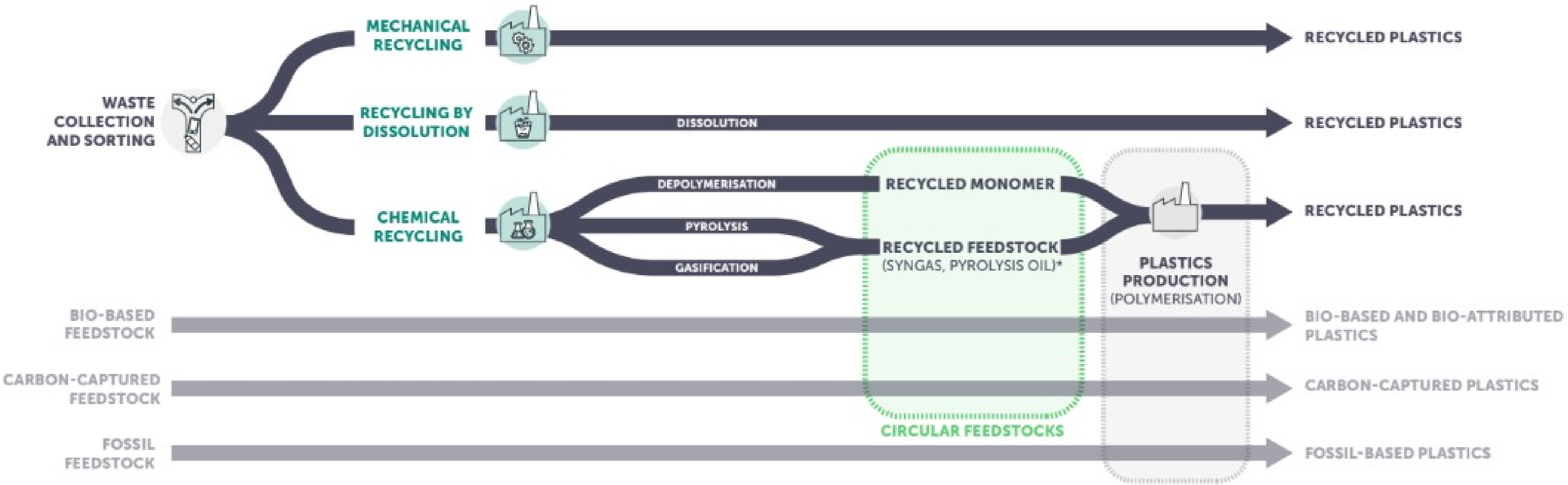

Source: THE CIRCULAR ECONOMY FOR PLASTICS, PlasticsEurope circularity report 2022

The US global recycled plastics market size evolution

- ❑ 46.09 billion USD in 2021
- ❑ 69 billions USD by 2030 (estimation)
- ❑ More than 4% of annual growth in the period 2022-2030.

Source: Recycled Plastic Market Size & Share Report 2030, edition 2022

- ❑ Could recycled Cellulose for alternatives precursors carbon fibers lead one day to High Performances carbon fibers ?

- ❑ Could more sustainable PP be used to produce PAN based carbon fibers ?
- ❑ Could economical viability be found in Bio based glycerol feedstock through acrolein route for the production of PAN carbon fibers ?

Source: Jean-Luc Dubois, Serge Kaliaguine, Acrylonitrile, industrial green chemistry, Dec. 2020

3. TOWARDS A CIRCULAR ECONOMY

THE NEW MINE

How many loops of circularity could plastics survive without losing their properties ?

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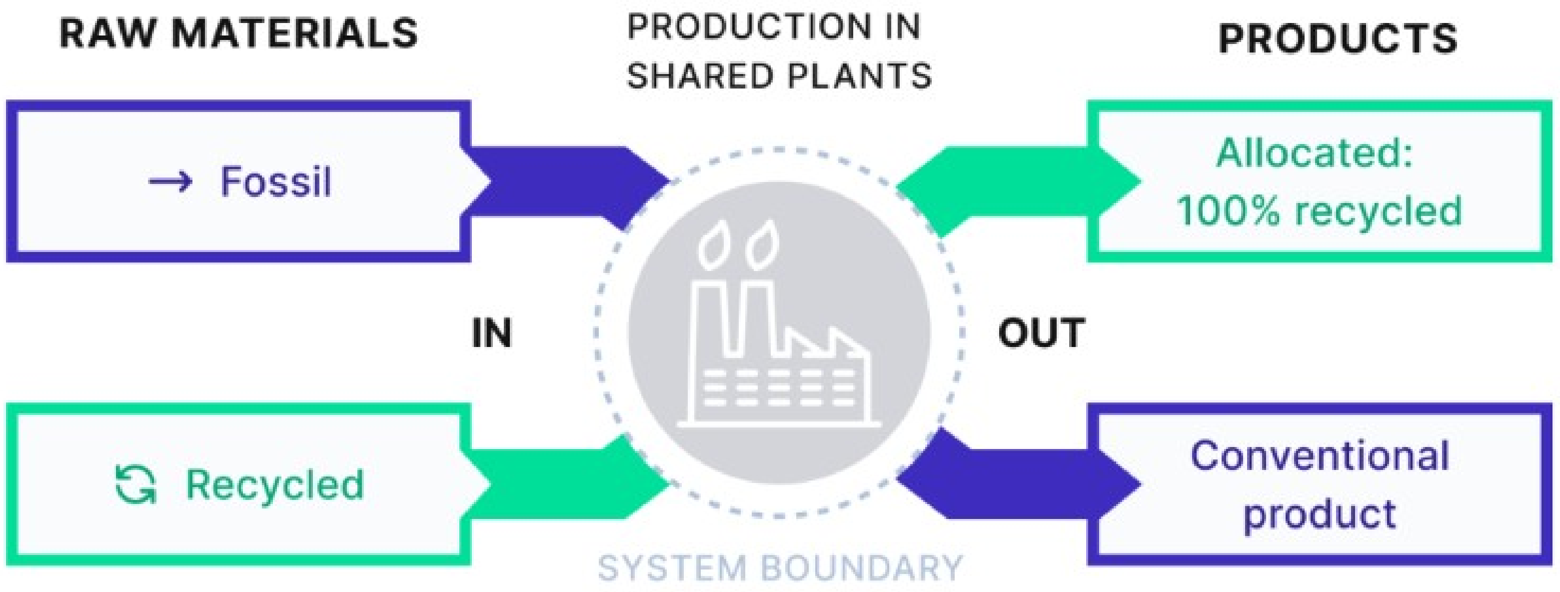
- Chain of custody model which provides the potential for businesses in the chemicals and plastics industry to incrementally transition to using sustainable feedstocks, without the need to set up separate production lines for sustainable products.
- Guaranteed by third party certification



"Mass balance approach for the sustainable chemicals transition" Chris Stretton, Mesbah Sabur, Igor Konstantinov, August 17, 2022. https://www.circularise.com/blog/mass-balance-approach-for-the-sustainable-chemicals-transition

3. TOWARDS A CIRCULAR ECONOMY

Mass Balance Approach

Mixed of Fossil & recycled feedstock incl. Biobased

Same industrial system

Sustainable credits allocated to one product

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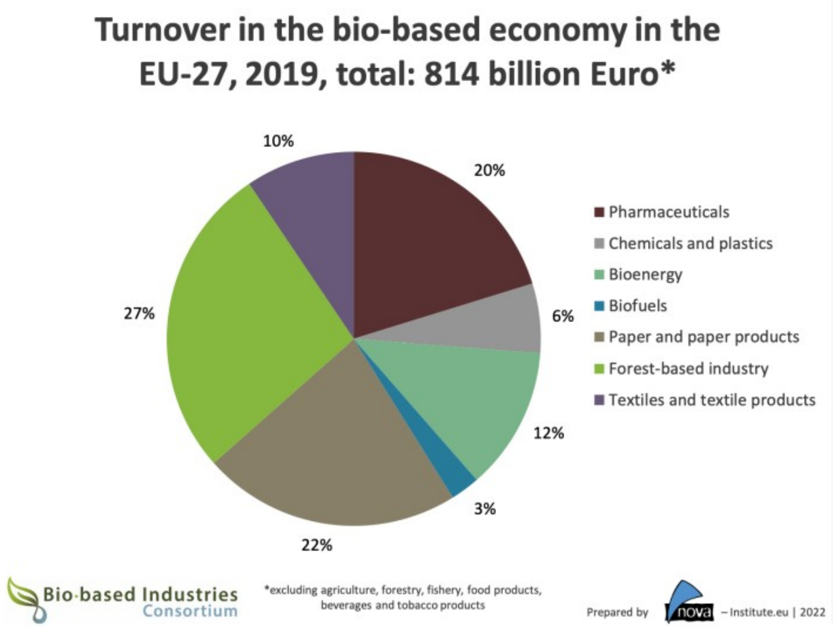
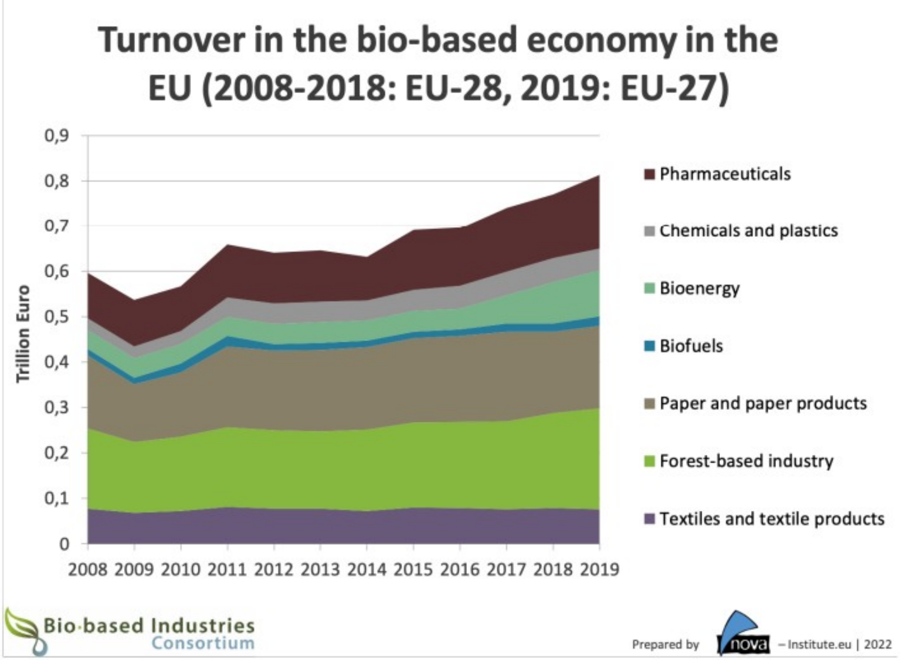




3. TOWARDS A CIRCULAR ECONOMY

BIO-BASED ECONOMY

The turnover of only the EU industrial sectors

814 M€ in 2019
6% share for chemicals and plastics

EU Growth +4% in 2019 compared to 2018 despite Brexit

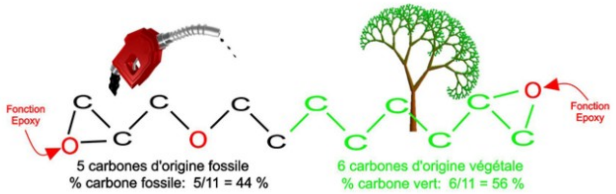
Chemicals and plastics sector turnover from EU-28 : +68% 2008-2019

New sources of monomers / Bio-sourced Renewable

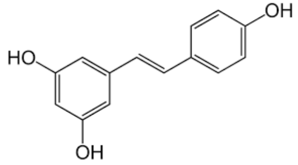
Can be purified or synthetized by enzymatic process

Selectivity and Yield can be boost by catalysis

SICOMIN - example Greenpoxy

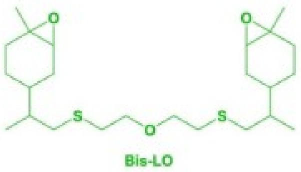


Resveratrol



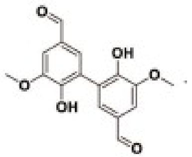
2020, Tian &al. https://doi.org/10.1016/j.cej.2019.123124

Bis-Limonene Oxide



Molecules 2018, 23, 2739; doi:10.3390/molecules23112739

Di-Vanillin



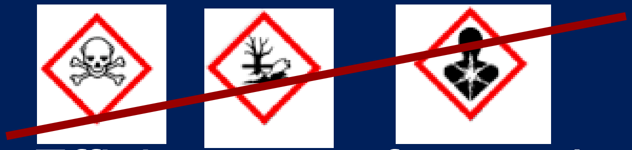
Bio-based curing agent from divanillin derivatives: DMAN

Savonnet & al., 2019 (doi/10.3389/fchem.2019.0066

3. TOWARDS A CIRCULAR ECONOMY

BIO BASED RESIN

Should be also harm substance free



Efficient use of natural ressources

Agro based feedstocks (carbohydrate ie: sugar cane ; corn,..),
Ligno Cellulosic feedstock,
Organic wastes feedstock

Feedstock NOT Competing with Food (waste or byproducts)

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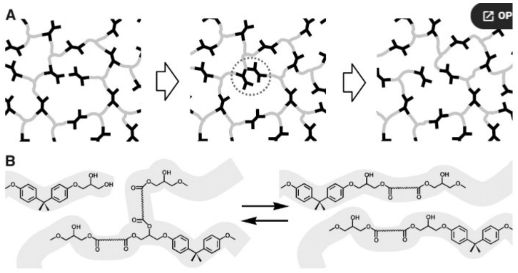
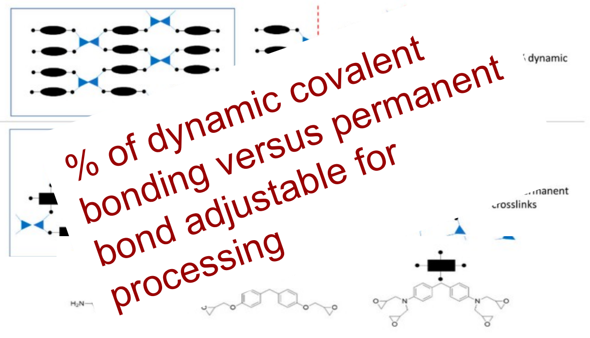
Macromolecular Design Built to Spec.

Vitrimers & Diels Alder Adducts



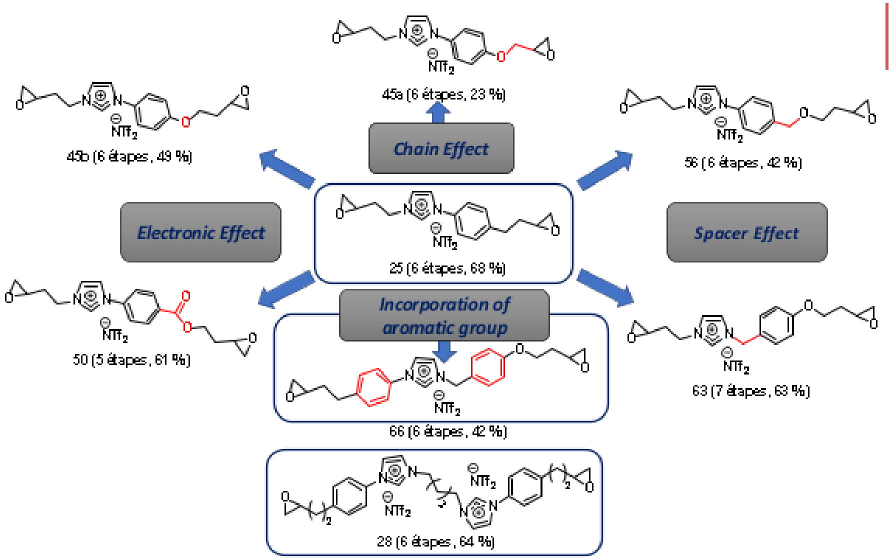
Leibler, & al. 2011 DOI: 10.1126/science.1212648



% of dynamic covalent bonding versus permanent bond adjustable for processing

Aerograde vitrimers based on disulfide covalent bond exchange (*Polymers 2022, 14, 3180. https://doi.org/10.3390/polym14153180*)

Design of new imidazolium ILs bearing two epoxy functions



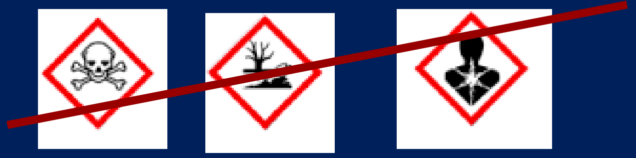
C. Chardin, J.H. Rouden, S. Livi, J. Baudoux, Green Chemistry,129, (2017).
S Livi, L.C Lins, L. B. Capeletti, C Chardin, N Halawani, J. Baudoux, M.B. Cardoso, European Polymer Journal, 116, 56-64 (2019).

Can be designed for end of life chemical link degradation by enzymatic process

3. TOWARDS A CIRCULAR ECONOMY

MACROMOLECULAR ARCHITECTURES

Should be also harm substance free



Could be built to specification for Enzymes or Chemical catalysis for:
(1) Purification, (2) ring cleavage, (3) degradation of biopolymers and (4) cross-linking structure of monomers

Catalysis for selectivity and yield

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4. CONCLUSIONS

CFRP composites are opportunities as lightweight materials

Conditions for their futures are:

- ❑ Minimized the use of materials / Reduction of waste
- ❑ Repairability
- ❑ Incorporate functions for Disassembly/ Segregation / End of Life
- ❑ Reuse / Repurposed / Recycling
- ❑ Develop progressively no harm Bio based formulation with Recycled content
- ❑ Secure Mindful use of critical raw materials
- ❑ Secure raw material sourcing fully certified / Provide evidence through early Life Cycle assessment / Demonstrate costs models

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Advanced manufacturing and sustainable tooling for Carbon fibre Reinforced Thermoplastic processing

José Antonio Dieste
Engineering and Advanced Process Manager

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0034 627 441 629

Advanced manufacturing and sustainable tooling for Carbon fibre Reinforced Thermoplastic processing

COMPOSIFORUM

17 **November** 2022

José Antonio Dieste – Engineering and Advanced Process Manager

0034 627 441 629

Joseantonio.dieste@aitiip.com

Aitiip Technology Center

Fabricating Ideas since 1995

2021 Data

120

Multidisciplinary experienced professionals – Technology Centre and Spin-offs

15 M€ turnover

2 M€ yearly investment for key enabling technologies to the European Industry

17000 m^2

Innovative pilot lines for circular processes and sustainable products

200 customers

65% SMEs // 20% Large Industry // 15% Research, Innovation & Development Centers

1-INTRODUCTION

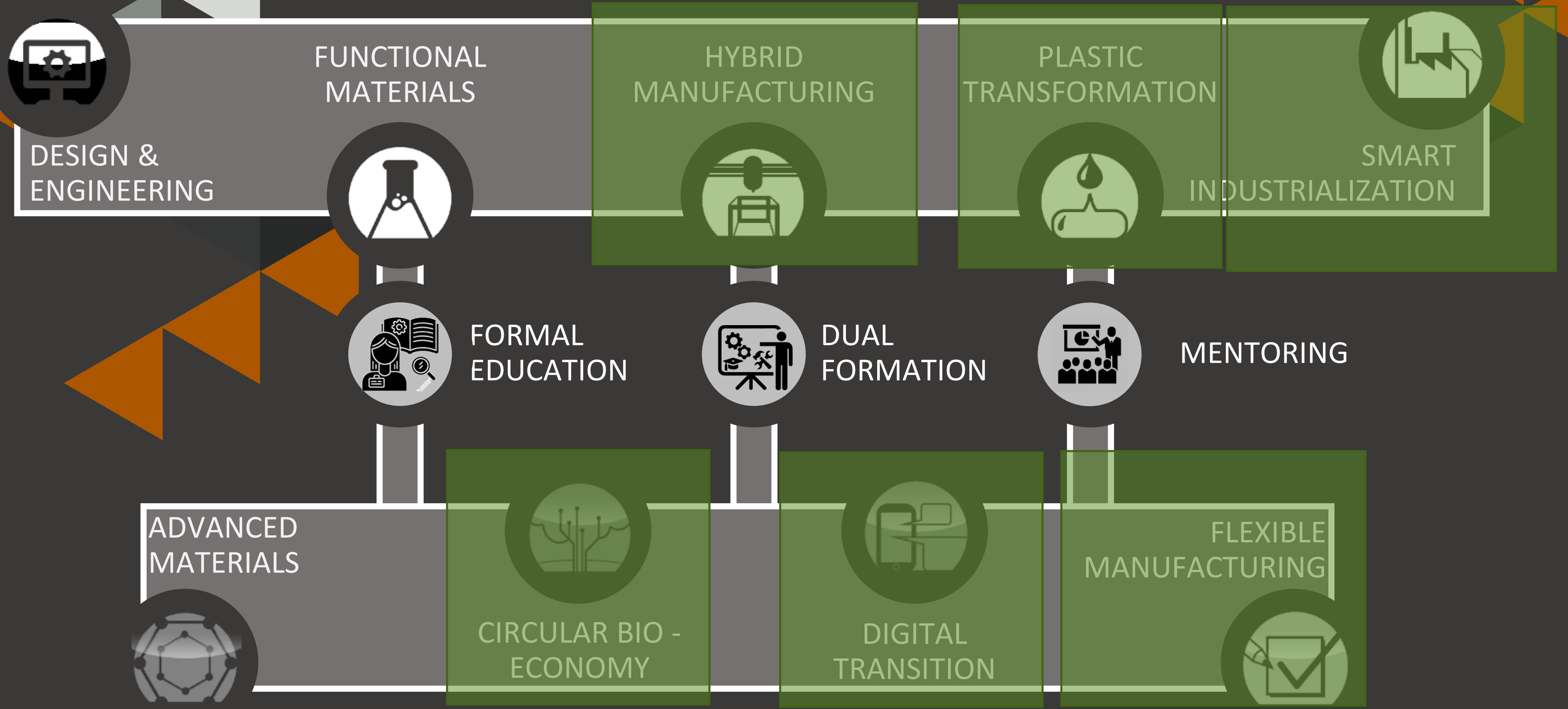
2-Carbon Fibre **Reinforced Thermoplastics**

3-Novel **Process** for **CFRTP**

4-**Joining** CFRTP

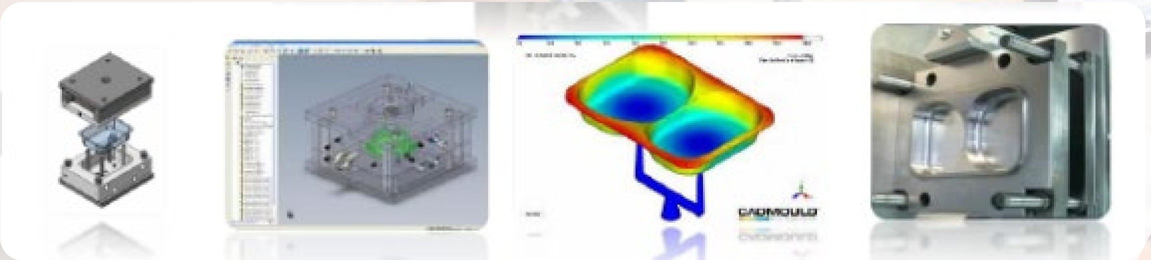
5-Smart Tooling for **CFRP**

Mixed approach - Advanced Industrial Services with Collaborative R&D Projects for a skilled and effective value chain



Design and Engineering

We collaborate effectively in the development of your product from the concept and we optimize it in a dedicated way to its manufacturing process (injection, blow molding, 3D printing, thermoforming...). We carry out CAM, CAD and CAE.



Additive Manufacturing– 3D Printing

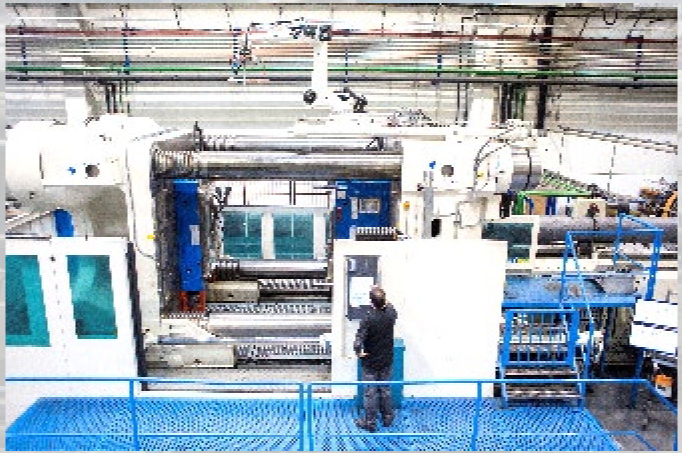
We are the best-qualified European entity for industrial 3D printing for plastic, metal, composite and ceramic parts. We manufacture very large and certified parts and tools. We have FDM, SLS, Polyjet, WAAM technologies…

Mechanical Manufacturing

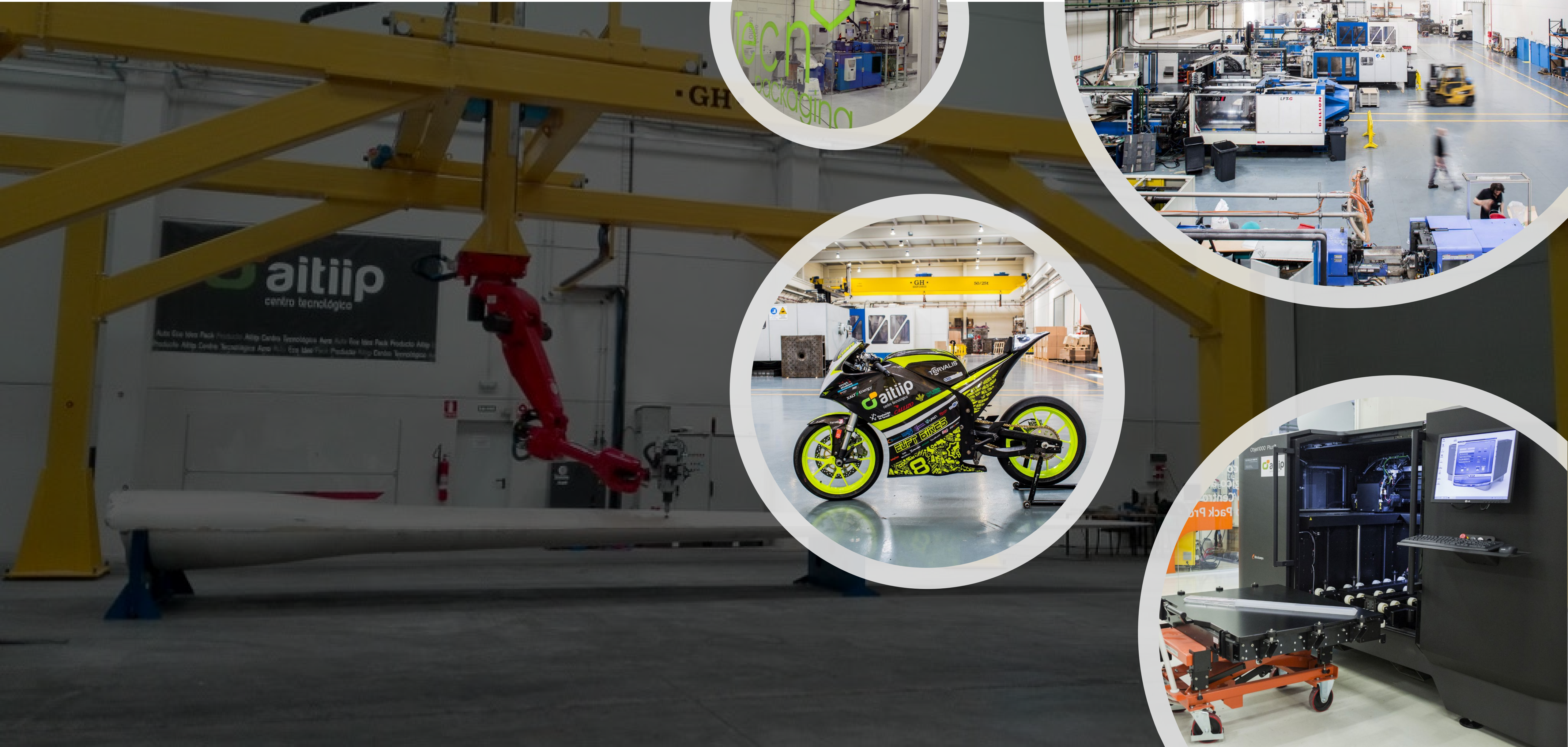
We offer our clients the most advanced means of production in the field of mechanical manufacturing for the production of moulds, tools and unitary parts with the highest dimensional and functional quality.

Plastic Transformation

We have all the technologies for the transformation of plastic: injection thermoplastics (25t to 4000t), blown extrusion, thermoforming and blown film and thermosetting, composite, biobased and biodegradable materials.



Large scale demonstration & **Spin off** creation



1-INTRODUCTION

2-Carbon Fibre Reinforced Thermoplastics

3-Novel **Process** for **CFRTP**

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Carbon Fibre **Reinforced Thermoplastics**

THERMOSET POLYMERS

POSSITIVE

- Able to be moulded with different tolerances
- Allows for flexible product designs
- Improved structural integrity through variable wall thicknesses
- Typically, cheaper than components fabricated from metals
- Superb electrical insulation properties
- Excellent heat resistance at high temperatures
- Corrosion resistant
- Strong dimensional stability
- Low thermal conductivity
- Cheaper setup and tooling costs than with thermoplastics
- High strength-to-weight ratio
- Water resistant
- Wide range of colours and surface finishes

NEGATIVE

- Cannot be reshaped or remoulded
- Cannot be recycled

THERMOPLASTIC POLYMERS

POSSITIVE

- Good adherence to metals
- High quality aesthetic finish
- Can be recycled and reshaped with little impact on material properties
- Resistant to chemicals and detergents
- Good electrical insulation
- High impact resistance
- Enhanced anti-slip properties
- Can create both rubbery and hardened crystalline surfaces
- Resists chipping
- Corrosion resistant

NEGATIVE

- Not suited to all applications due to softening when heated
- Typically, more expensive than thermosetting polymers

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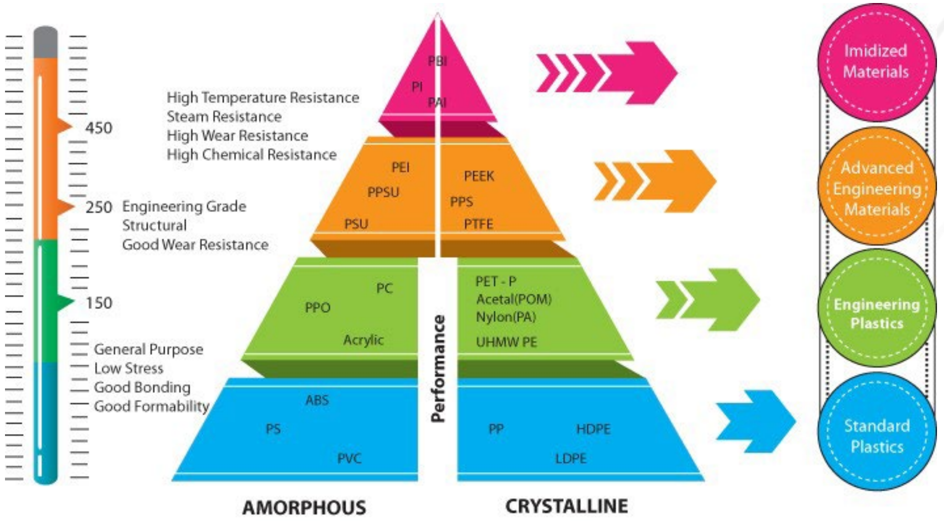
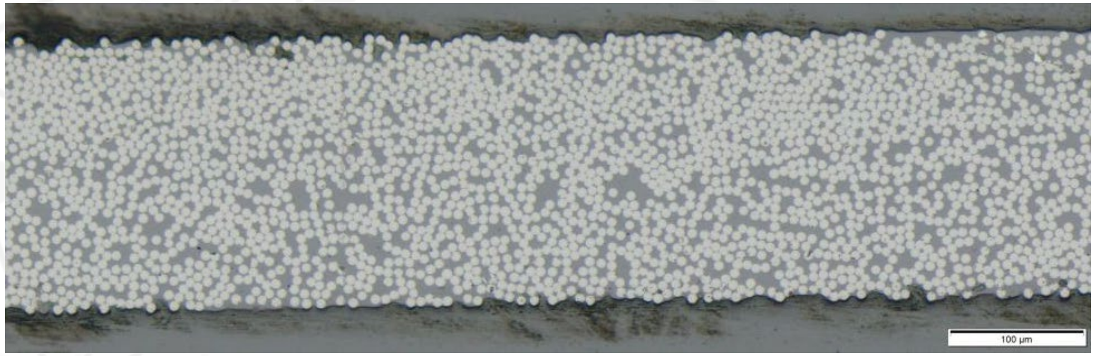
Carbon Fibre **Reinforced Thermoplastics**

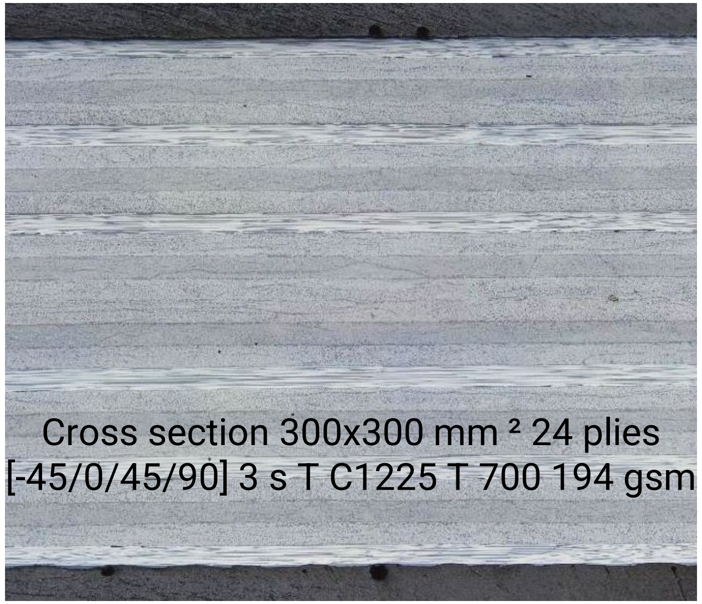
THERMOPLASTIC POLYMERS

Polyaryletherketones (PAEK) are semicrystalline polymers. They exhibit good stability and mechanical strength at high temperatures. PAEK is extremely resistant to chemicals and hydrolysis, making them ideal for medical applications, oil drilling components, automotive gears, etc.





PROPERTY	VALUE
Nominal Consolidated Ply Thickness (TC1225 194gsm) (mm)	0,185
Nominal resin content (%)	34
Glass Transition Temperature (ºC)	147
Melt Temperature (ºC)	305
Typical processing temperature (ºC)	340-385



Cross section 300x300 mm ² 24 plies
[-45/0/45/90] 3 s T C1225 T 700 194 gsm

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1-INTRODUCCIÓN

2-Carbon Fibre Reinforced Thermoplastics

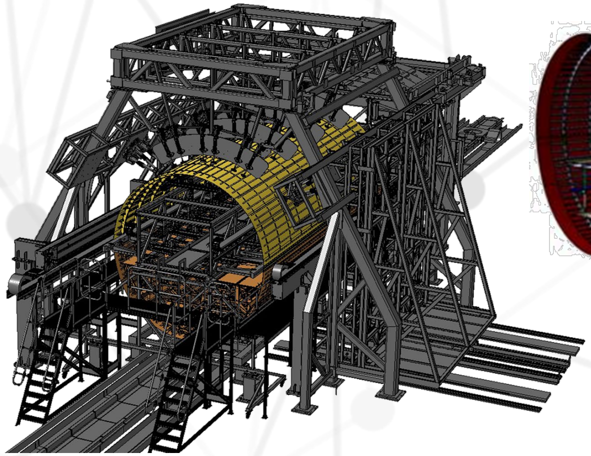
3-Novel Process for CFRTP

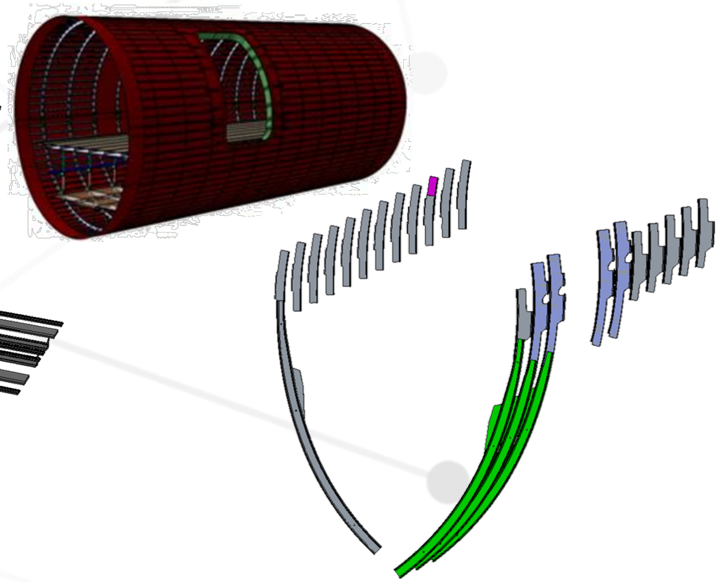
4-**Joining** CFRTP

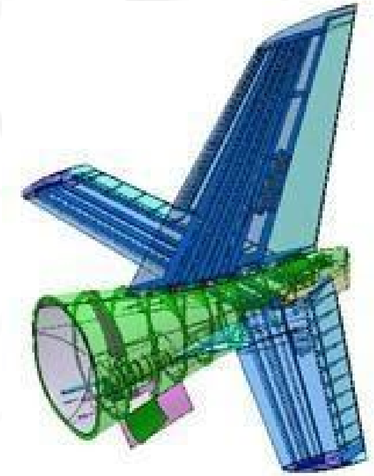
5-Smart Tooling for **CFRP**

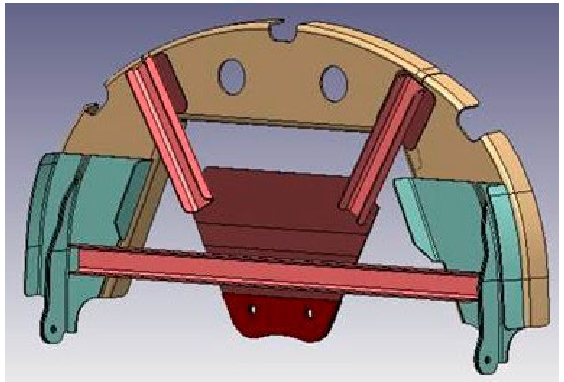
Novel **Process** for **CFRTP**

The next generation Multifunctional Fuselage Demonstrator (leveraging thermoplastics for cleaner skies)









leverage the full potential of thermoplastic composites in aviation

weight reduction and the lowering of recurring costs in aircraft production when using thermoplastic composites

high potential combinations of airframe structures, cabin, cargo and system elements using composite thermoplastics

processing is evaluating thermoplastics which are easy to model by pressing or stamping using high-production processes

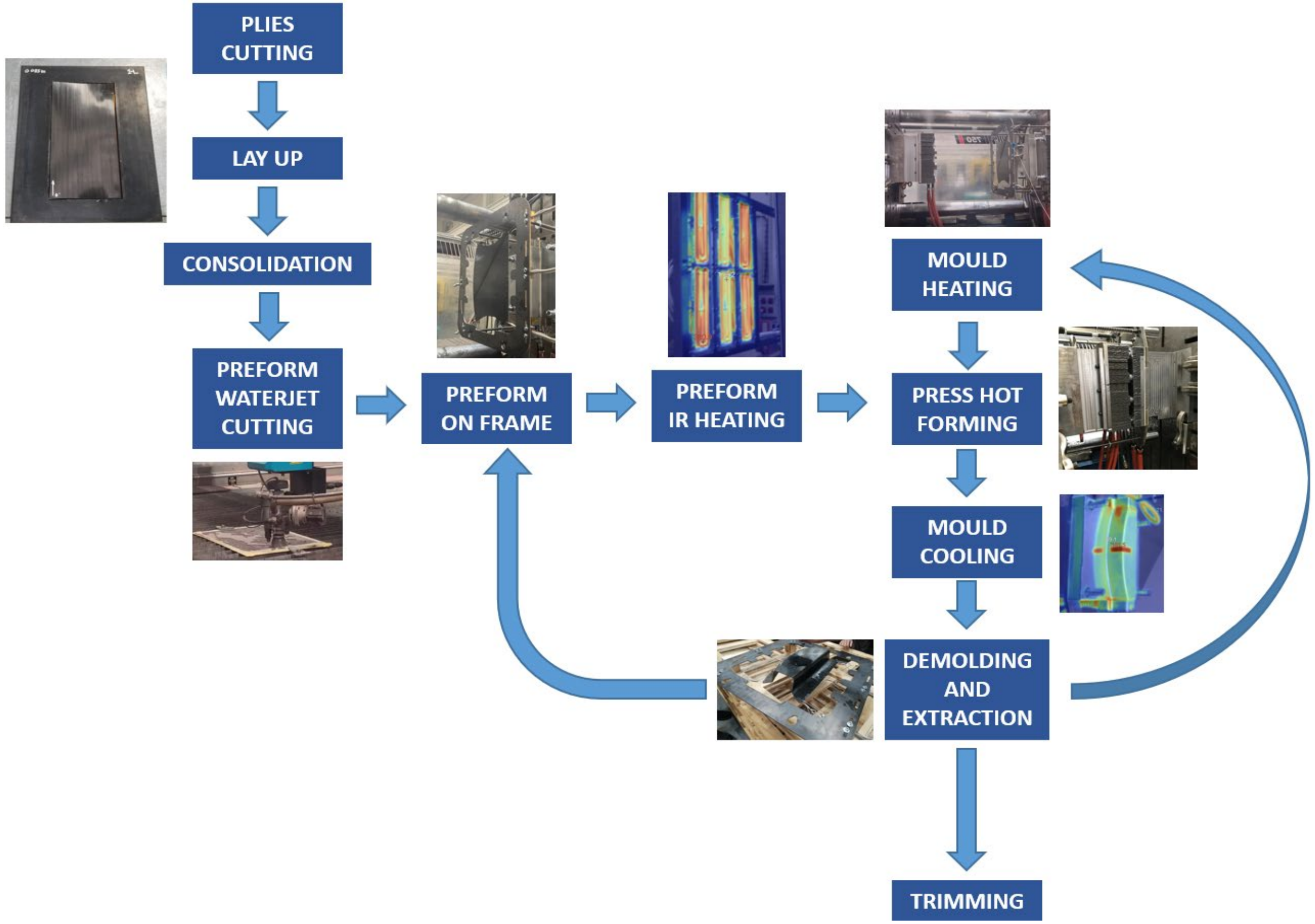
using thermoplastic material, components at the end of their service life can be recycled

new thermoplastic joining technologies that enable moulded elements to be combined into larger components

Novel **Process** for **CFRTP**

While it can be made malleable through the application of heat, because the natural state of the thermoplastic resin is solid, it's difficult to impregnate it with reinforcing fibre. The resin must be heated to the melting point and pressure must be applied to integrate fibres, and then, the composite has to be cooled, all while still under pressure.

Special tooling, techniques, and equipment must be used, many of which are expensive. The process is much more complex and expensive than traditional thermoset composite manufacturing.



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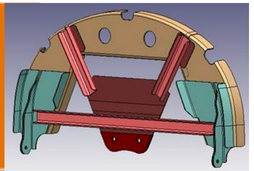
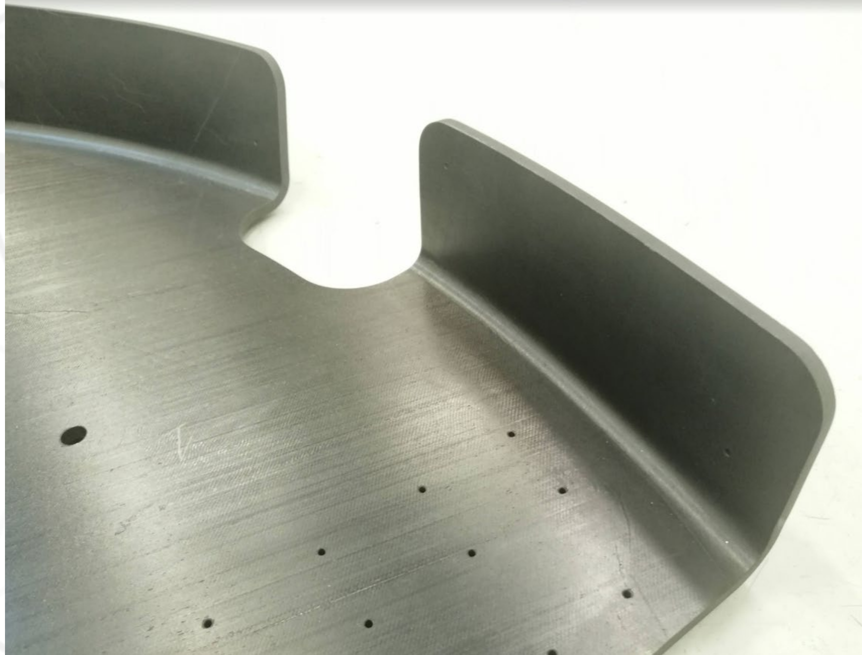
IMI-03
750

Novel Process for CFRTP





INNOTOOL
INNOVATIVE TOOLING DESIGN

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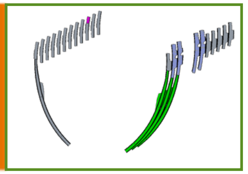
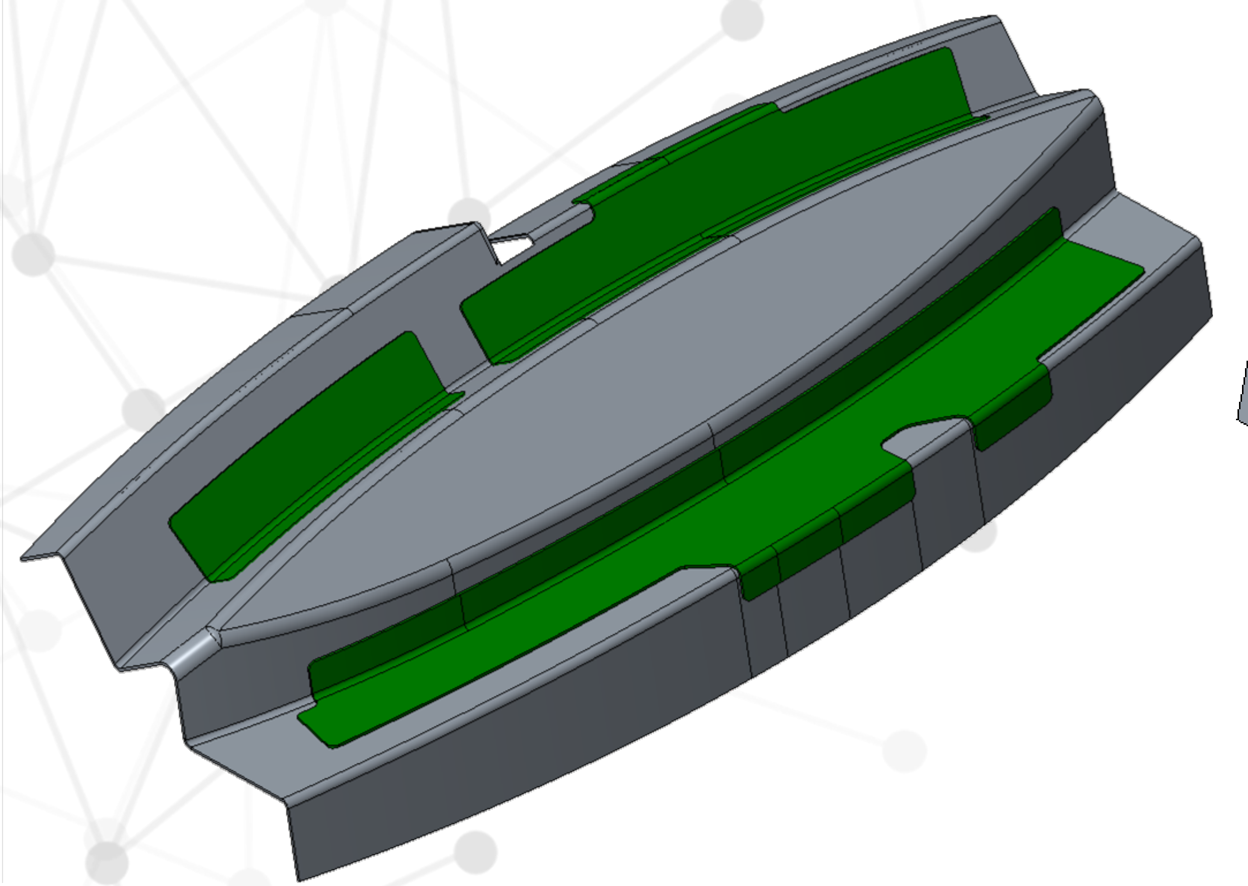
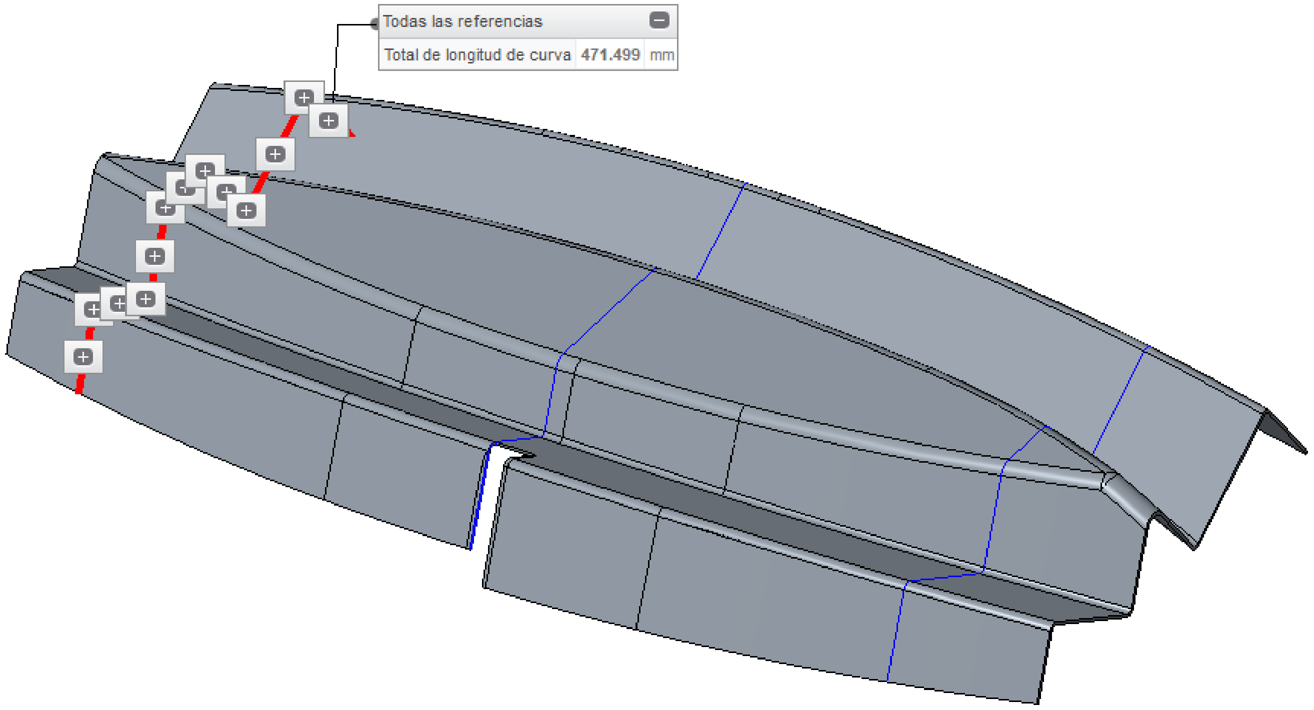
Novel Process for CFRTP



Blanket preparation

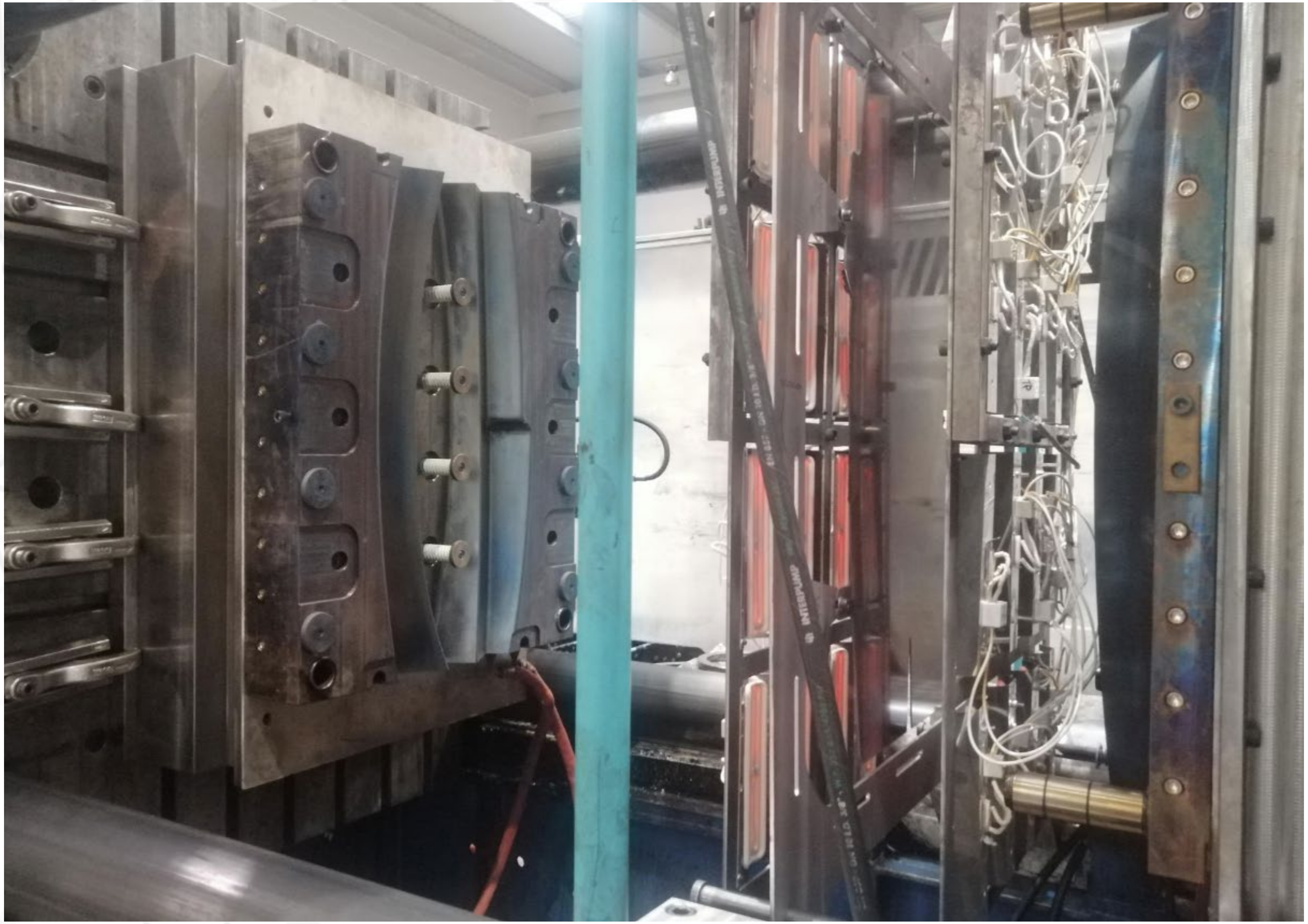


Water Jet. No delamitation

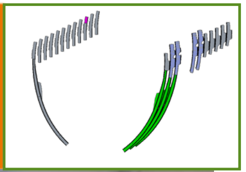


Flat: 325mm
Curved: 475 mm

Novel Process for CFRTP



Novel Process for CFRTP



1-INTRODUCTION

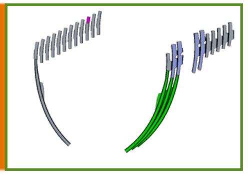
2-Carbon Fibre Reinforced Thermoplastics

3-Novel Process for CFRTP

4-Joining CFRTP

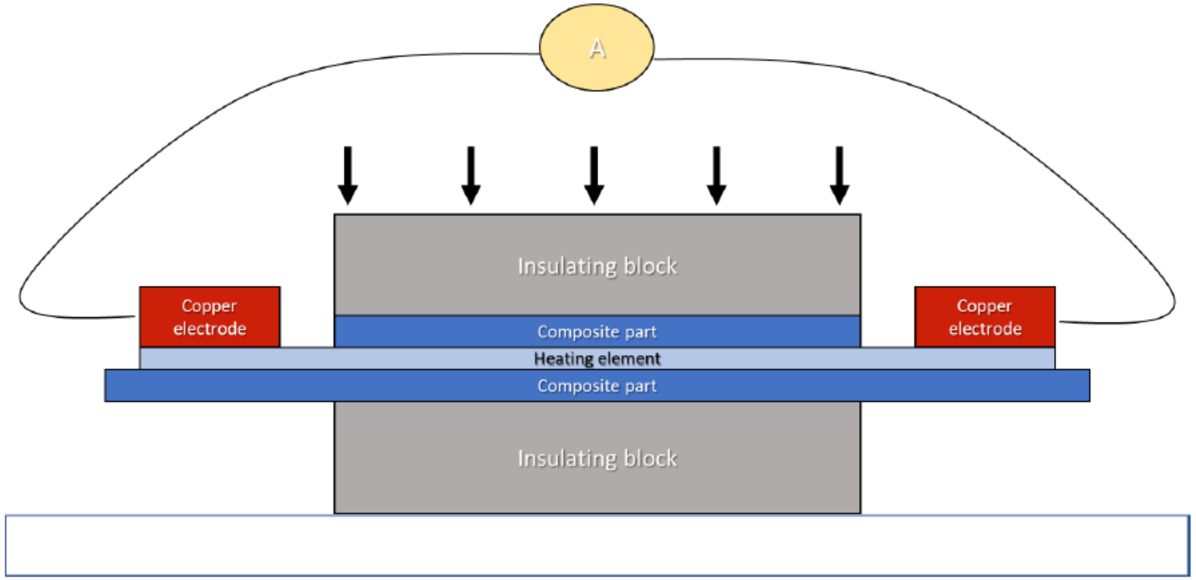
5-Smart Tooling for **CFRP**

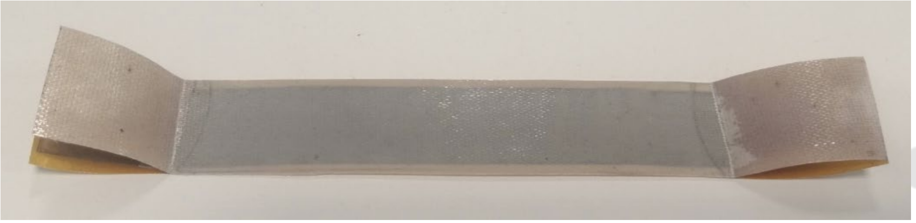
Novel **Process** for **CFRTP (Joining)**

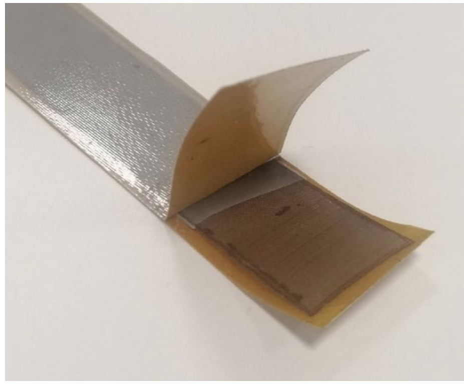


RESISTANCE WELDING

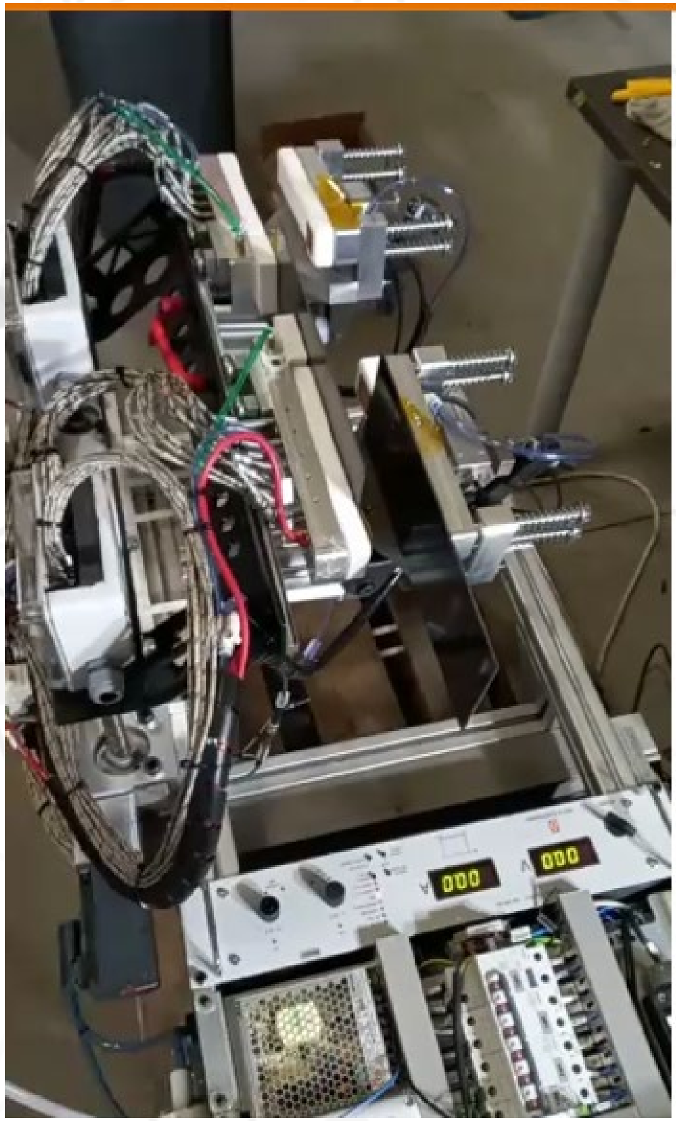
Resistance welding is a well-known technique which entails the use of a heating element sandwiched between the parts to weld Electrical power, provided to the heating element through electrode connection, heat up the material, following the Joule's Law, where the energy dissipated (E) from the resistor is proportional to the resistance (R), current (I) and time (t)

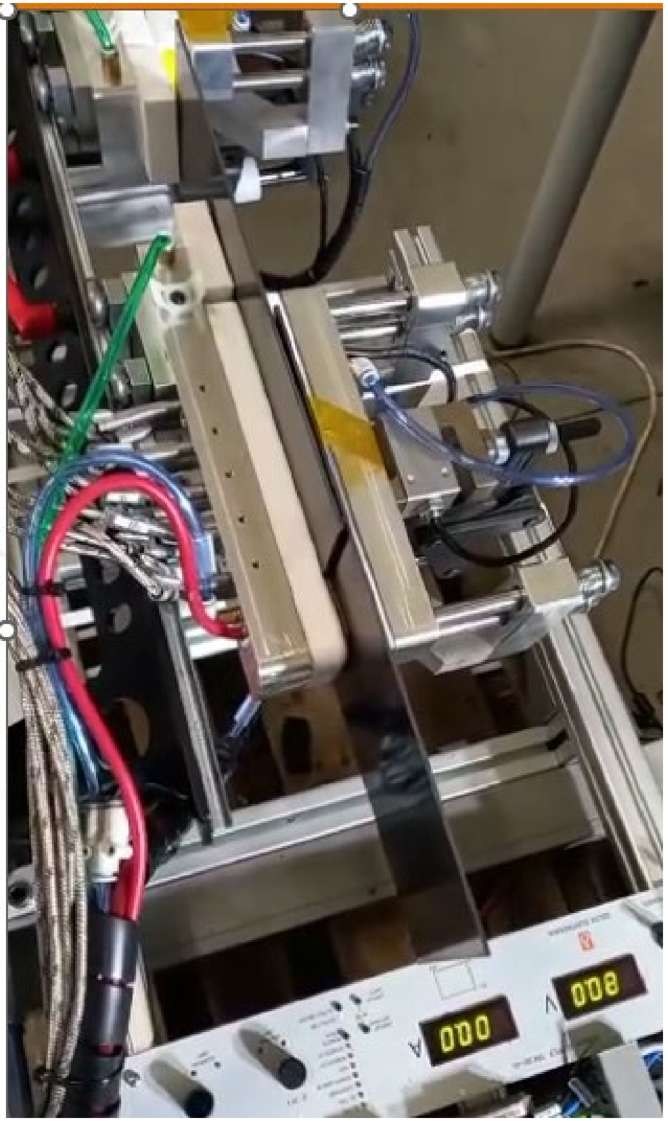






Novel Process for CFRTP (EoL)





RESISTANCE UN-WELDING

Future EoL of CFRTP aircraft. Product recovery, by disassembling

1-INTRODUCTION

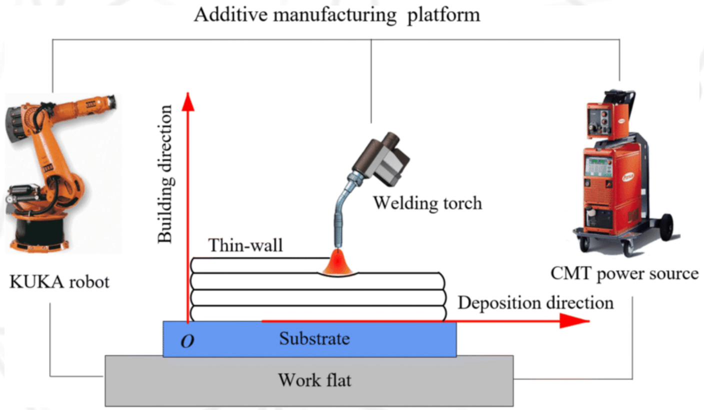
2-Carbon Fibre Reinforced Thermoplastics

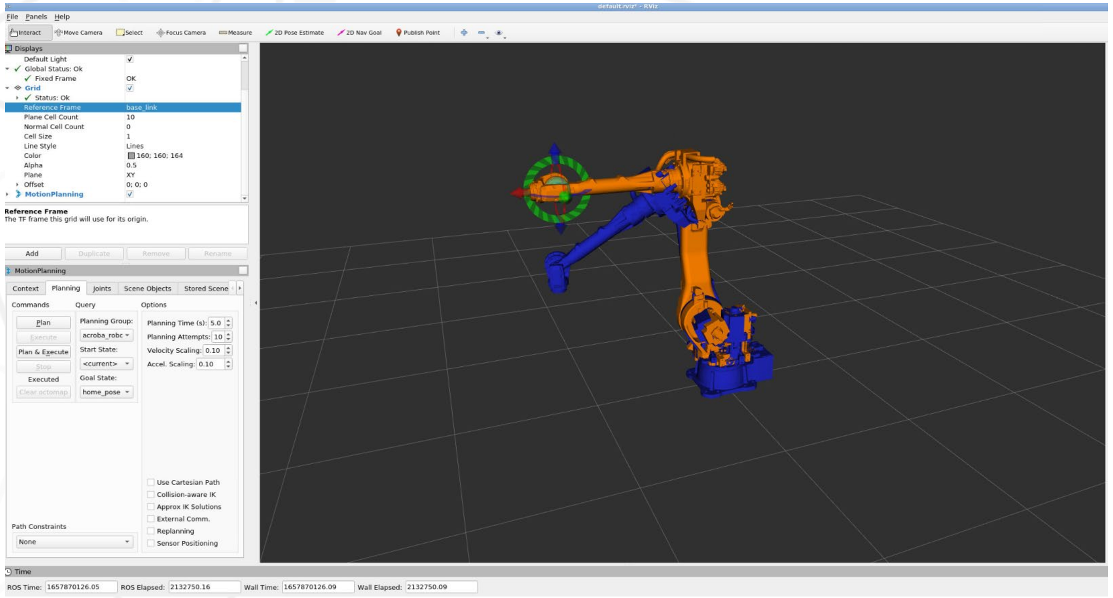
3-Novel Process for CFRTP

4-Joining CFRTP

5-Smart Tooling for CFRP

Smart Tooling for CFRP





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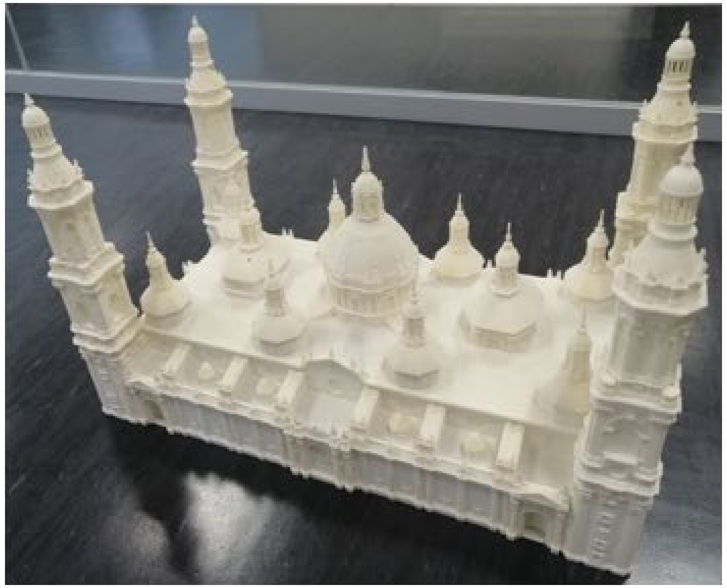

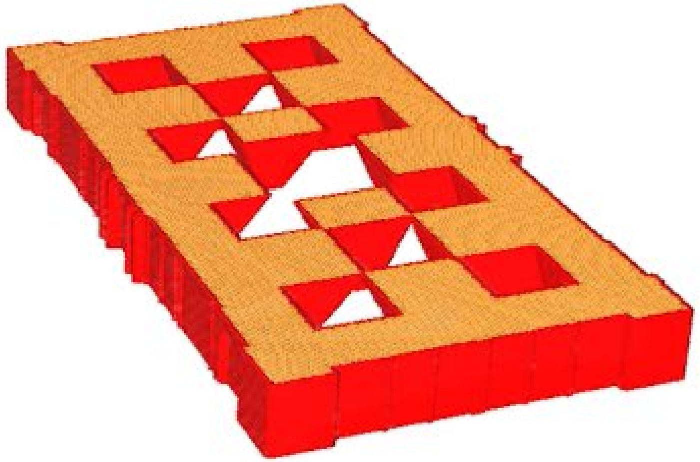

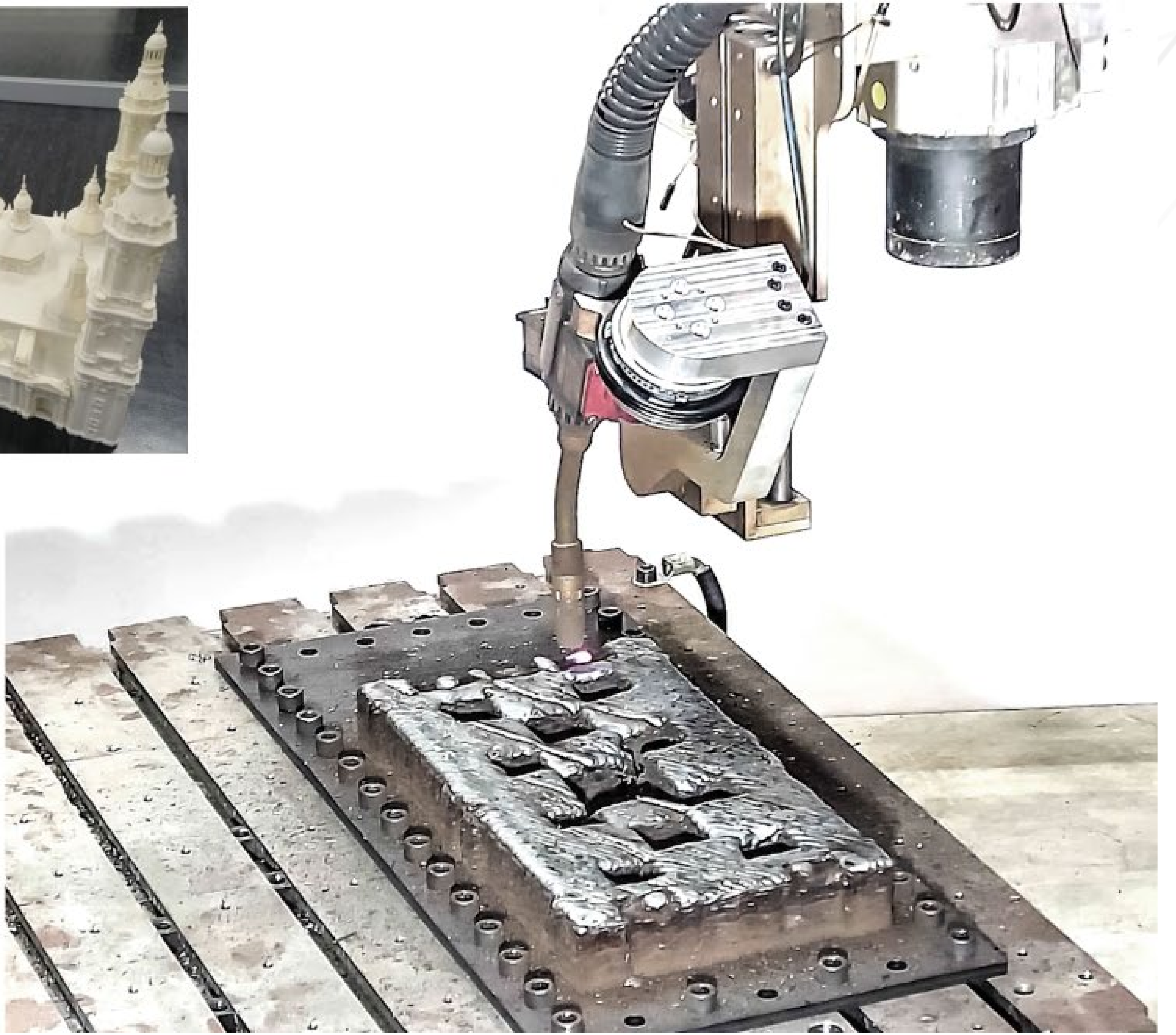

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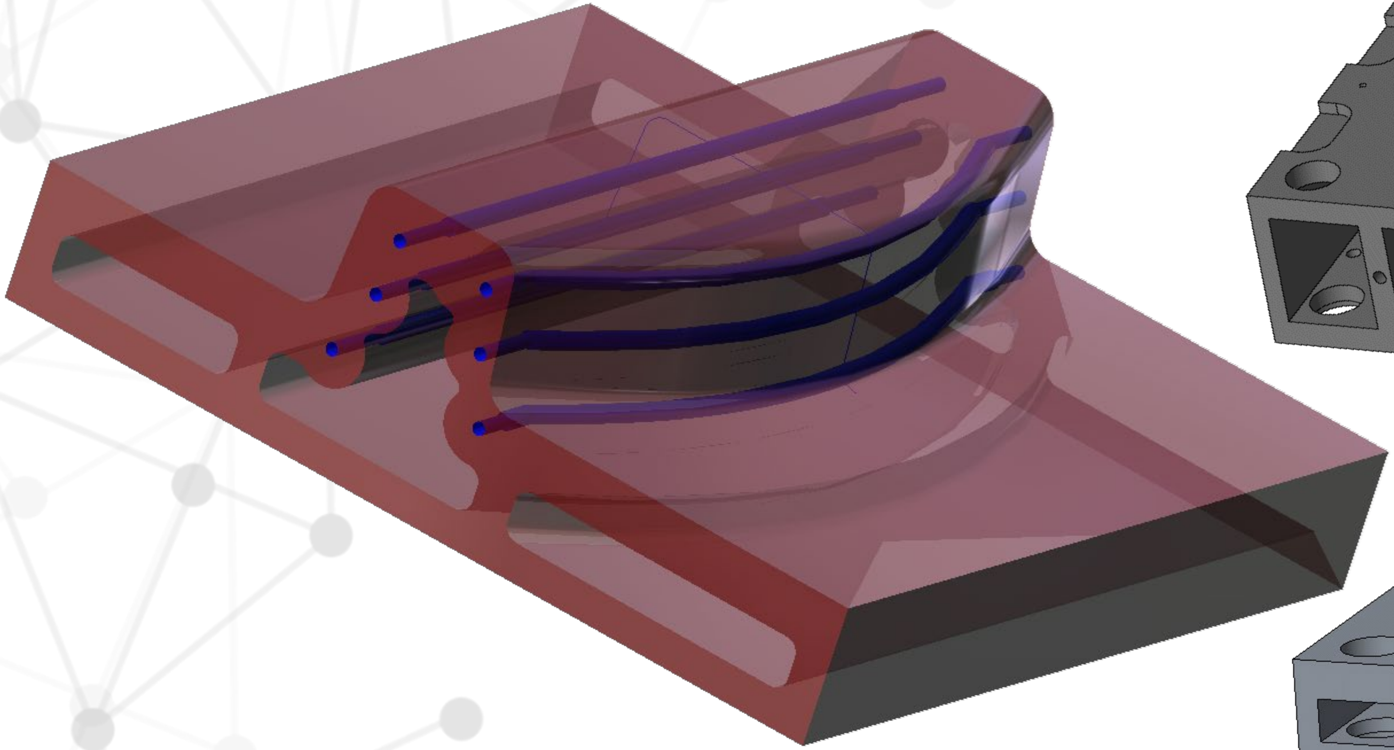
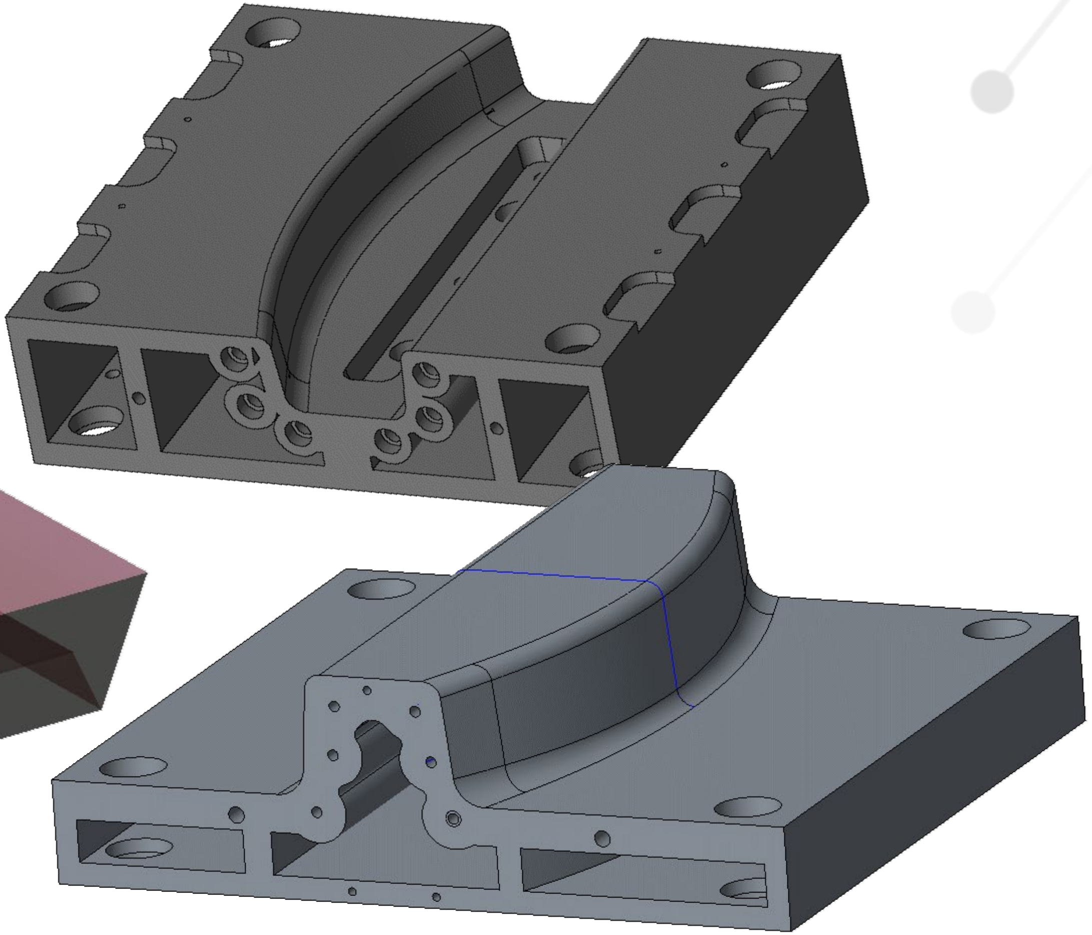
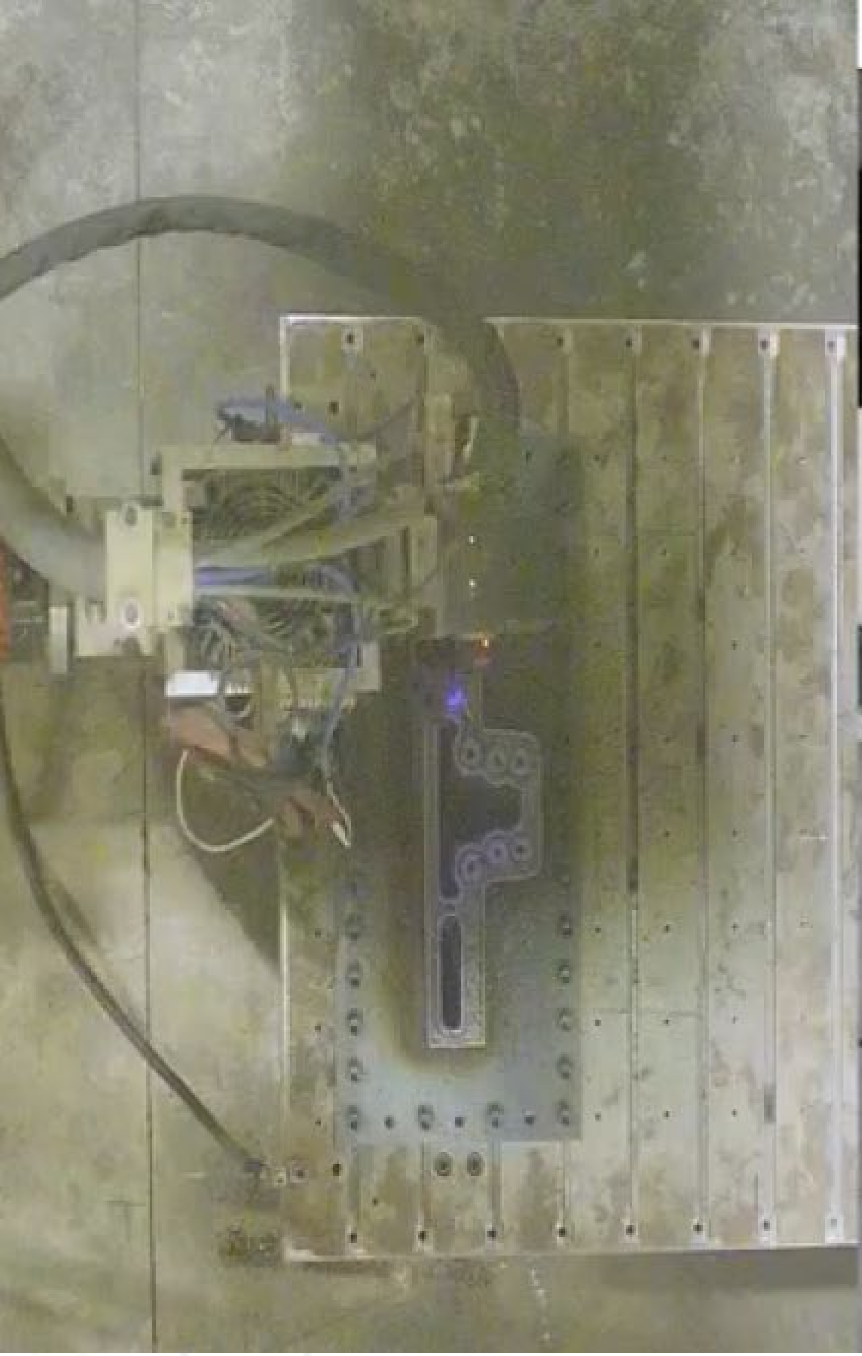
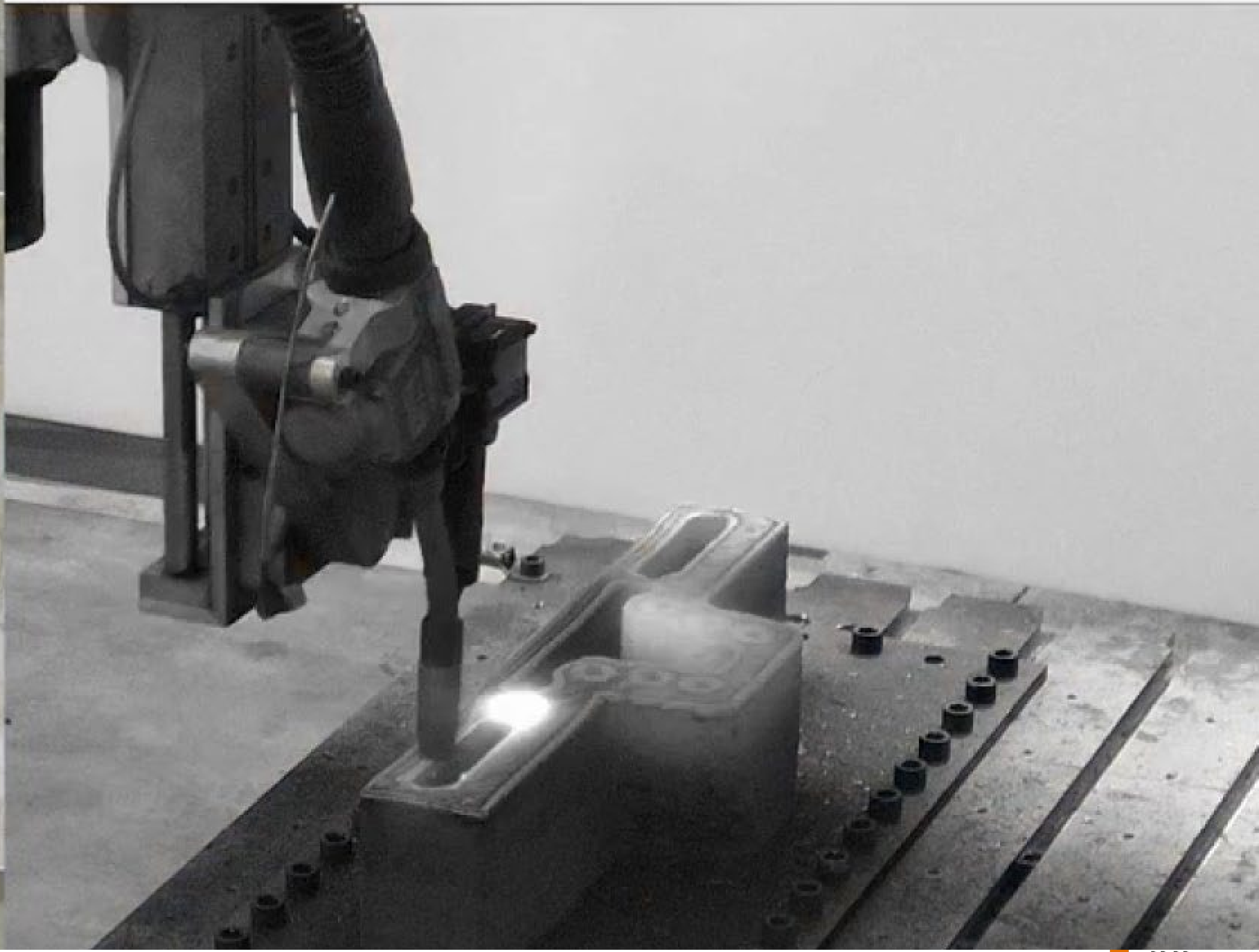
Smart Tooling for **CFRP**









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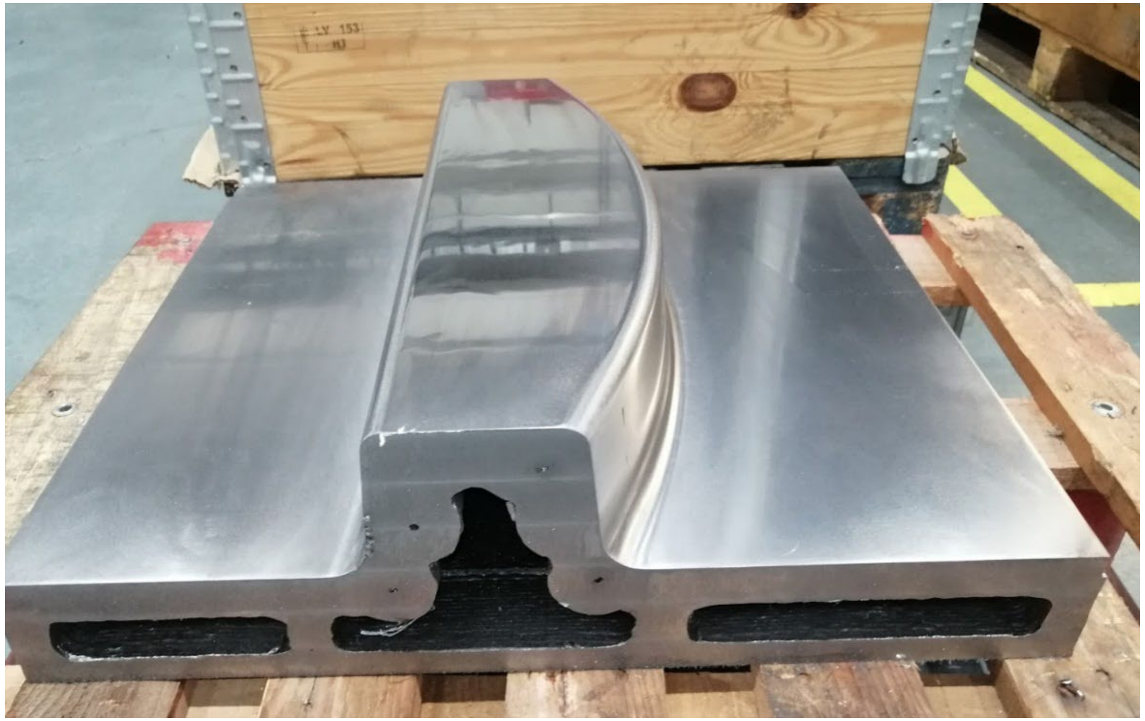
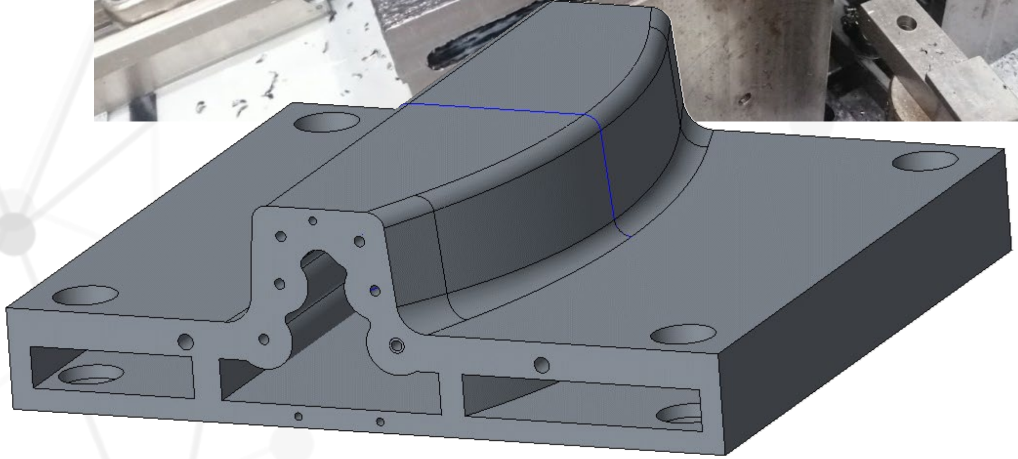
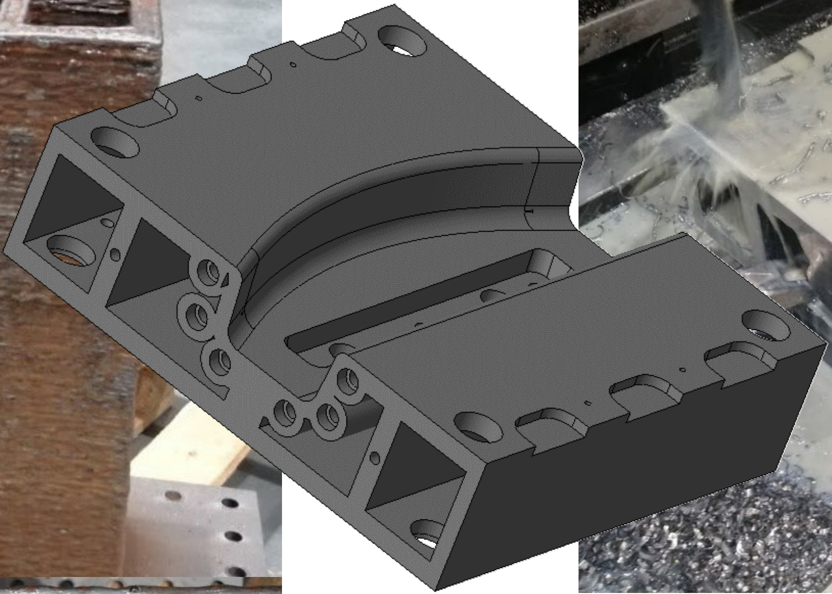
Smart Tooling for **CFRP**

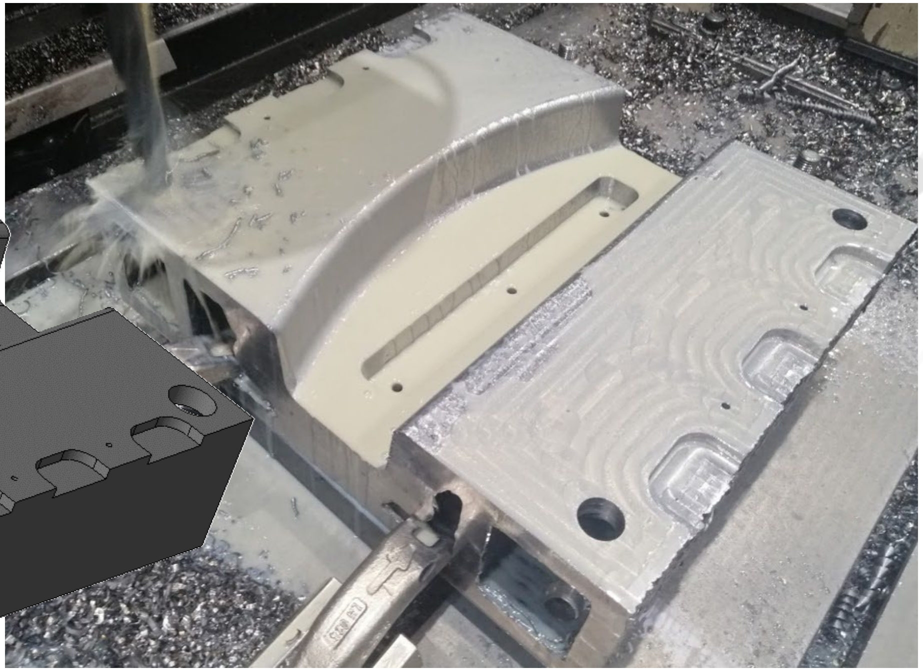




TRADITIONAL MANUFACTURING	**RAW MATERIAL**	**260 kg**
	FINAL WEIGHT	**156,5kg**
INNOTOOL MANUFACTURING	**RAW MATERIAL**	**145 kg**
	FINAL WEIGHT	**96,5kg**

Smart Tooling for **CFRP**





TRADITIONAL MANUFACTURING	**RAW MATERIAL**	**230 kg**
	FINAL WEIGHT	**199kg**
INNOTOOL MANUFACTURING	**RAW MATERIAL**	**171,5 kg**
	FINAL WEIGHT	**118,5kg**

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Smart Tooling for **CFRP**

IMPACT RESULTS

THERMAL INERTIA REDUCTION:

Core plate: Thermal Inertia Reduction 38%

Cavity plate: Thermal Inertia Reduction 40%

RAW MATERIAL CONSUMPTION

Core plate: Material consumption reduction: 45%

Cavity plate: Material consumption reduction: 25%

EXPECTED BENEFITS FOR AIRCRAFT INDUSTRY

Manufacturing time reduction: Thermal inertia reduction will reduce heating and cooling time, thus reducing the press hot forming time.

Increase of the production capabilities: Potential increasement of the production batches

Environmental. Reduction of the raw material consumption for tooling manufacturing. Energy reduction consumption as manufacturing time is reduced.

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THANK YOU FOR YOUR ATTENTION

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Sesión de Circularidad

Bringing thermoset materials to a circular economy through recycling technologies

Julio Vidal
Head of composite materials-Aitiip

0034 684 468 701 julio.vidal@aitiip.com

Bringing thermoset materials to a circular economy through recycling technologies

COMPOSIFORUM

17 November 2022

Julio Vidal- Head of composite materials

0034 684 468 701

julio.vidal@aitiip.com

Aitiip Technology Center

Manufacturing Ideas since 1995

2021 Data

120

Multidisciplinary experienced professionals – Technology Centre and Spin-offs

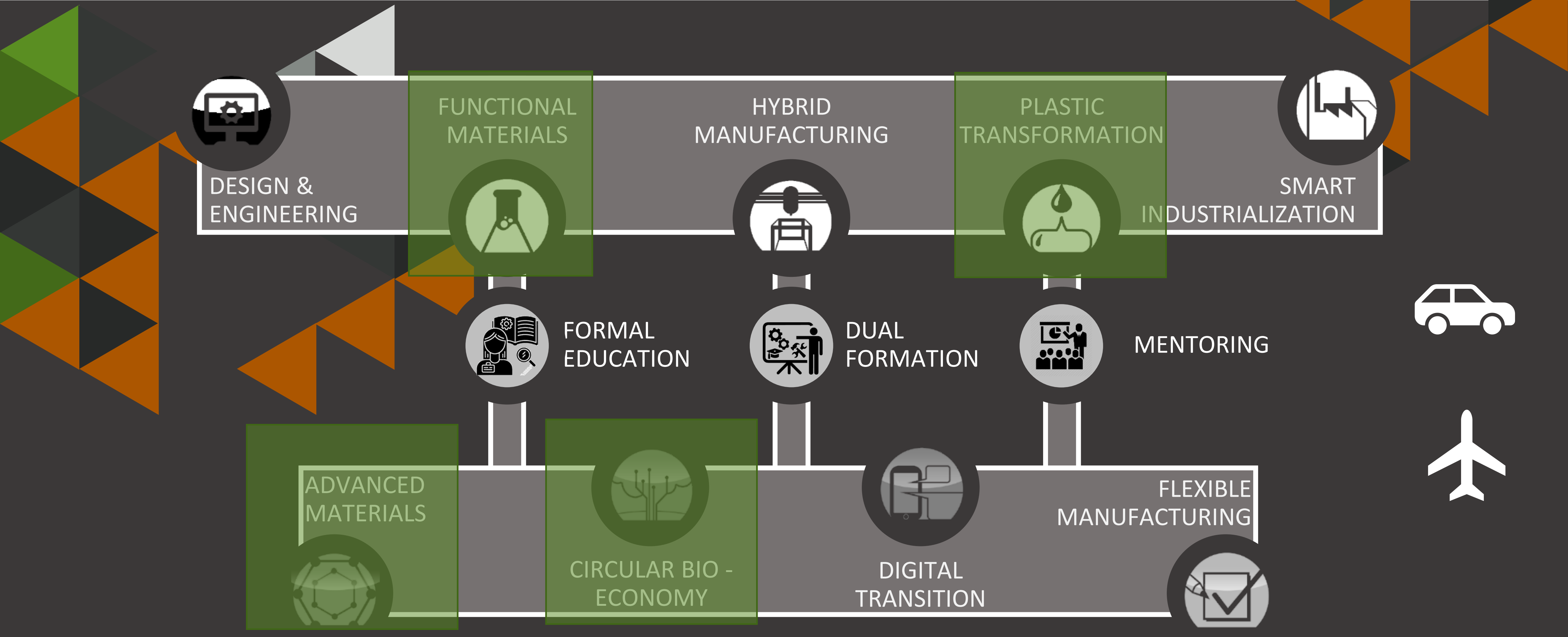
17,000 m^2

Innovative pilot lines for circular processes and sustainable products

200 customers

65% SMEs // 20% Large Industry // 15% Research, Innovation & Development Centers

Mixed approach - Advanced Industrial Services with Collaborative R&D Projects for a skilled and effective plastic value chain



Your partner for industrial demonstration in international projects

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Aitiip makes transfer of knowledge to its spin-offs and Industry

+ 300 European partners

moses advanced materials

First EU Project

2 EU Projects

2022

14 EU Projects

2021

2019

9 EU Projects

2013

2012

First EU Project

2010

New facilities

tecno tp packaging

1995

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Our Spin-offs brings into the market Commercial Products & Technologies

Our Spin-offs are conceived as technology based with a strong R&D spirit

BIZENTE

Apply Ligninases To Resolve End-of-life Issues of Thermoset Composite Plastics

www.bizente.eu

VIBES

www.vibesproject.eu

REVOLUZION

www.revoluzionproject.eu

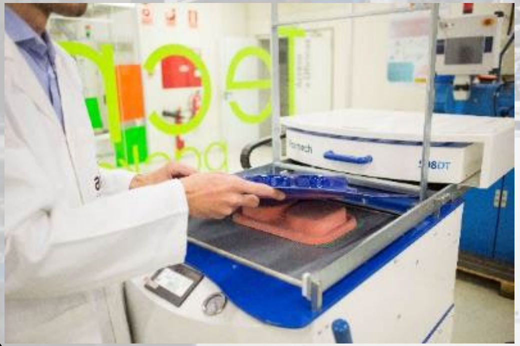
EOCENE

Economía Circular y Sostenibilidad de Composites Termoestables

Pilots plants

We offer all our capacities to install pilot demonstration plants in our industrial facilities.

Different technologies for thermoplastics: injection, blow molding, extrusion, casting, thermoforming, 3Dprinting.



Pilot Plants

We offer all our capacities to install pilot demonstration plants in our industrial facilities.

Different technologies for thermosets: RTM, infusion, hot-forming) SMC (Sheet Moulding Compound) y BMC (Bulk Moulding Compound)

Issue

This project has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N° 101023190.

Thermoset composite waste management aren't currently properly recycled and they are either incinerated (42.6%) or diverted to landfill (24.9%) due to their **inherent complexity.**

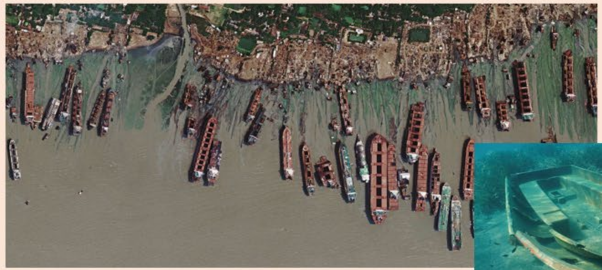
Hundreds of wind turbine blades buried in Wyoming in the US (February 2020)

Tucson, Arizona, 309th AMARG (Aerospace Maintenance and Regeneration Group) : The largest 'aircraft cemetery' in the world, with capacity for 5000 aircraft.

PLATA (Teruel Airport´s aircraft parking and dismantling area)

ACCIONA 100% composite civil constructions (Examples: lighthouse in Valencia & walkway in Madrid)

Thousands of retired cars waiting to be dismantled (Madrid, 2016)



1.6 kilometers of Bangladeshi coastline (Chittagong, 2014), where ships from all over the world embark and dismantle

Sunk & abandoned vessels

VEOLIA dismantling area at Torvilliers site (France)

VIBES

- **Decrease the amount of non-biodegradable polymers sent to disposal** or even discharged to the environment in more than 40%.
- **Development of a new green technology** focused on the **controlled separation and recovery** of composite materials **by means of developing customised biobased bonding materials (BBM).**

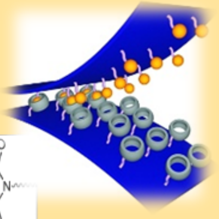
VIBES project proposed solution

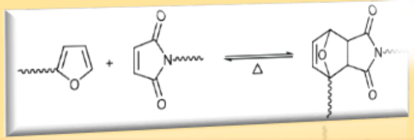
This project has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N° 101023190.

Building up the VC

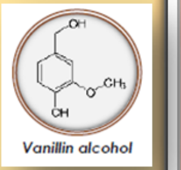
100% Biobased bonding materials:

- Supramolecular
- Diels-Alder
- Vitrimers

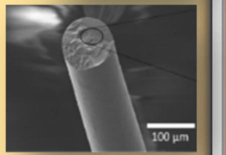




Alternative 100% **biobased thermoset precursors** and resins (bio-epoxy, -vinylester, -polyester)



Alternative **100% biobased fibers** (flax and TPU-lignin based BioCarbonFiber)

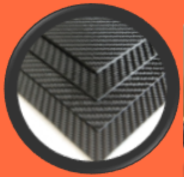


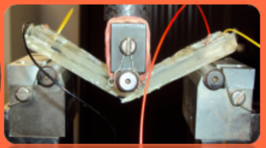
Activation of fiber´s surface (plasma, AP-PECVD)

Composite Components to obtain intrinsinc reciclable composite materials

- Modified fibers
- Modified fabrics (with/without sizing)
- Smart Bioresins

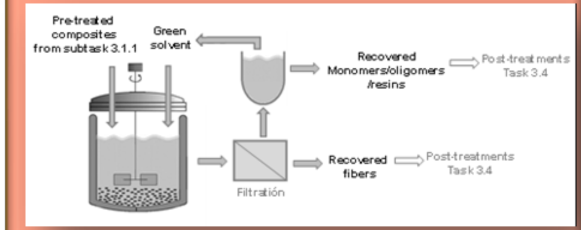
Ecodesign
Prototyping/Samples
Technical Validation





Recycling
Pre-treatment sequece

Washing with Green solvents



Designing and Implementing the Recycling Technology

Valorization of fibers and monomers/oligomers into new industrial products for selected sectors

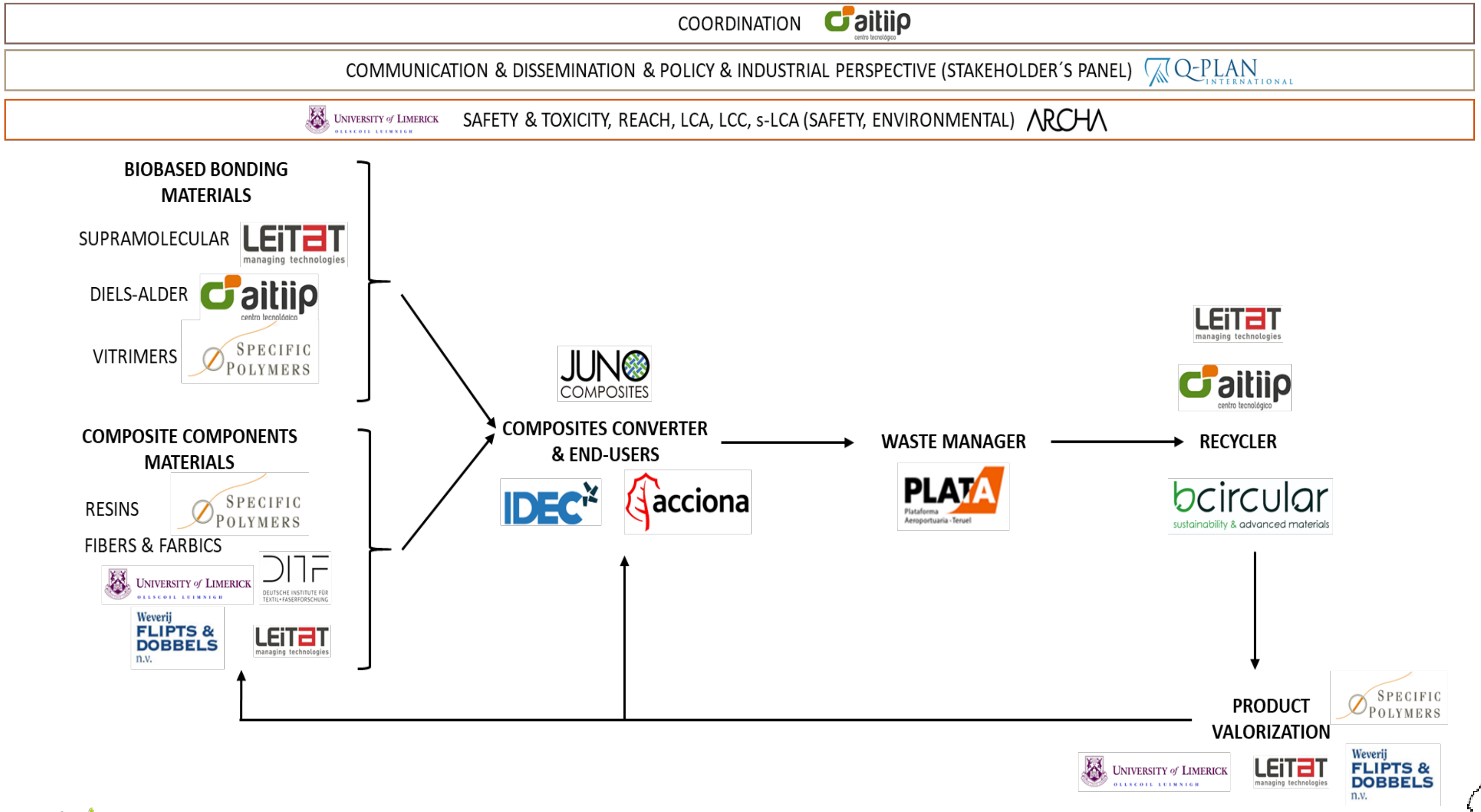
- Environmental assessment: **LCA**, **s-LCA** (social perspective), Economical assessment: **LCC**, market analysis
- **EPR** considerations
- **Collecting and Directing** waste
- **Regulation** compliance
- **Toxicity & Safety**
- Defined **IPRs & Business strategy**
- **Training plan** to create skilled jobs
- Dissemination and **social awareness**

FROM LAB SCALE TO PILOT SCALE

TRL3 → TRL5

VIBES consortium

CBE JU



BBI JU
Bio-based Industries Joint Undertaking

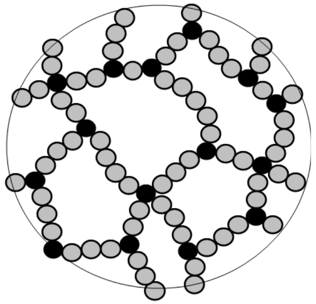
Dynamic Covalent Network (DCN)

This project has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N° 101023190.

Bridging the gap between thermoplastics and thermosets

VIBES

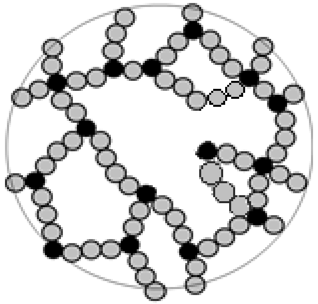
Immobile network



Dynamic Covalent Network

← low temperature | high temperature →

Mobile network



Reactive Extrusion

Supramolecular approach

Vitrimer-like (CAN) approach

Diels-Alder (DA) approach

Biobased **B**onding **M**aterials (BBM)

DCN- Supramolecular

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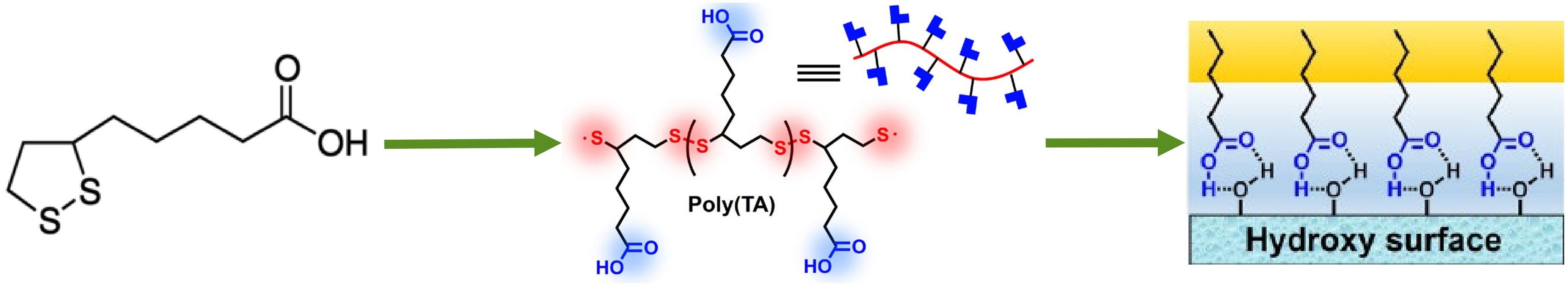
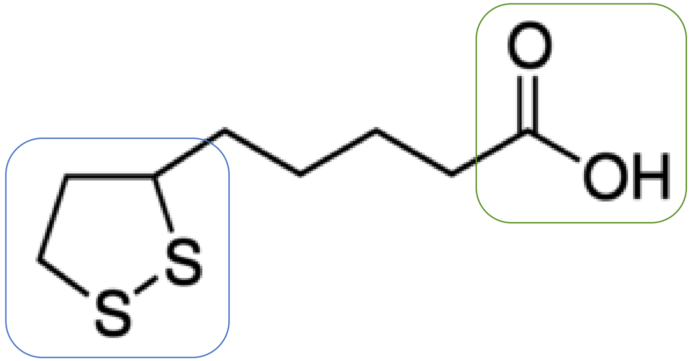
The BBM strategy of Leitat is based in TA and its derivatives



Dynamic covalent bond

5-membered ring for ROP
Click-chemistry based functionalization



Non-covalent site

Non-covalent site for supramolecular interactions
Susceptible group

DCN- Vitrimers

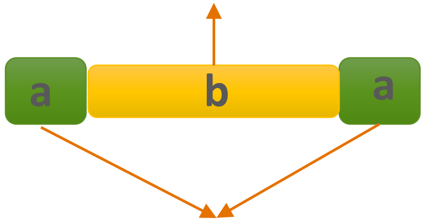
This project has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N° 101023190.

Vitrimers are covalent networks, which can change their topology through a thermally activated reactions (bonds)

BBM – resin/resin interface – resin hardeners

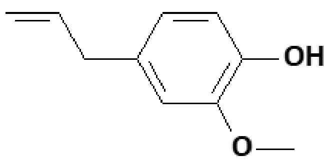
Disulfide/imine

To impart the BBM with reversible properties

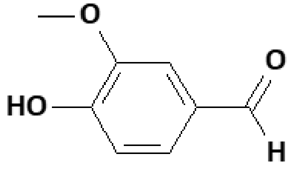


To connect the BBM to the resin

Amine/epoxide/ vinyl ester



Eugenol

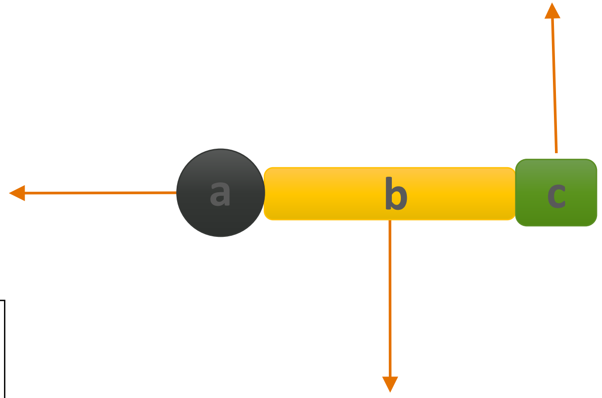


Vanillin

BBM – fiber/resin interface

Epoxy/methacrylate/ amine

To connect the BBM to the resin



To connect the BBM to the fiber surface

Alkoxysilane/amine/ acids/isocyanate

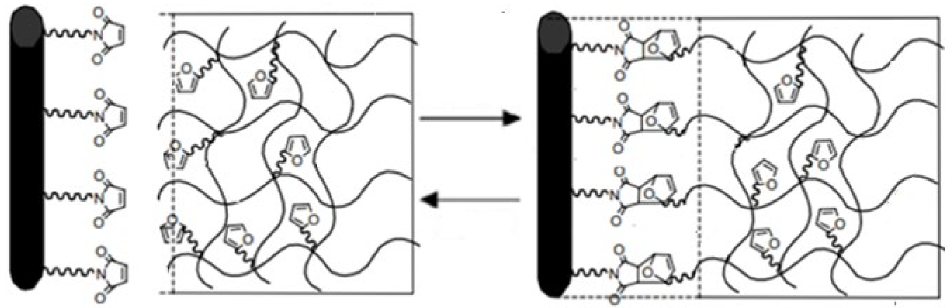
To impart the BBM with reversible properties

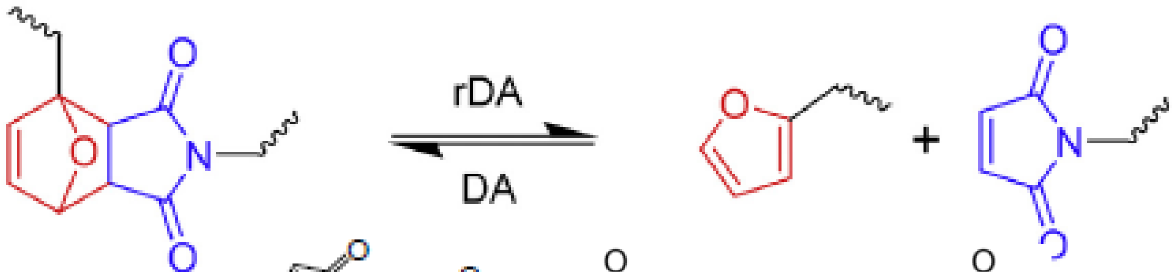
Disulfide/imine

DCN- Diels-Alder

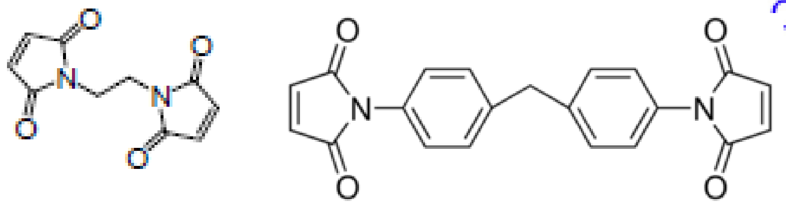
This project has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N° 101023190.

Diels-Alder adduct between the resin and the fiber

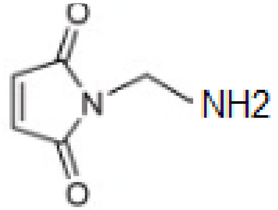




MALEIMIDE

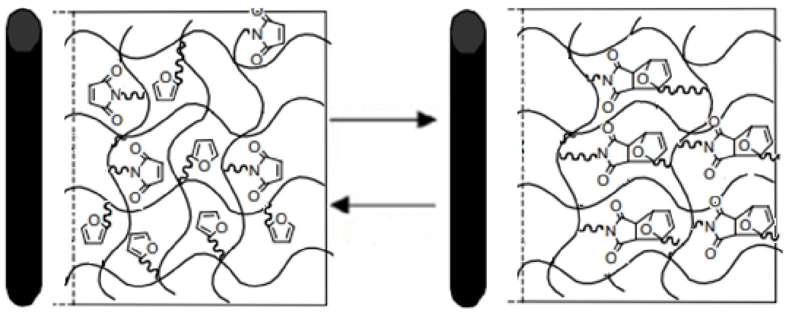


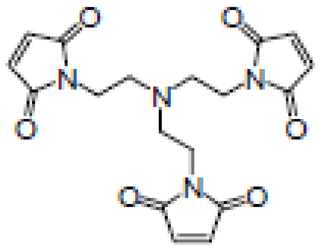
Dimaleimide



Maleimide amine

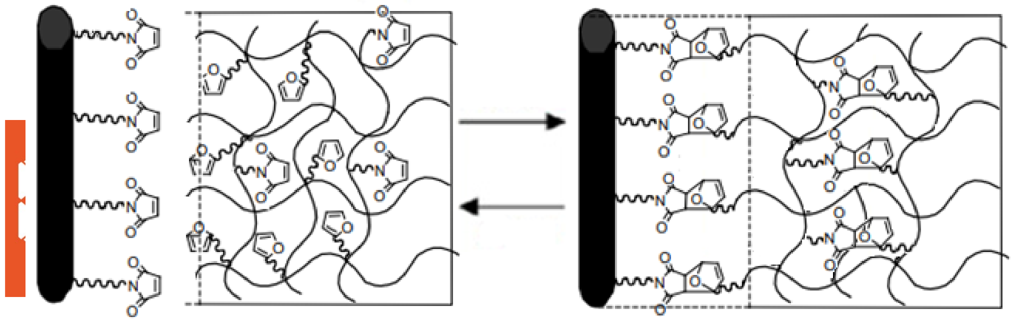
Diels-Alder adduct into the resin





Trimaleimide

Diels-Alder adduct into the resin, and between the resin and the fiber



FURFURAL

Furfuryl alcohol

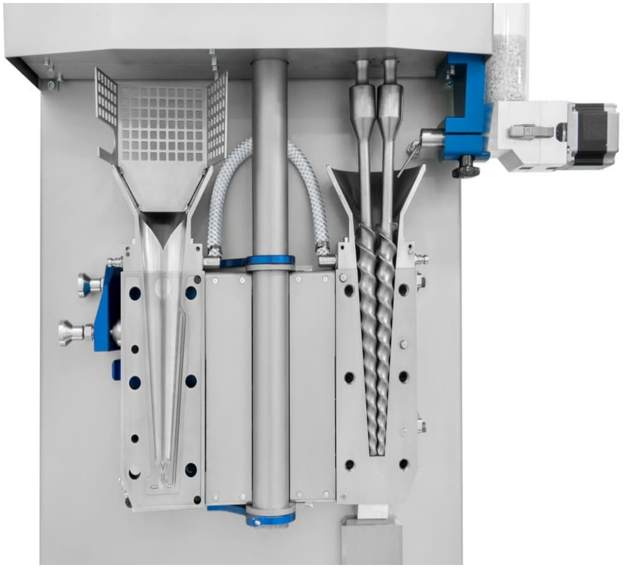
Furfuryl amine

Synthesis of bio carbon fiber

This project has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N° 101023190.

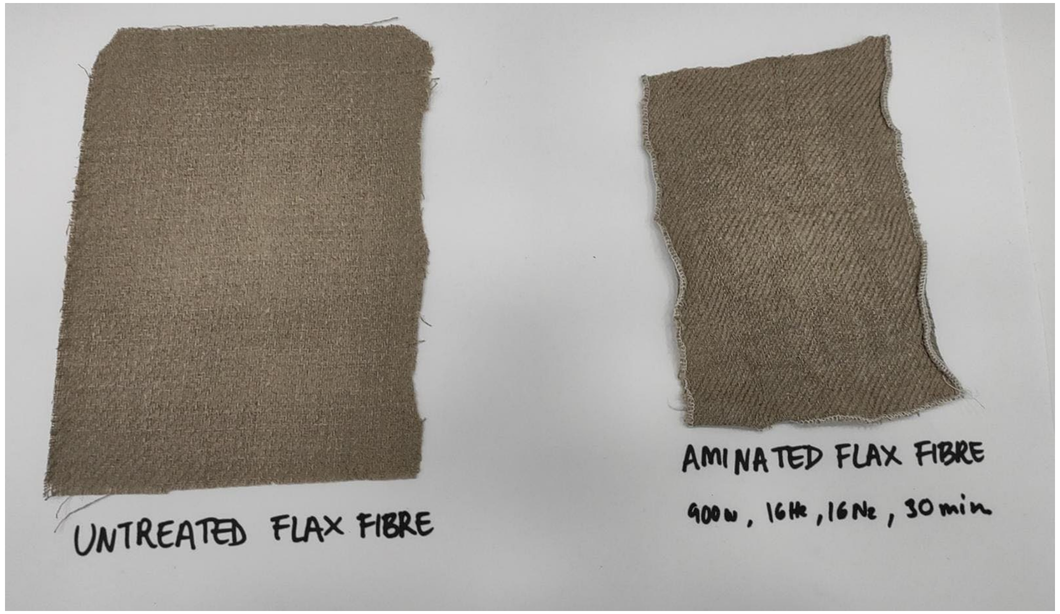
- Lignin: TPU ratio (50:50/ 45:55/ 40:60)
- Coating and sizing to improve the thermal stabilisation step (250 ºC) Using natural acids such as citric acid

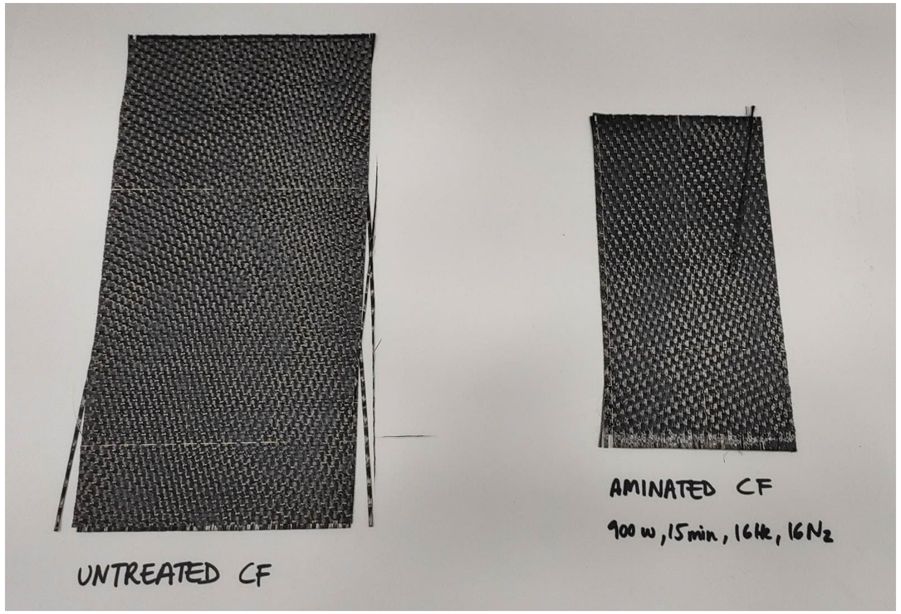
- Carbonisation carried out at 1000 ºC



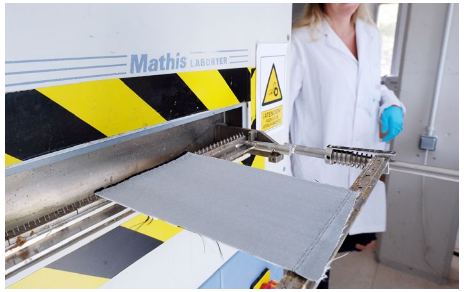
Fiber treatments

This project has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N° 101023190.

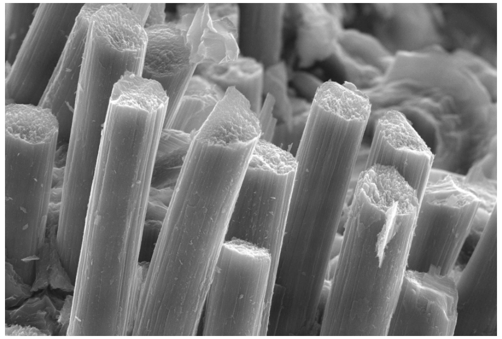


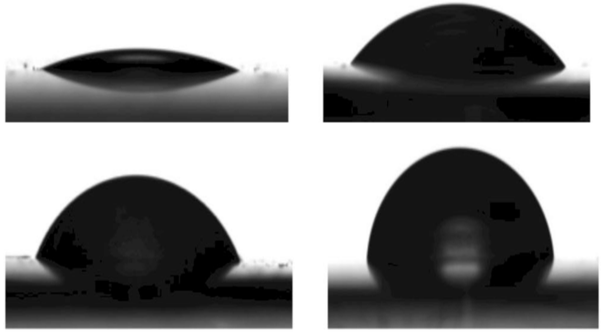


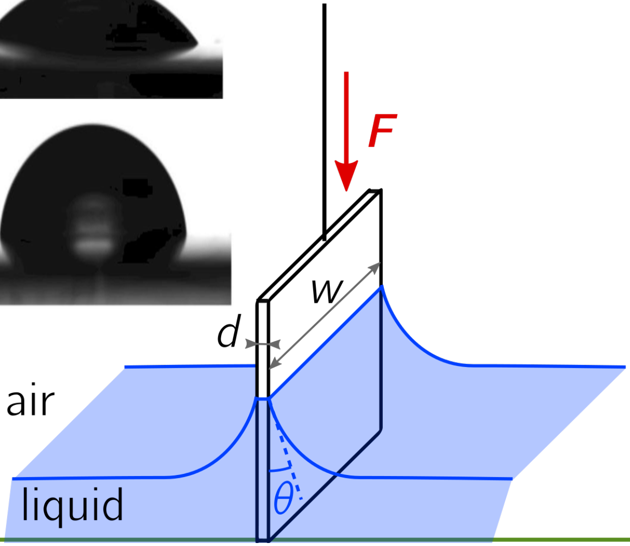
Textile treatments:



Padding



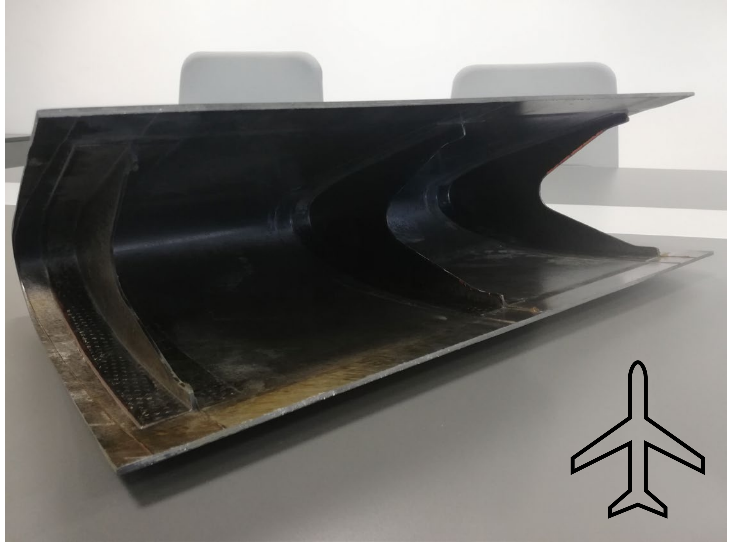


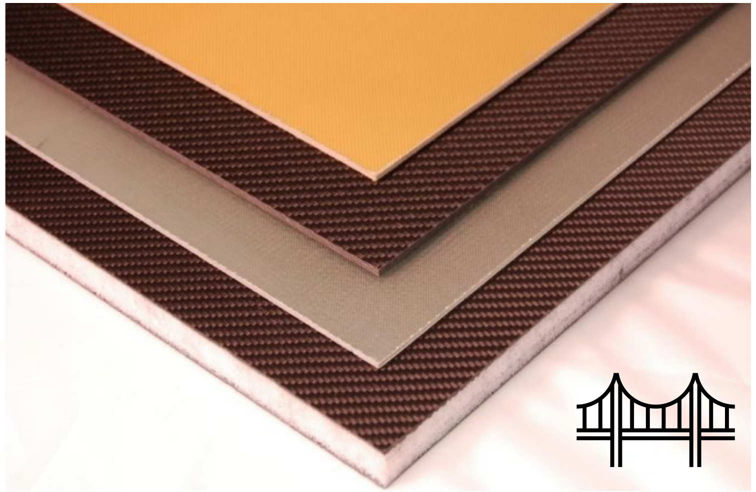


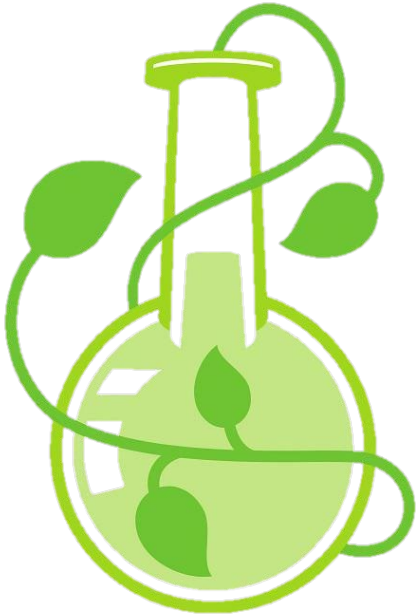
Exhaustion

Bringing results to the industry

This project has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N° 101023190.







THANK YOU FOR YOUR ATTENTION

Calle Romero 12, P.I. Empresarium, La Cartuja Baja. 50720 – Zaragoza (ES) +34 976 46 45 44 aitiip@aitiip.com www.aitiip.com

Julio Vidal
Head of composite materials
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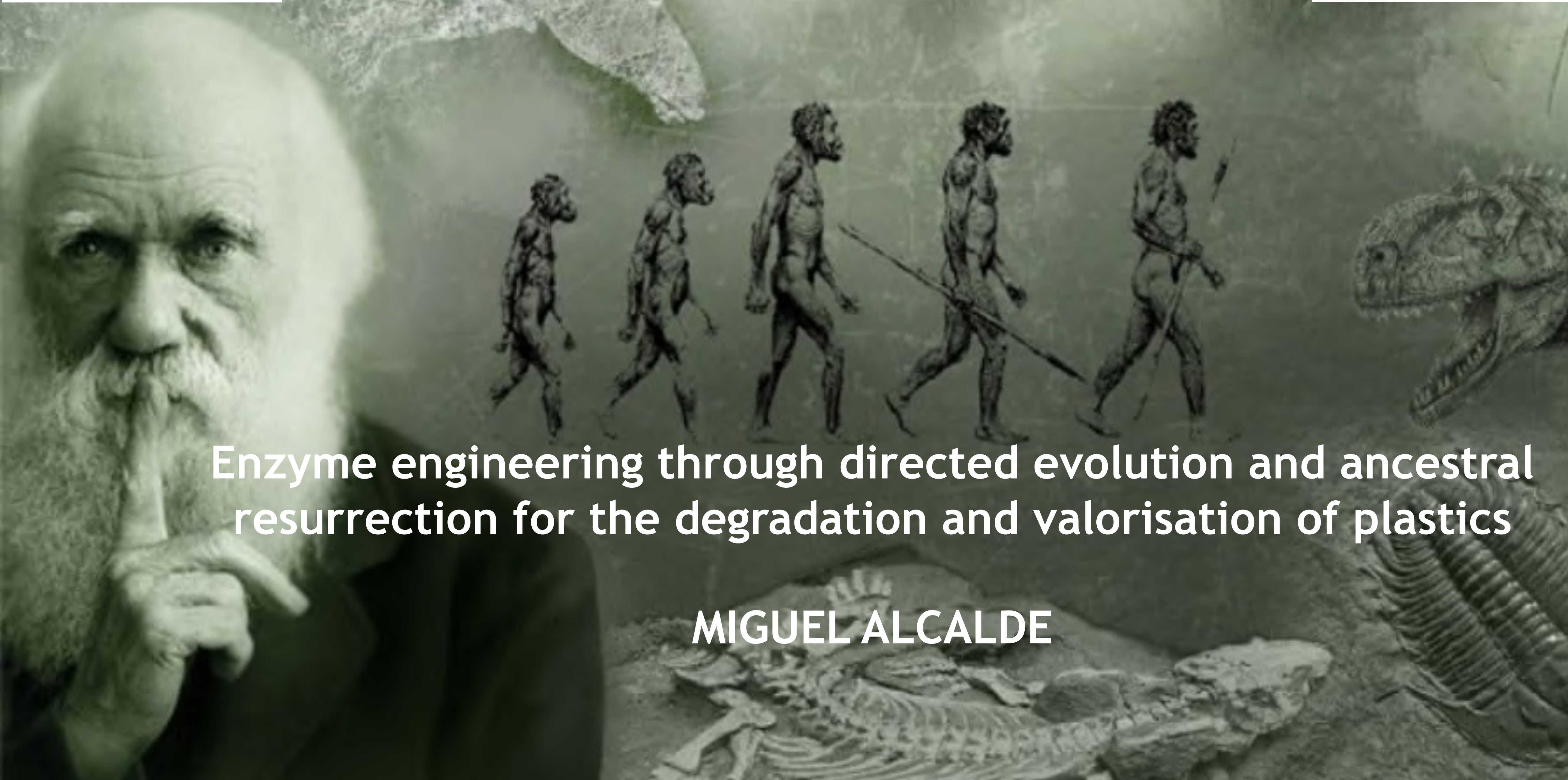
Enzyme engineering through directed evolution and ancestral resurrection for the degradation and valorisation of plastics

Miguel Alcalde
Co-fundador y consejero en EvoEnzyme y Profesor Investigador en el Instituto de Catálisis del CSIC



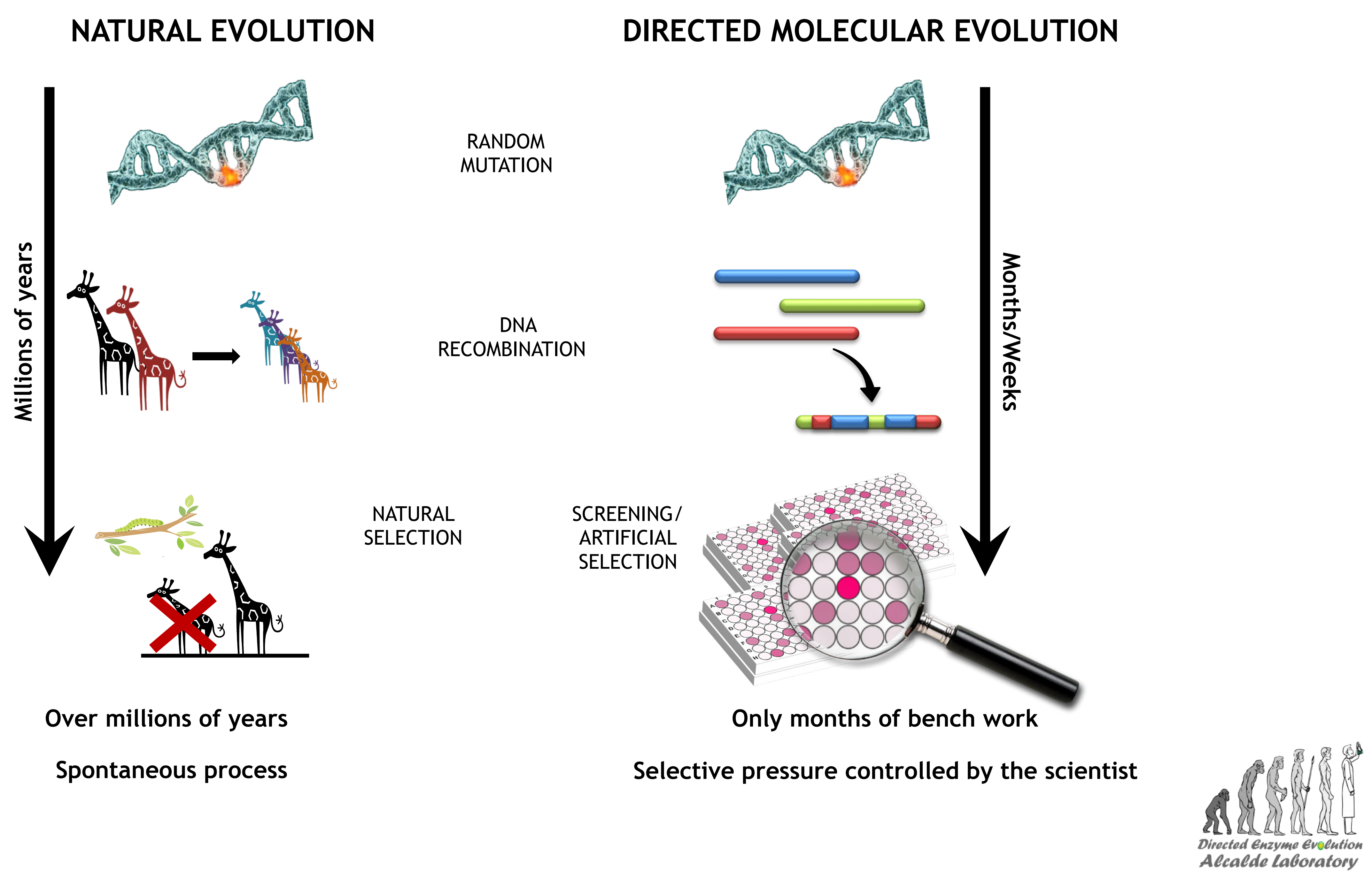
EvoEnzyme
Customized Biocatalysts

CSIC
Consejo Superior de Investigaciones Científicas

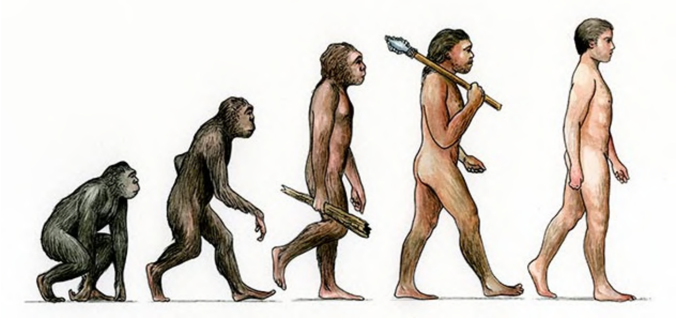
Enzyme engineering through directed evolution and ancestral resurrection for the degradation and valorisation of plastics

MIGUEL ALCALDE

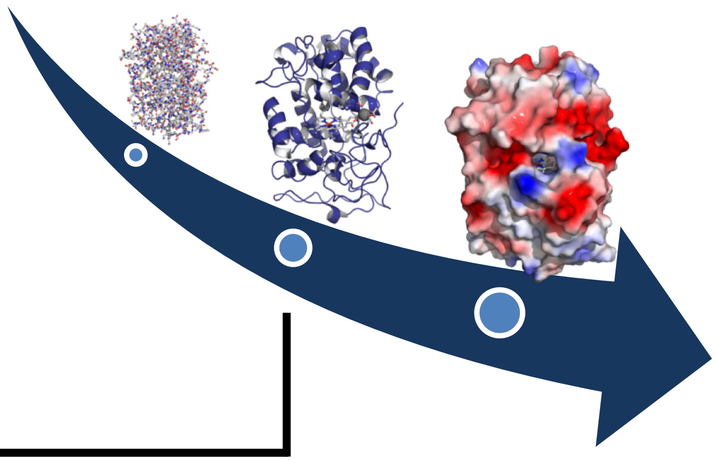

Courtesy of Prof. Victor Guallar
(Barcelona Supercomputing Center)

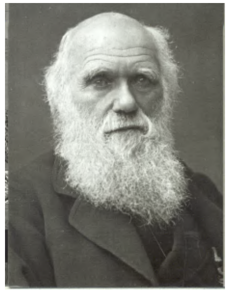

NATURAL EVOLUTION
DIRECTED MOLECULAR EVOLUTION
Millions of years
Months/Weeks
RANDOM
MUTATION
DNA
RECOMBINATION
NATURAL
SELECTION
SCREENING/
ARTIFICIAL
SELECTION
Over millions of years
Spontaneous process
Only months of bench work
Selective pressure controlled by the scientist
Directed Enzyme Evolution
Alcalde Laboratory

Natural evolution



Artificial evolution





DARWINIAN ALGORITHM:
MUTATION
RECOMBINATION
SELECTION

FITNESS OR SURVIVAL

ACTIVITY:
- Novel substrate specificities
- To modify regio- quimio- and stereo-selectivities

STABILITY:
- Temperature
- Organic co-solvents
- Inhibitors
- Functional expression

Design *ad-hoc* enzymes

Directed Enzyme Evolution
Alcalde Laboratory

Second “Biotech” revolution: Directed molecular evolution

Premio en Química para los padres de la evolución molecular dirigida: Frances H. Arnold, George Smith y Gregory P. Winter

Un Nobel para la segunda revolución biotecnológica

MIGUEL ALCALDE

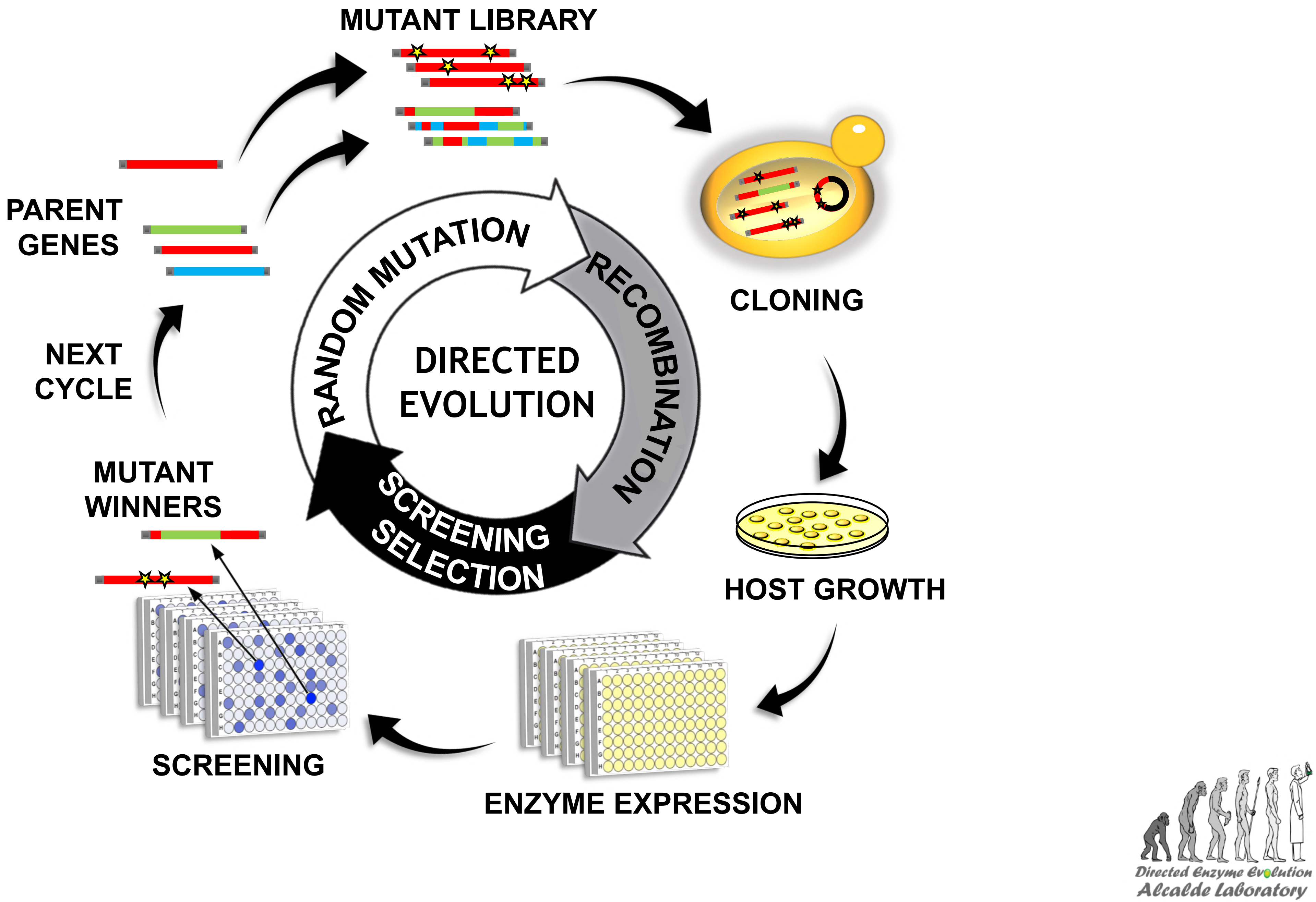
Investigador del CSIC/ Dpto. de Biocatálisis

Frances Arnold ya fue galardonada con los premios Draper 2011 y Millenium 2016 (equivalentes a los Nobel de ingeniería), así como la medalla nacional de Tecnología EE UU 2013, por lo que el Nobel de ayer en Química era un premio espe-

cuentran aplicación inmediata en la producción de biocombustibles, procesos de descontaminación o síntesis de fármacos, entre otros ejemplos.

La evolución dirigida consiste en emular en el laboratorio los procesos de evolución natural (mutación, recombinación del material genético y selección) aplicados al diseño de enzimas

Directed Enzyme Evolution
Alcalde Laboratory


MUTANT LIBRARY
PARENT GENES
CLONING
NEXT CYCLE
RANDOM MUTATION
RECOMBINATION
DIRECTED EVOLUTION
SCREENING SELECTION
HOST GROWTH
MUTANT WINNERS
SCREENING
ENZYME EXPRESSION
Directed Enzyme Evolution
Alcalde Laboratory

There are 5700 possibilities for one substitution anywhere in a 300 amino-acid protein…

….and 16,000,000 possibilities for two substitutions!!!!.

To reduce screening effort by using **COMPUTATIONAL ALGORITHMS**

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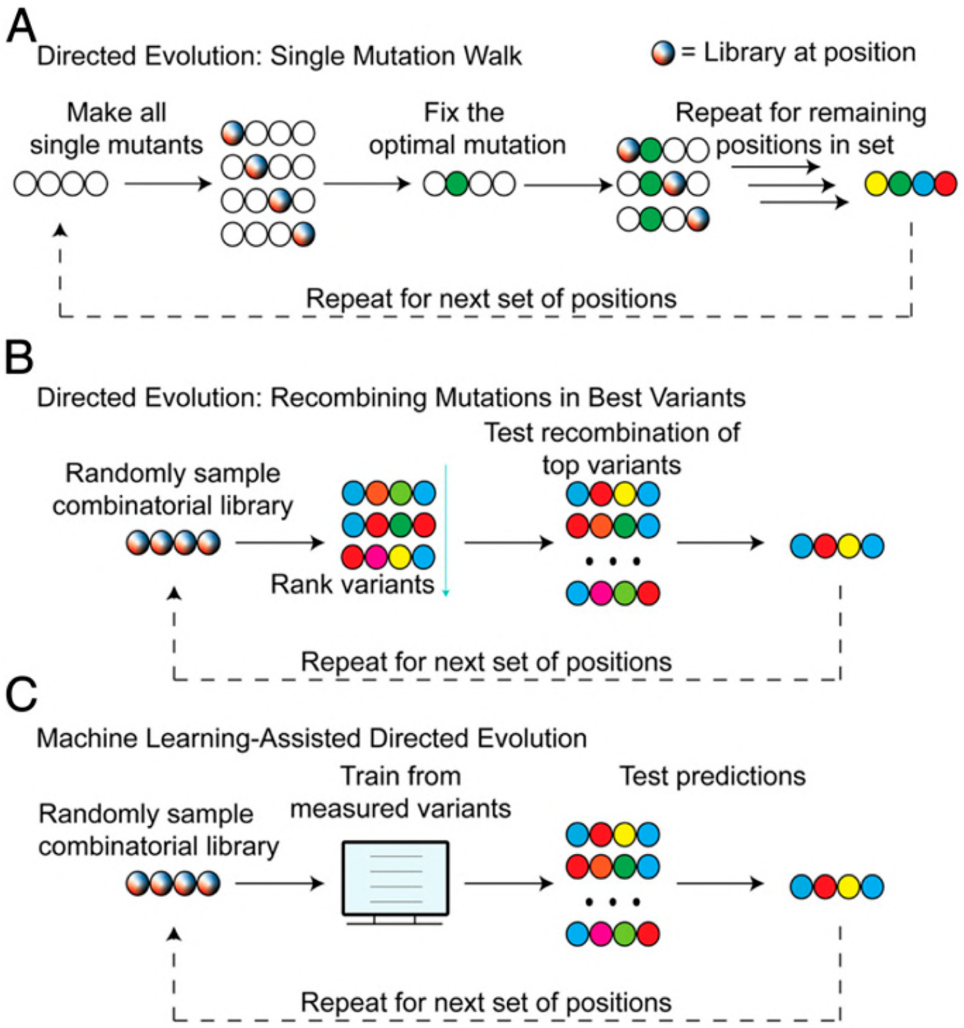
Alcalde Laboratory

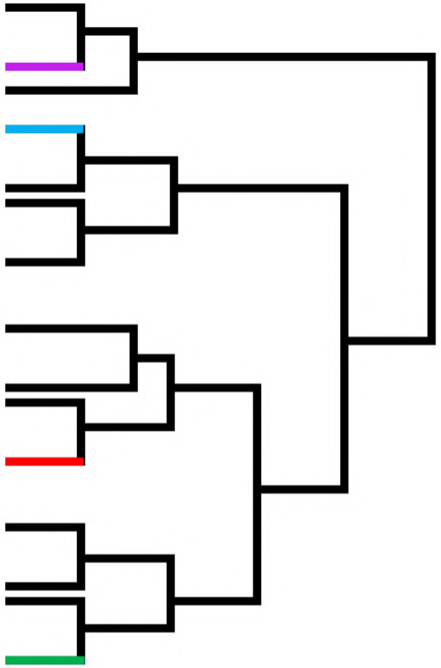
MACHINE LEARNING GUIDED DIRECTED EVOLUTION



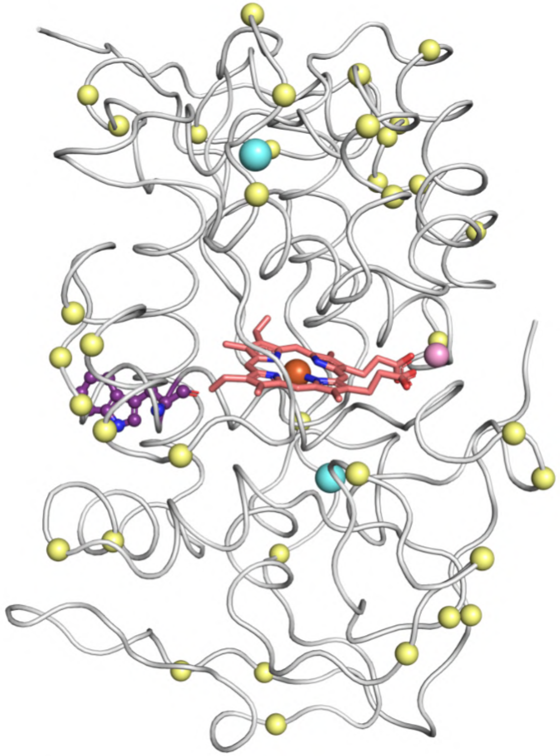
Wu *et al*. (2019). *PNAS* 116: 8852-8858.

DEEP LEARNING *AB INITIO* STRUCTURE PREDICTION METHODS

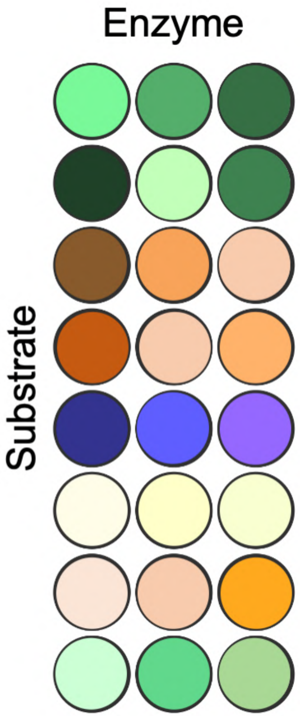
Sarel Fleishman
(Weizmann Institute of Science, Israel)



Sequence selection



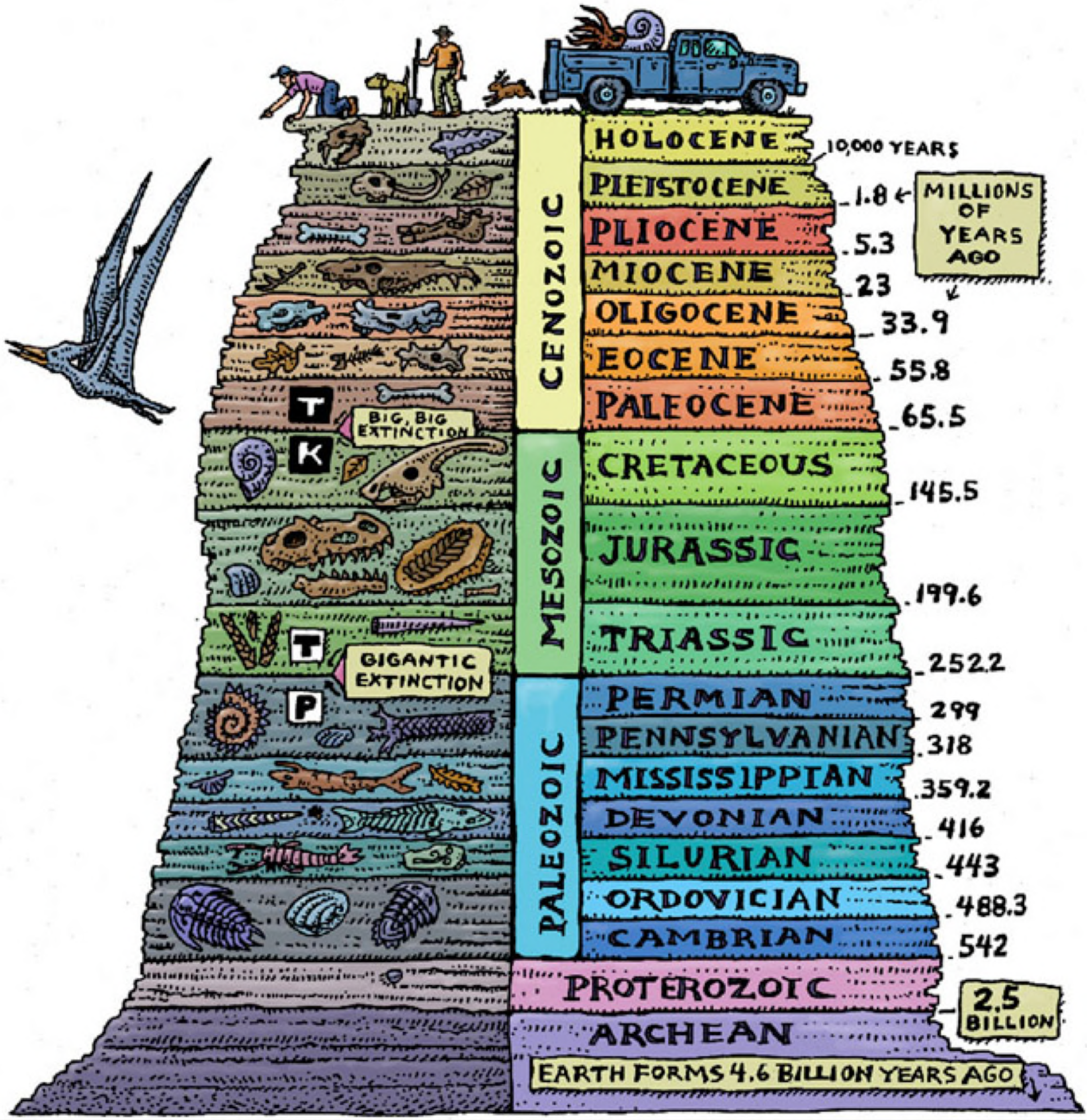
Structure prediction & PROSS design



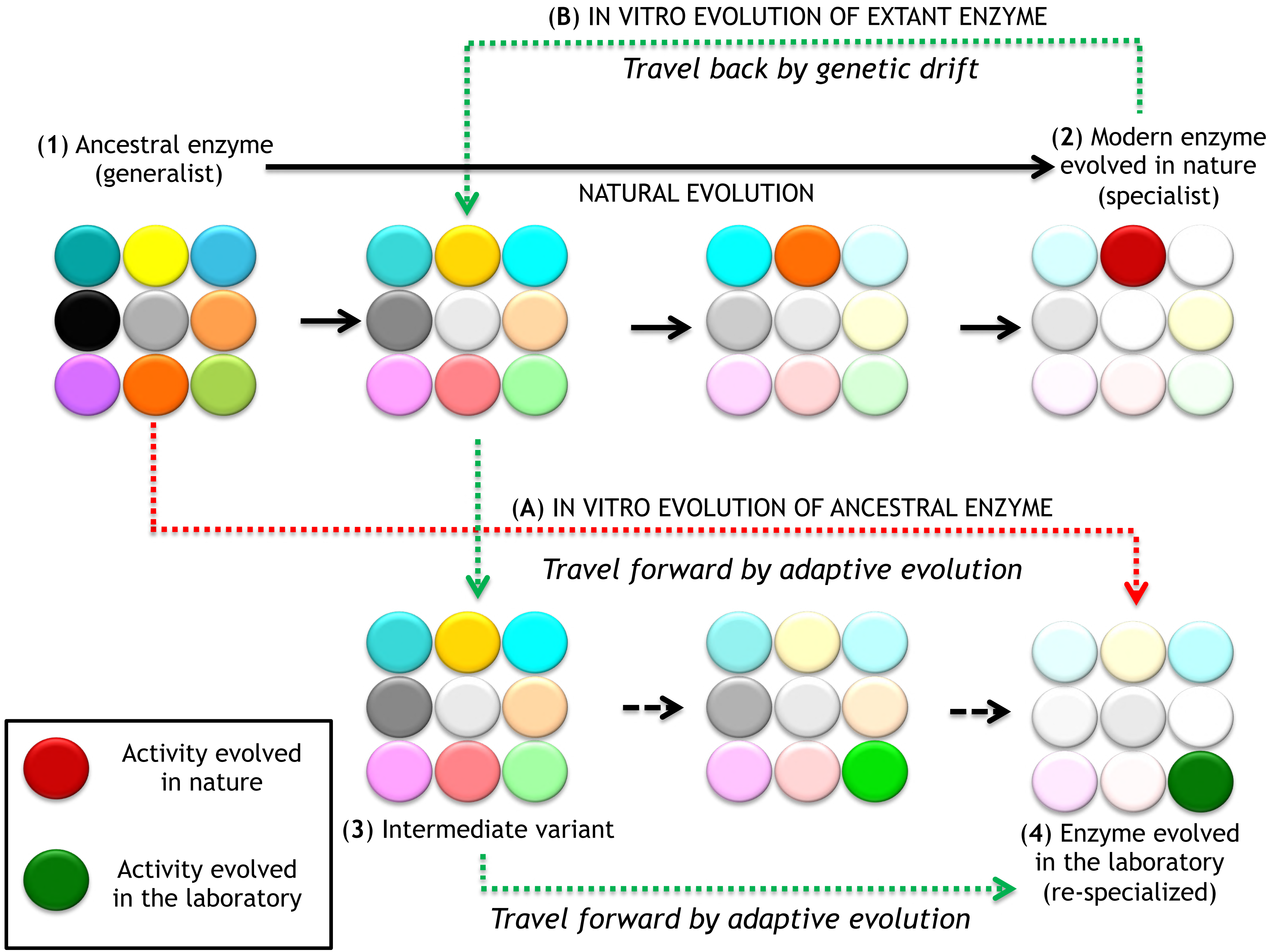
Diverse functional profiles

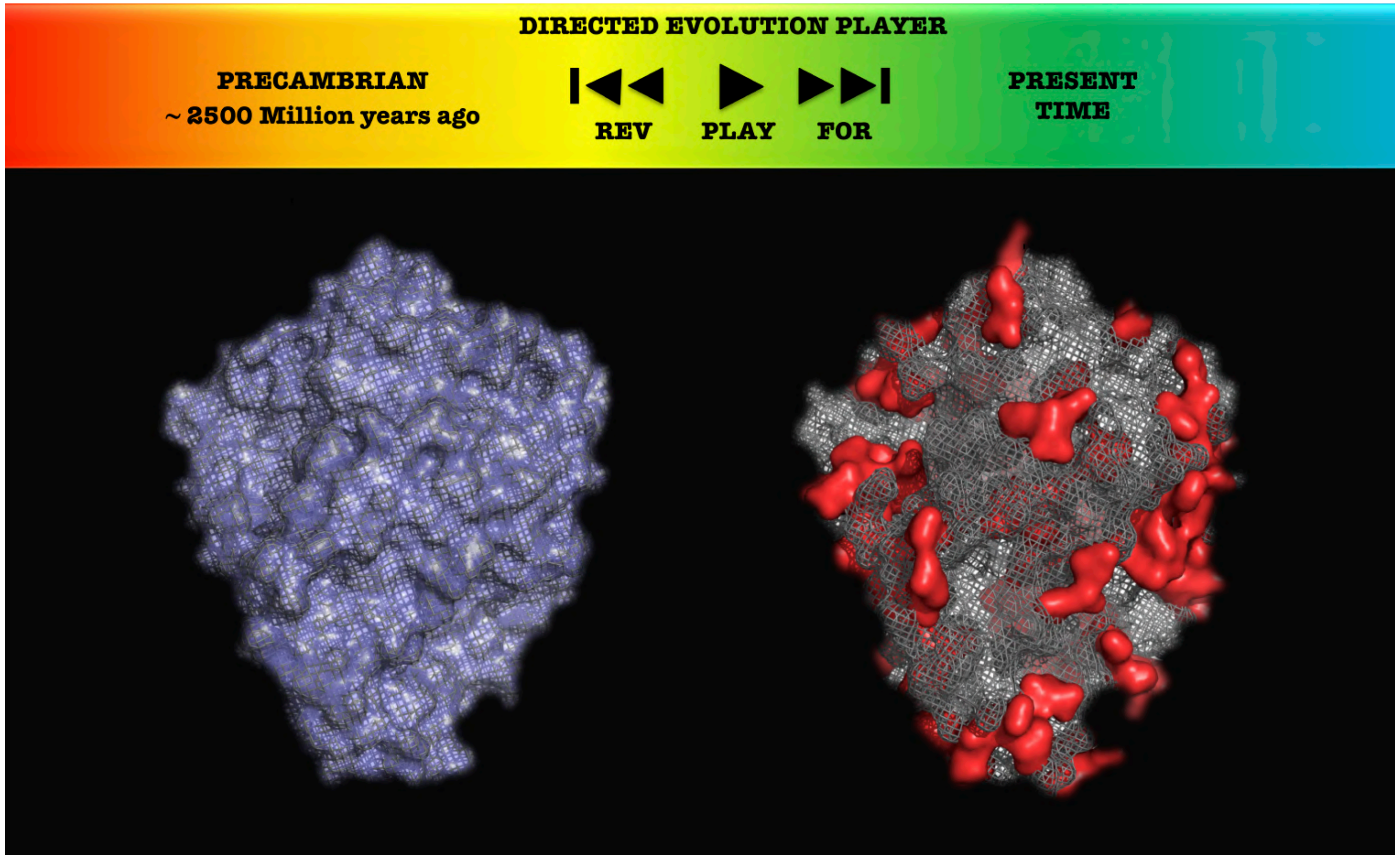
Barber-Zucker *et al*. (2022). *Journal of the American Chemical Society*. 144: 3564-3571.

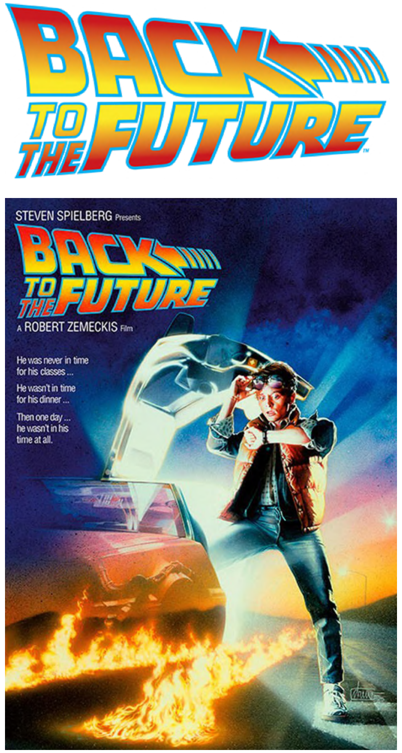
Barber-Zucker et al. (2022). *ACS Catalysis*. In press



Prof. José Manuel Sánchez-Ruiz
(Universidad de Granada)


(B) IN VITRO EVOLUTION OF EXTANT ENZYME
Travel back by genetic drift
(1) Ancestral enzyme (generalist)
(2) Modern enzyme evolved in nature (specialist)
NATURAL EVOLUTION
(A) IN VITRO EVOLUTION OF ANCESTRAL ENZYME
Travel forward by adaptive evolution
Activity evolved in nature
Activity evolved in the laboratory
(3) Intermediate variant
(4) Enzyme evolved in the laboratory (re-specialized)
Travel forward by adaptive evolution



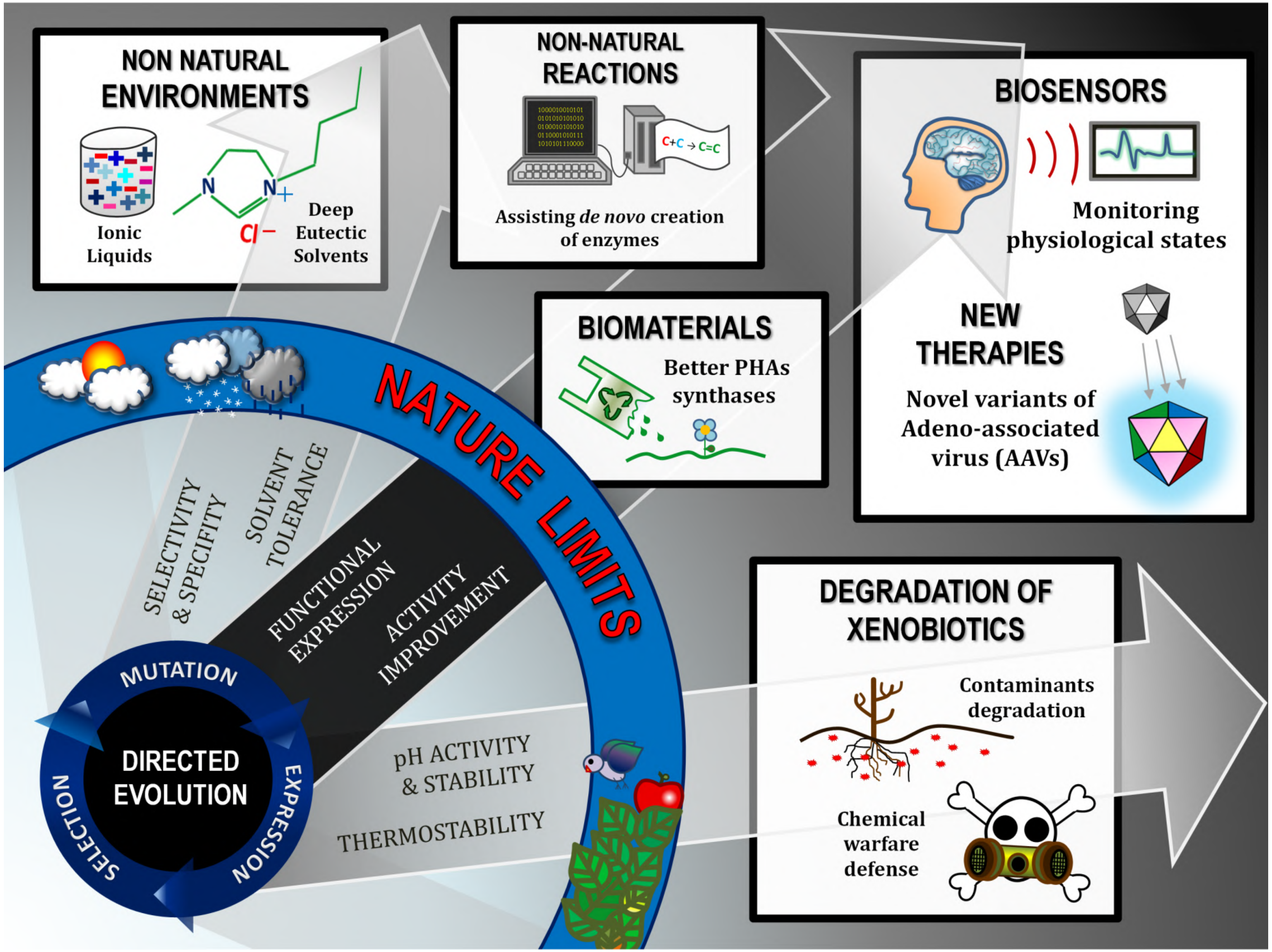


Directed evolution of resurrected enzymes can be a suitable vehicle to:

- Engineer novel catalytic functions and/or more robust biocatalysts.
- Explore natural evolutionary principles (protein robustness and evolvability).

Alcalde M. (2015). *Trends in Biotechnology* 33: 155-162.
Alcalde M. (2017). *Microbial Biotechnology* 10: 20-24.

Directed Enzyme Evolution
Alcalde Laboratory

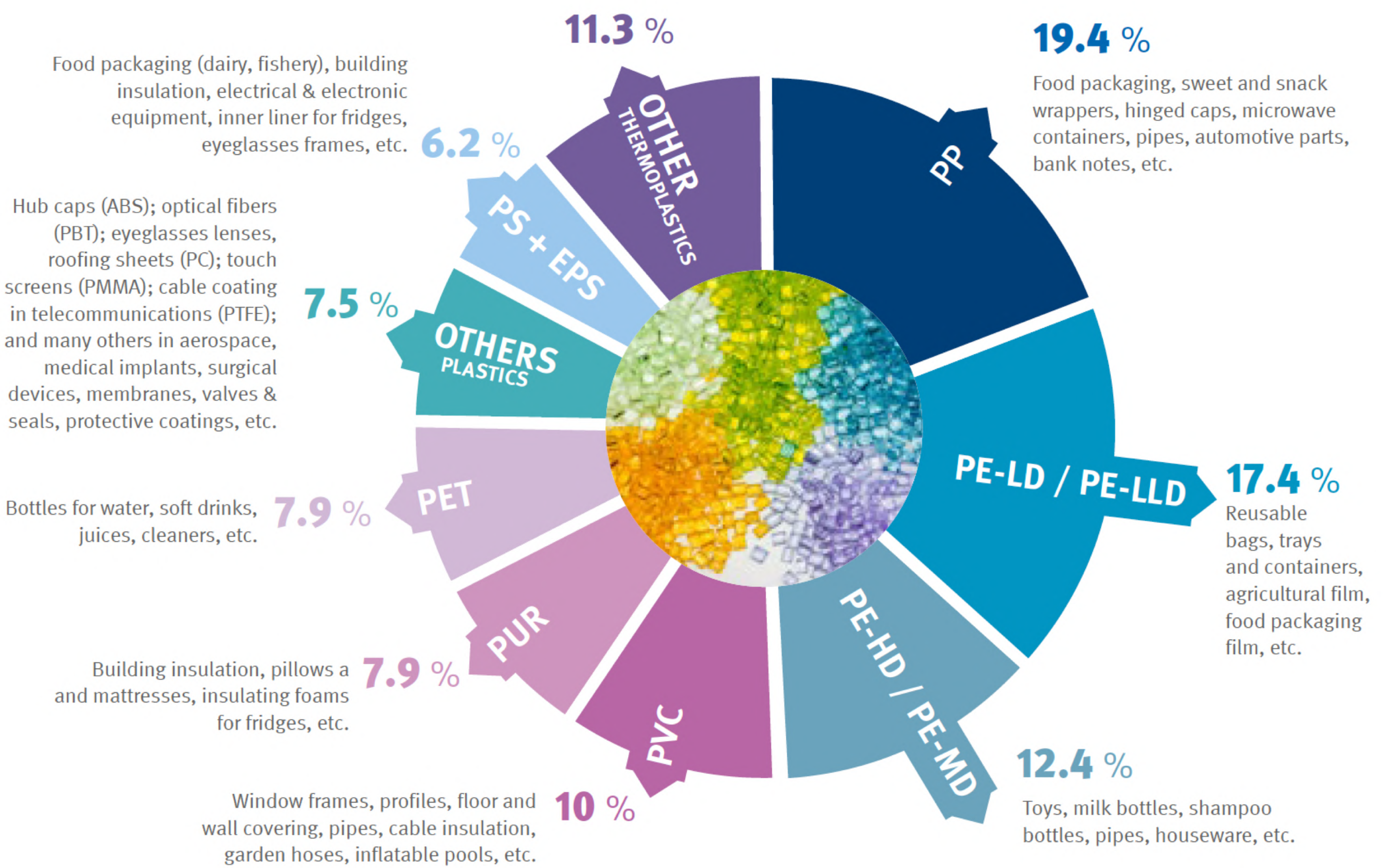


Molina-Espeja et al. (2016). *Biotechnology Advances*. 34: 754-767.

PLASTICS DEMAND DISTRIBUTION BY RESIN TYPE 2019

Data for EU28+NO/CH.

SOURCE: PlasticsEurope Market Research Group (PEMRG) and Conversio Market & Strategy GmbH



Directed Enzyme Evolution
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Horizon2020
European Union Funding
for Research & Innovation

BIO-BASED INDUSTRIES
Public-Private Partnership

BIZENTE

Apply Ligninases To Resolve End - of - life Issues of Thermoset Composite Plastics

BIZENTE project presents a biocatalytic model of enzymatic degradation as a novel alternative to the end-of-life of thermoset composites.

https://bizente.eu

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Customized Biocatalysts

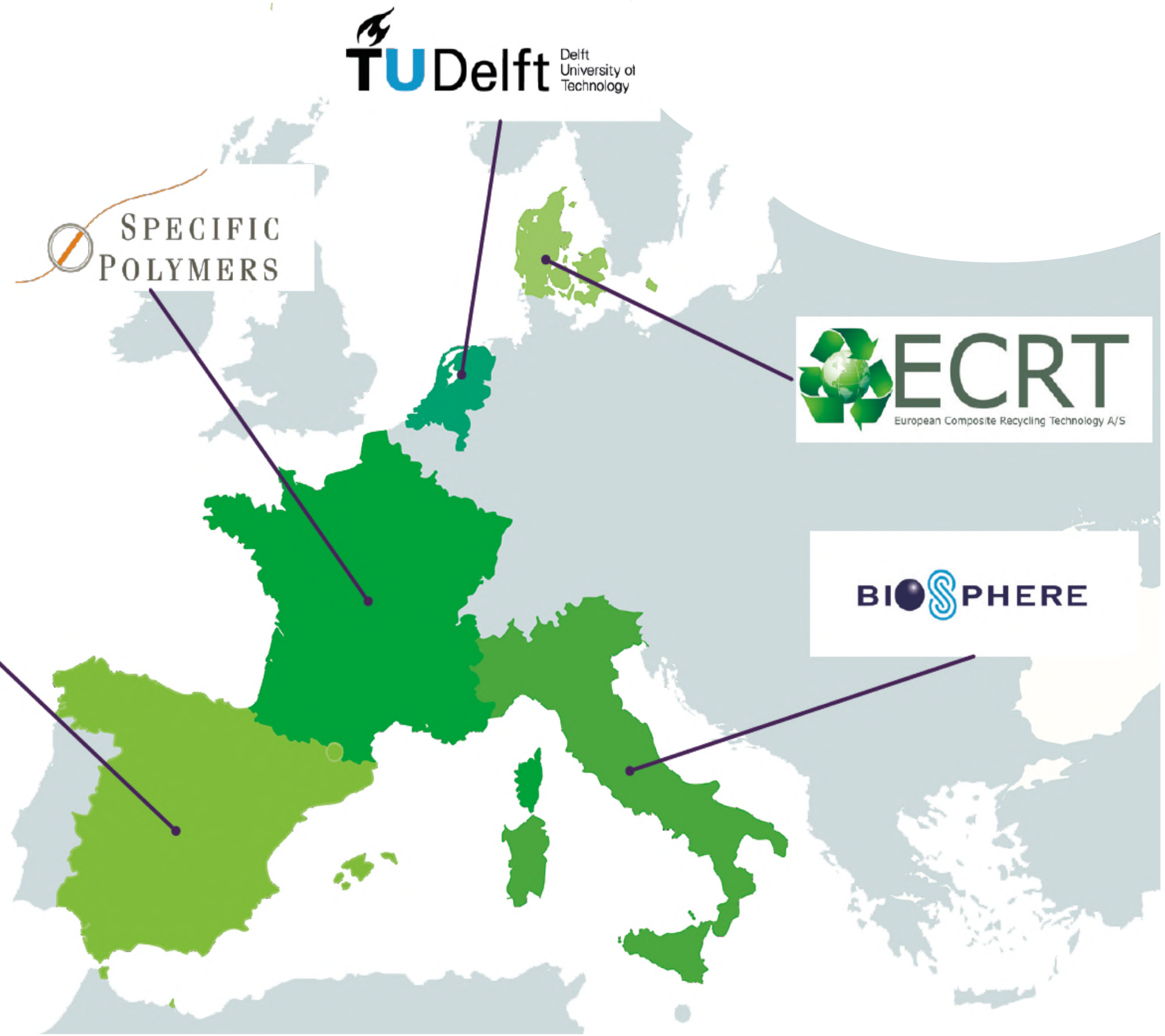
PLATA
Plataforma
Aeroportuaria - Teruel

acciona

AERnnova
composites

UCA Universidad de Cádiz

aitiip
centro tecnológico



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Think & Build in Green

EvoEnzyme
Customized Biocatalysts

Who we are

EvoEnzyme
Customized Biocatalysts

PARQUE CIENTIFICO DE MADRID
CAMPUS DE LA AUTONOMA
MADRID - SPAIN

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
ICP

A Spin Off from Miguel Alcalde lab (https://miguelalcaldelab.eu)
Instituto de Catálisis y Petroleoquímica ICP-CSIC

+20 years of experience in the Academy
EvoEnzyme started in Sep2019

Experts in Biocatalysis & and Protein Engineering

- Own Technology & Library creation Methods
- Broad mutant Library

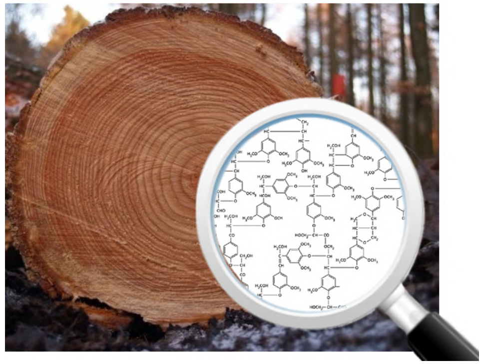
100% PhDs

*"Improving **Enzymes by Directed Evolution**"*

Who we are

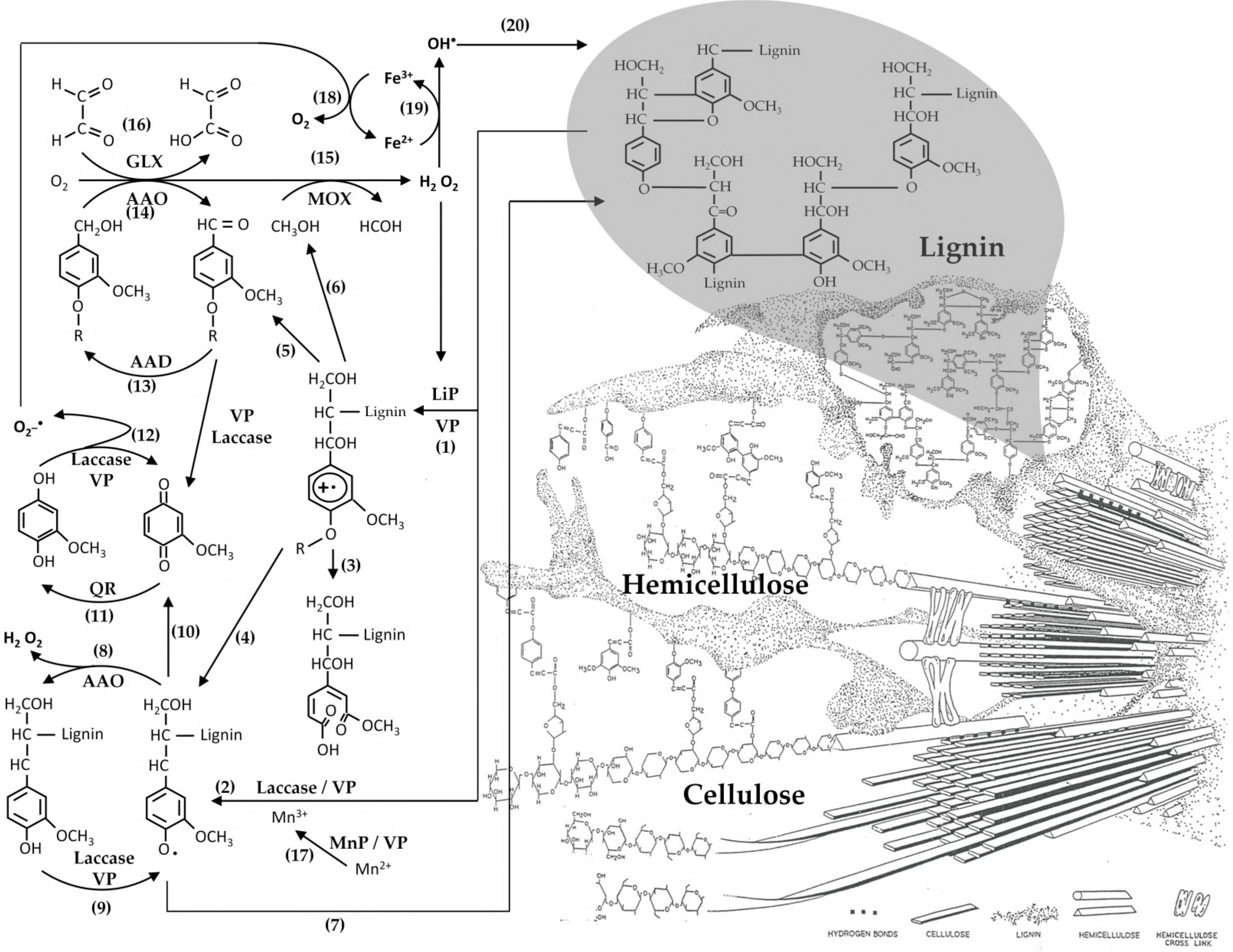
EvoEnzyme
Customized Biocatalysts

WHITE-ROT FUNGI



LIGNINOLYTIC ARMOURY

- Laccases
- Lignin peroxidase (LiP)
- Mn-peroxidase (MnP)
- Versatile peroxidase (VP)
- Dye-decolorizing peroxidase (DyP)
- Unspecific/Aromatic peroxygenase (UPO)
- H_2O_2-supplying enzymes (*e.g.* AAO)



Alcalde M. (2015). Engineering the ligninolytic enzyme consortium. *Trends in Biotechnology* 33: 155-162.

Directed Enzyme Evolution
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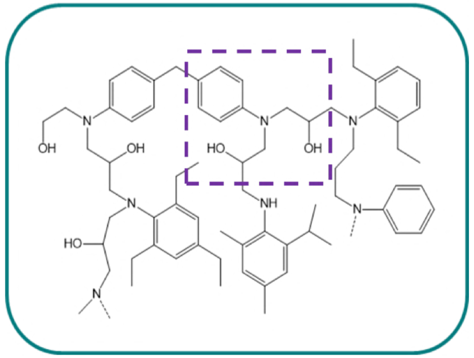
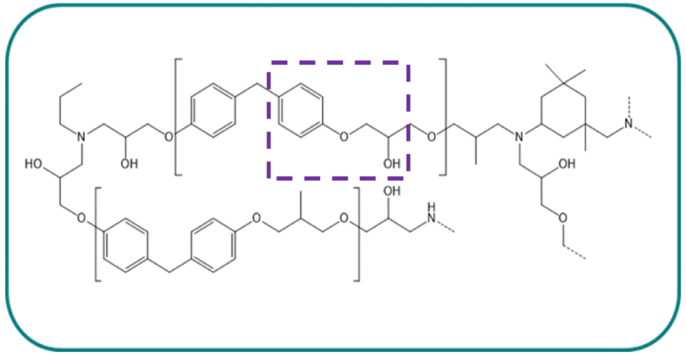
AERONAUTIC SECTOR

Hexflow RTM6



- Medium volume production rates
- High quality components

Araldite LY 1568

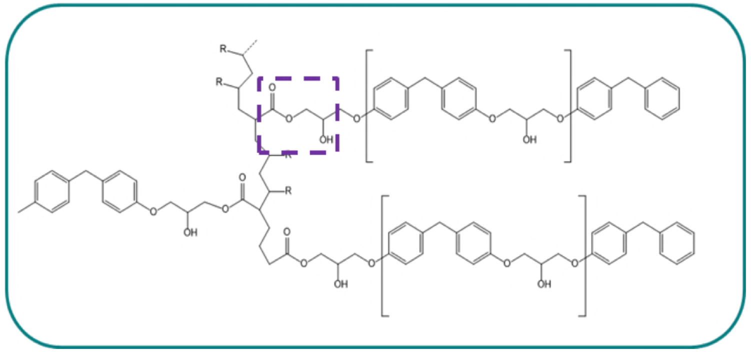


- High resin-to-glass ratios and superior mechanical properties

CONSTRUCTION BUILDING

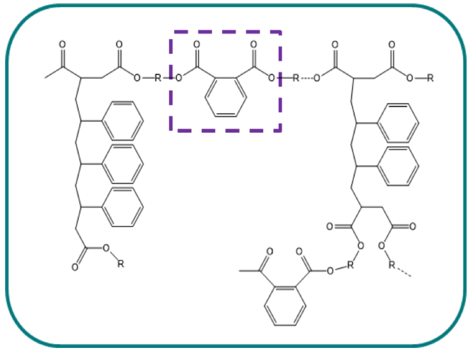
CONSTRUCTION BUILDING

DION IMPACT 9102



- Solid or hollow
- Flat bars, channels, pipes, tubing, rods

R930A



- Sidewalls
- Covers around the doors

RAILWAY INDUSTRY

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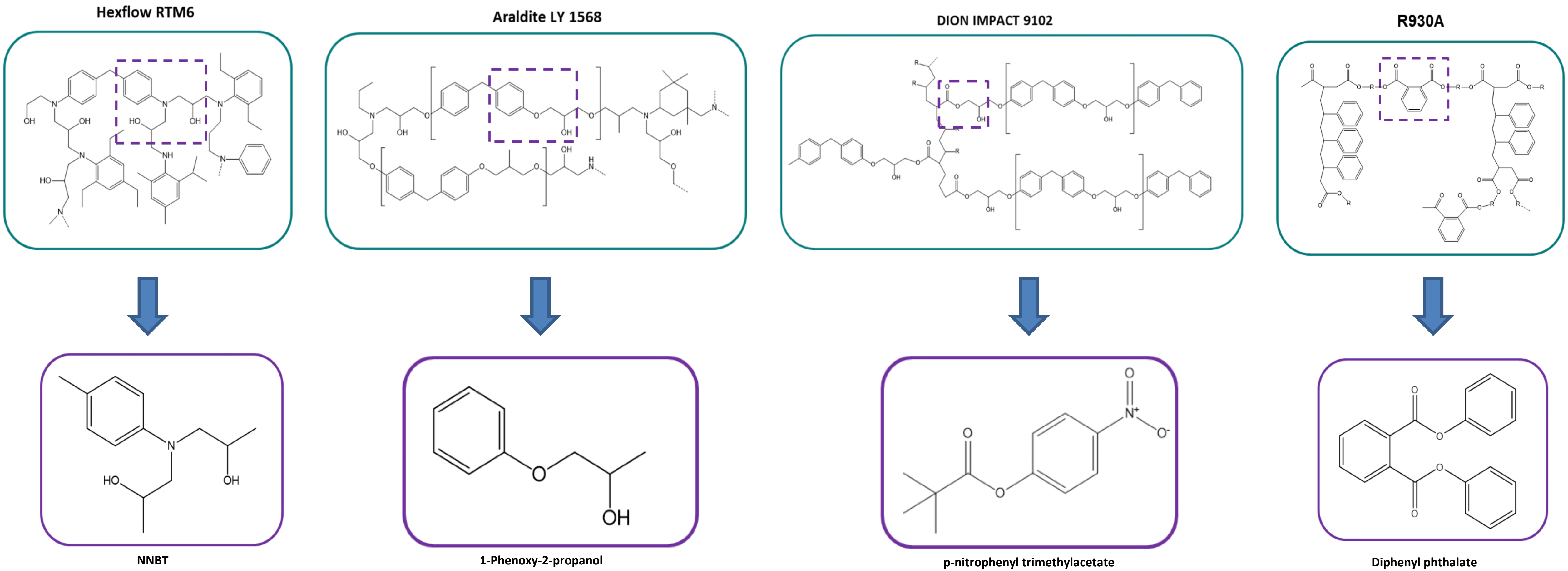
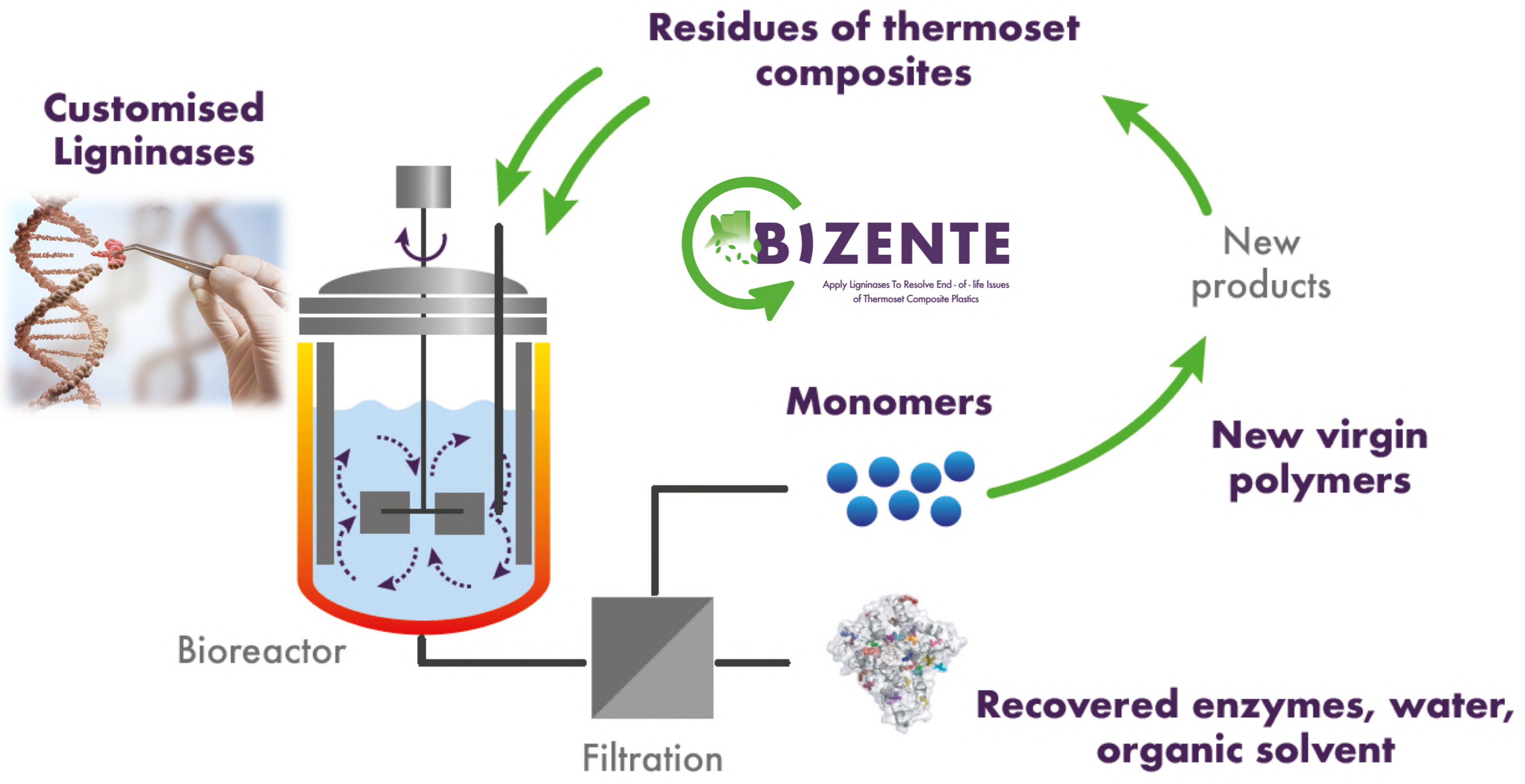
Alcalde Laboratory



Dolz *et al.* (2022). *Frontiers in Catalysis.* 2: 883263

Directed Enzyme Evolution
Alcalde Laboratory



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Alcalde Laboratory

https://revoluzionproject.eu

Directed Enzyme Evolution
Alcalde Laboratory

NEW SUSTAINABLE PRODUCTS

Biodegradation & Compostability

The aim of RevoluZion project is to research and develope **innovative bioplastic materials** based on biobased components (biopolyester blends as matrix and enzymatic functional additives) with a **programmed biodegradation** for a twofold sustainable end-of-life scenario:

- On-demand degradation in different managed (faster industrial and home composting) and unmanaged environments (soil, freshwater, marine)
- Fostering clean recycling by avoiding cross contamination with other recyclable conventional plastics.

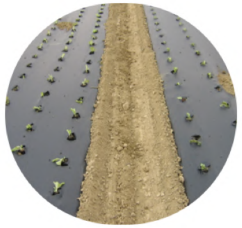
In the framework of the project, 3 product prototypes will be developed for the food industry:

Coffee biocapsules

Material programmed to reduce industrial composting time by up to three times.

Food Packaging

Material that will enable home compostability.



Agricultural films

Material that will support biodegradation in the field.

https://revoluzionproject.eu

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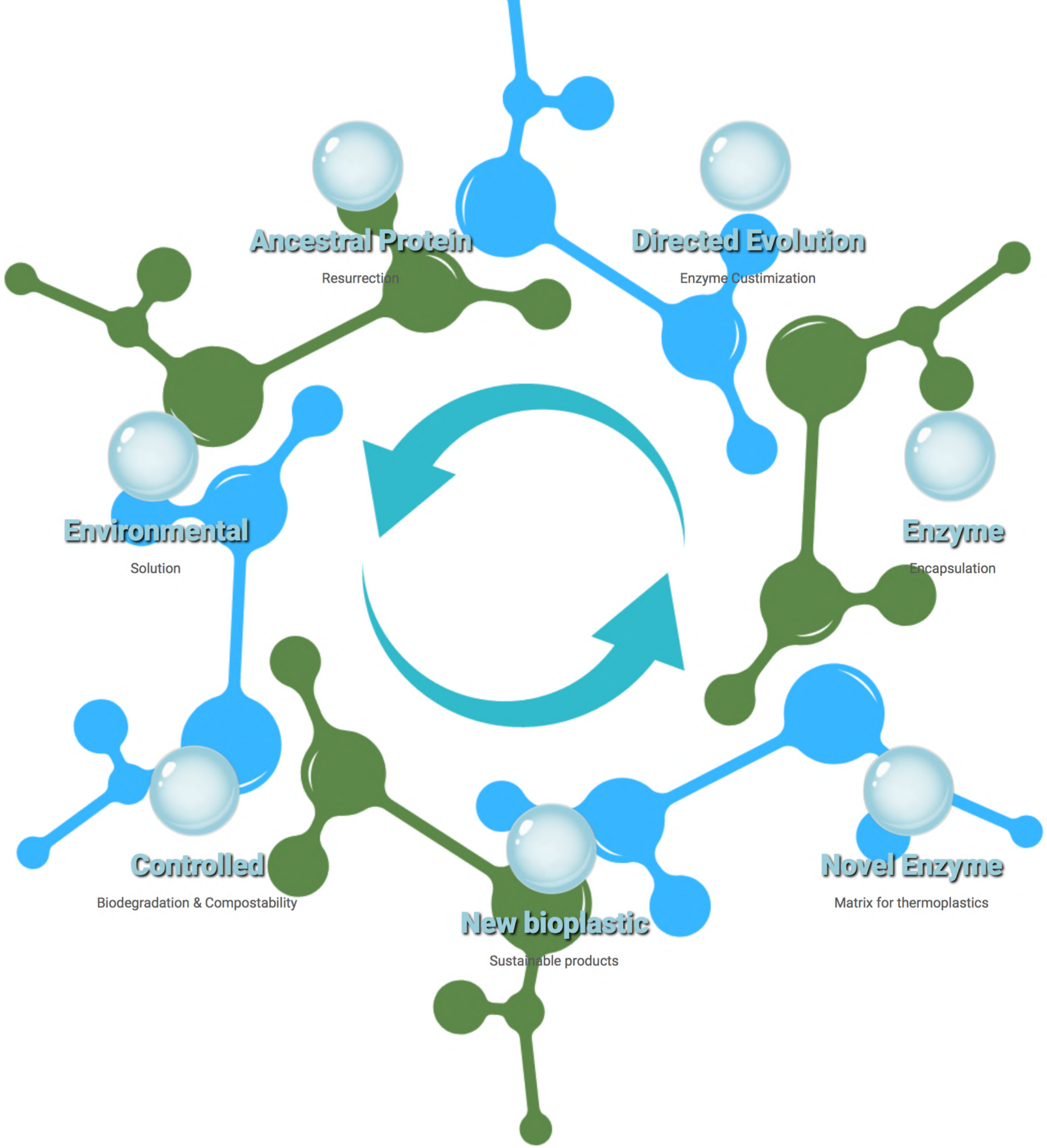


https://revoluzionproject.eu

Directed Enzyme Evolution
Alcalde Laboratory

Consortium

Kompuestos™ · CSIC – Consejo Superior de Investigaciones Científicas · aitiip centro tecnológico · CIB Margarita Salas · CSIC ICP · Universidad de Granada

ABOUT

Proyecto PLEC2021-008188 financiado por MCIN/AEI /10.13039/501100011033 y por la Unión Europea NextGenerationEU/ PRTR

RECENT POSTS

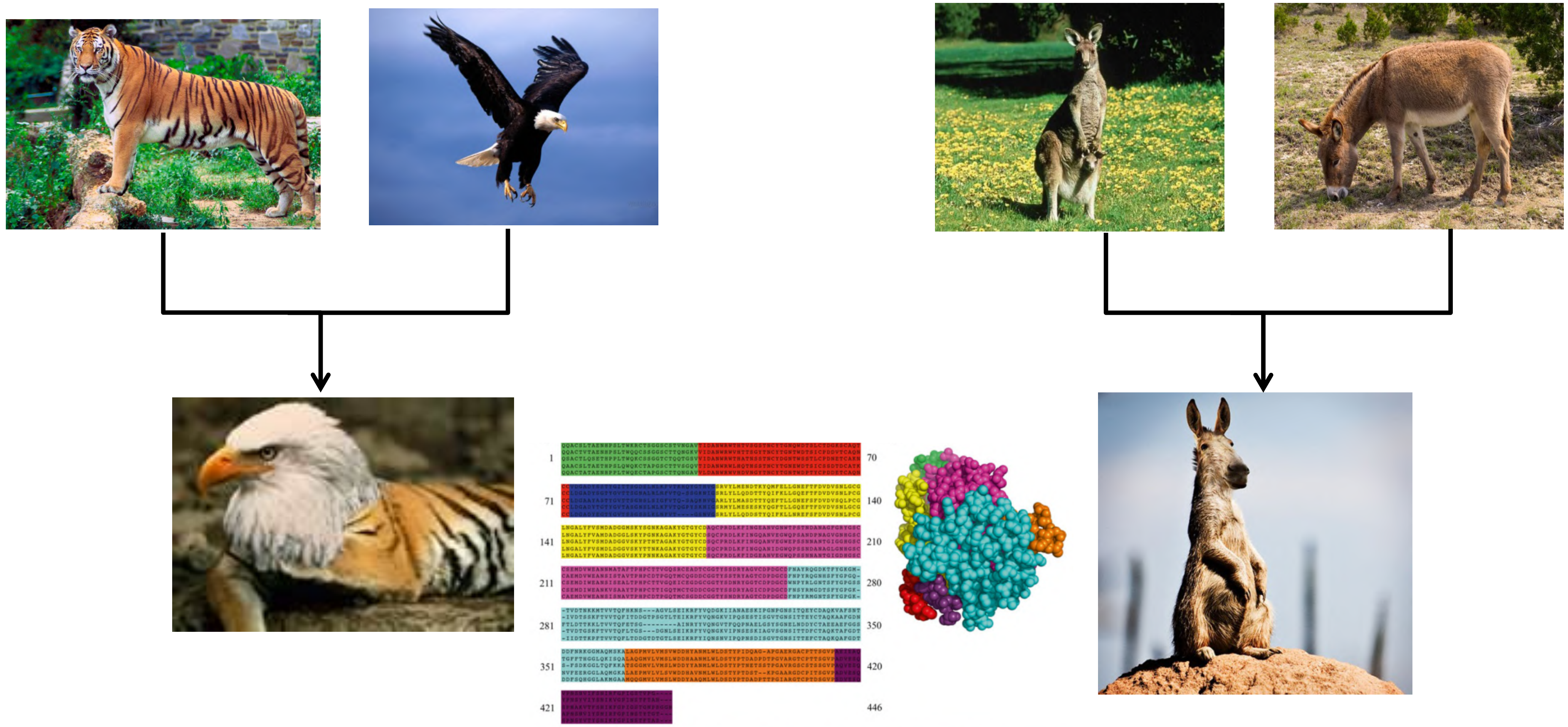
- Download our Brochure!
- Revoluzion leads the Workshop "Bio-based solutions for the plastic of the future"

Ministerio de Ciencia e Innovación · Financiado por la Unión Europea NextGenerationEU · Plan de Recuperación, Transformación y Resiliencia · Agencia Estatal de Investigación

https://revoluzionproject.eu

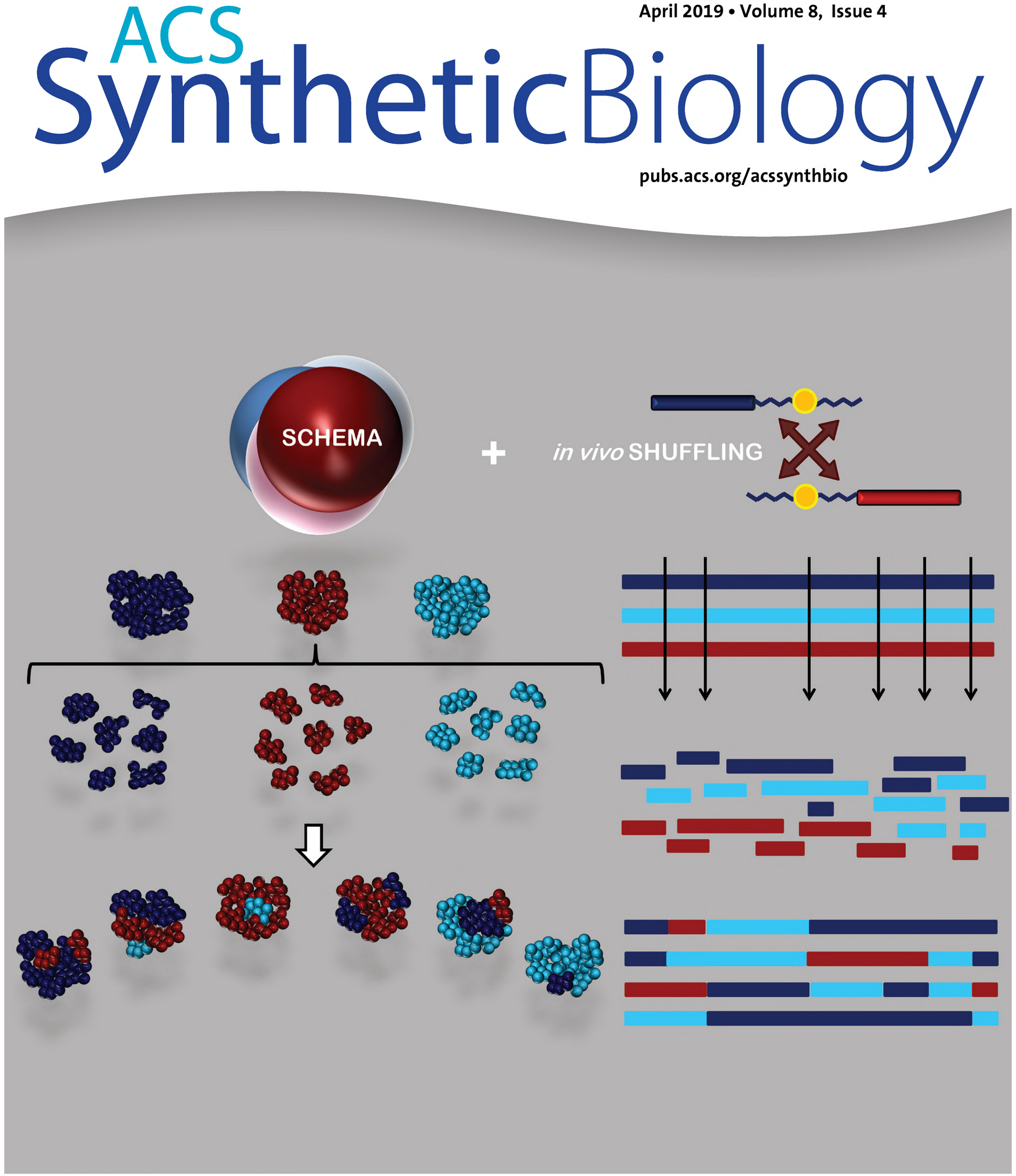
Directed Enzyme Evolution
Alcalde Laboratory

Chimeric enzymes by DNA recombination



Use of *in vivo*, *in vitro* DNA and computational recombination methods

Directed Enzyme Evolution
Alcalde Laboratory



Frances Arnold

Generation of Thermostable Chimeric Enzymes by SCHEMA Structure-guided Recombination in vivo

Protein sequences are splitted into blocks at fixed crossover locations to be recombined minimizing the disruption of the 3D structure

Mateljak *et al.* (2019). *ACS Synthetic Biology*. 8: 833-843.

Directed Enzyme Evolution
Alcalde Laboratory

SusPlast

Interdisciplinary Platform for Sustainable Plastics towards a Circular Economy

GOBIERNO DE ESPAÑA | MINISTERIO DE CIENCIA E INNOVACIÓN

CSIC

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

EvoEnzyme

Customized Biocatalysts

Horizon2020
European Union Funding
for Research & Innovation

BIO-BASED INDUSTRIES

Public-Private Partnership

Comunidad de Madrid

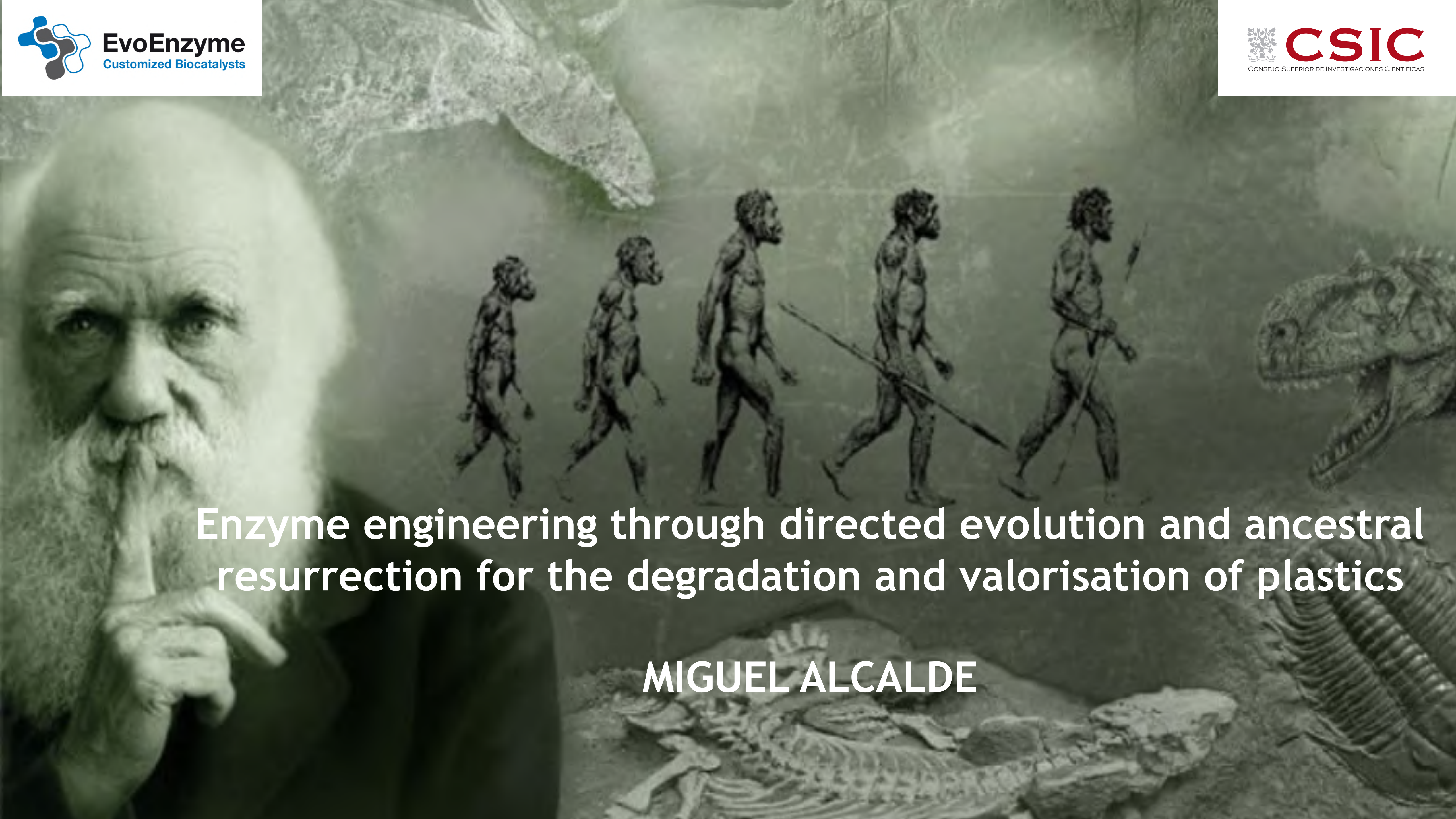
Directed Enzyme Evolution

Alcalde Laboratory

FUNDING: the Comunidad de Madrid Synergy CAM Project Y2018/BIO-4738-EVOCHIMERA-CM, the Spanish Government Project PID2019-106166RB-100-OXYWAVE, the CSIC Project PIE-201580E042 and the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 Research and Innovation program (Grant Agreement No.: 886567, BIZENTE project), the Spanish Government project PLEC2021-008188 funded by MCIN/AEI /10.13039/501100011033 and the EU NextGenerationEU/ PRTR and the SusPlast (Interdisciplinary Platform for Sustainable Plastics towards a Circular Economy-Spanish National Research Council (SusPlast-CSIC), Madrid, Spain).

EvoEnzyme
Customized Biocatalysts

CSIC
Consejo Superior de Investigaciones Científicas



Enzyme engineering through directed evolution and ancestral resurrection for the degradation and valorisation of plastics

MIGUEL ALCALDE

Turning carbon of complex organic urban waste streams into value-added products

Natalia Alfaro
Responsable de proyectos I+D+i en Urbaser y
Coordinadora del Proyecto Circular “Biocarbon”

CIRCULAR BIOCARBON

2022

CIRCULAR BIOCARBON

Turning carbon of complex organic urban waste streams into value-added products

COMPOSIFORUM 2022, , Session VI

Zaragoza (Spain), 17th November 2022

Natalia Alfaro Borjabad
nalfaro@urbaser.com

urbaser

circularbiocarbon.eu

BBI JU

Bio-based Industries Consortium

Horizon 2020
European Union Funding
for Research & Innovation

This project has received funding from the Bio-based Industries Joint Undertaking (JU) under the European Union's Horizon 2020 research and innovation programme under grant agreement No 101023280. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Bio-based Industries Consortium.

CIRCULAR BIOCARBON Project

Project info

Title	Turning carbon of complex organic urban waste streams into value-added products
Acronym	CIRCULAR BIOCARBON
Call	H2020-BBI-JTI-2020
Topic	BBI2020.SO1.F1 – Valorise the organic fraction of municipal solid waste through an integrated biorefinery at commercial level
Type of action	BBI-IA-FLAG Flagship
Grant Agreement	101023280
Duration	60 months 01.06.2021 – 31.05.2026
Budget	Overall budget: € 22 952 297,50 EU contribution: € 14 999 999,75
CORDIS	https://cordis.europa.eu/project/id/101023280

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CIRCULAR BIOCARBON Project

Consortium

Project Coordinator

4 RTOs, 2 SMEs and 5 Large Companies

CIRCULAR BIOCARBON Project

Turning carbon of complex organic urban waste streams into value-added products

Context and main challenge

- Even though the recycling of waste has improved a lot in the past decades, **municipal solid waste still contains a large part of organic fraction that is not used efficiently** but rather incinerated with the municipal solid waste or sent to landfills.
- Through the **concept of a biorefinery**, **OFMSW** can be **managed more efficiently** in terms of circular economy.

CIRCULAR BIOCARBON Project

Turning carbon of complex organic urban waste streams into value-added products

Objectives

- The **first-of-a-kind flagship biorefinery** based on a **unique model** in which the **OFMSW and SS** will be **valorised into high added-value products** and a variety of intermediate products.

- The project will **open up new business frameworks** based on a **new circular vision of waste treatment in a city towards a sustainable bioeconomy**.

CIRCULAR BIOCARBON Project

Turning carbon of complex organic urban waste streams into value-added products

- CIRCULAR BIOCARBON supports the new Circular Economy Action Plan for Europe by **demonstrating the feasibility, at a commercial level**, of a biorefinery of this kind.

- CIRCULAR BIOCARBON project **represents a milestone for Europe**, both in terms of its **implementation scale (industrial level)** as well as for its **replicability potential**.

- In the CIRCULAR BIOCARBON biorefinery, the OFMSW and sewage sludge, after pretreatment processes, will be processed **through a pool of cascading technologies (biological, physical, chemical and mechanical ones) and steps**, starting from anaerobic digestion process, allowing to **obtain high-added value products, moving towards new models** based on a **new circular vision of waste treatment** in a city in the framework of a **sustainable bioeconomy**.

Sewage Sludge (SS)

Organic Fraction of Municipal Solid Waste (OFMSW)

CIRCULAR BIOCARBON Project

CIRCULAR BIOCARBON is a **flagship integrated biorefinery** located in:

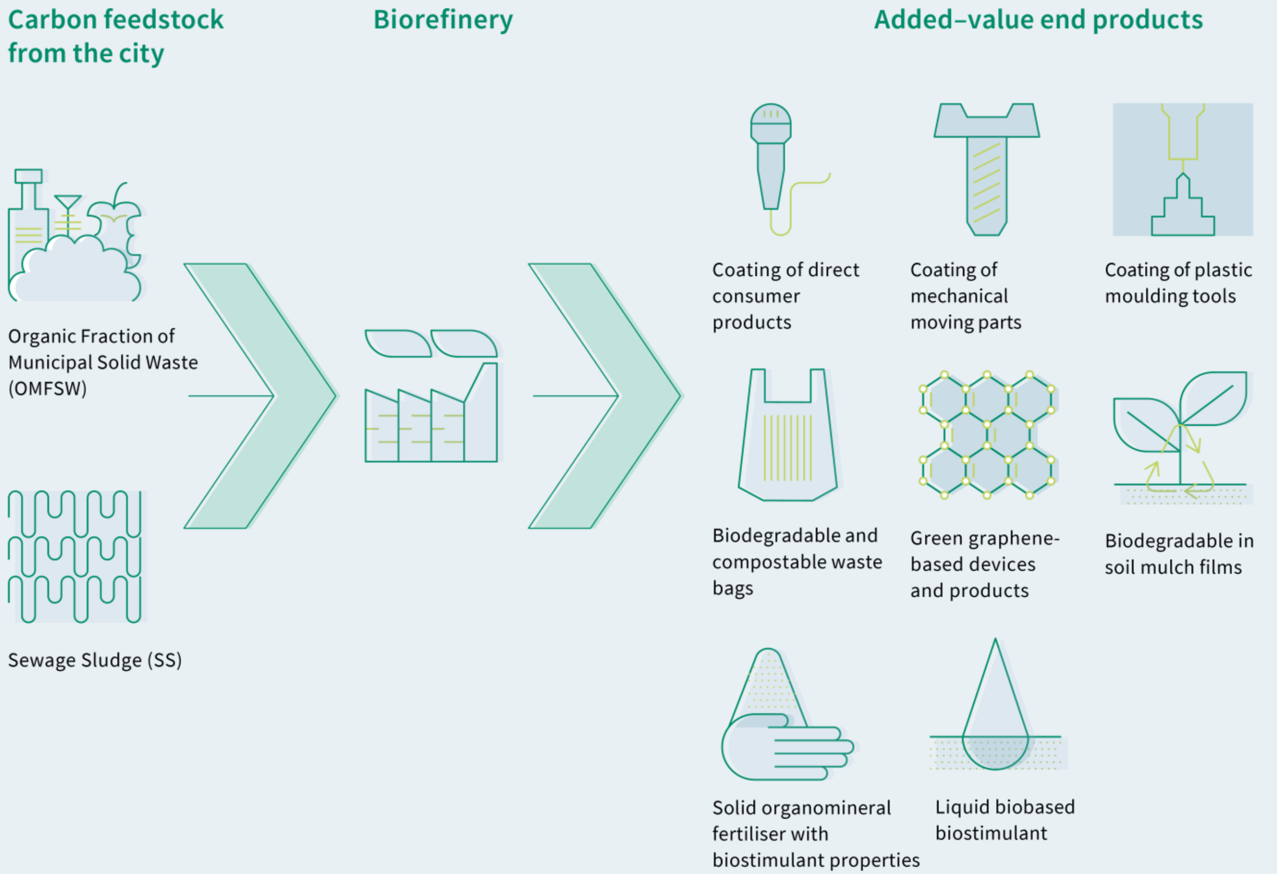
for logistical, customer, and market reasons

Multi-location implementation supports also the **replicability of the concept** by testing it against **different waste management schemes**, **ecosystems** and **practices** in **different territories**.

Bio-based industries are part of the climate solution, and **CIRCULAR BIOCARBON** biorefinery **will contribute to provide bio-based materials to industries moving towards their transition to be bio-based.**

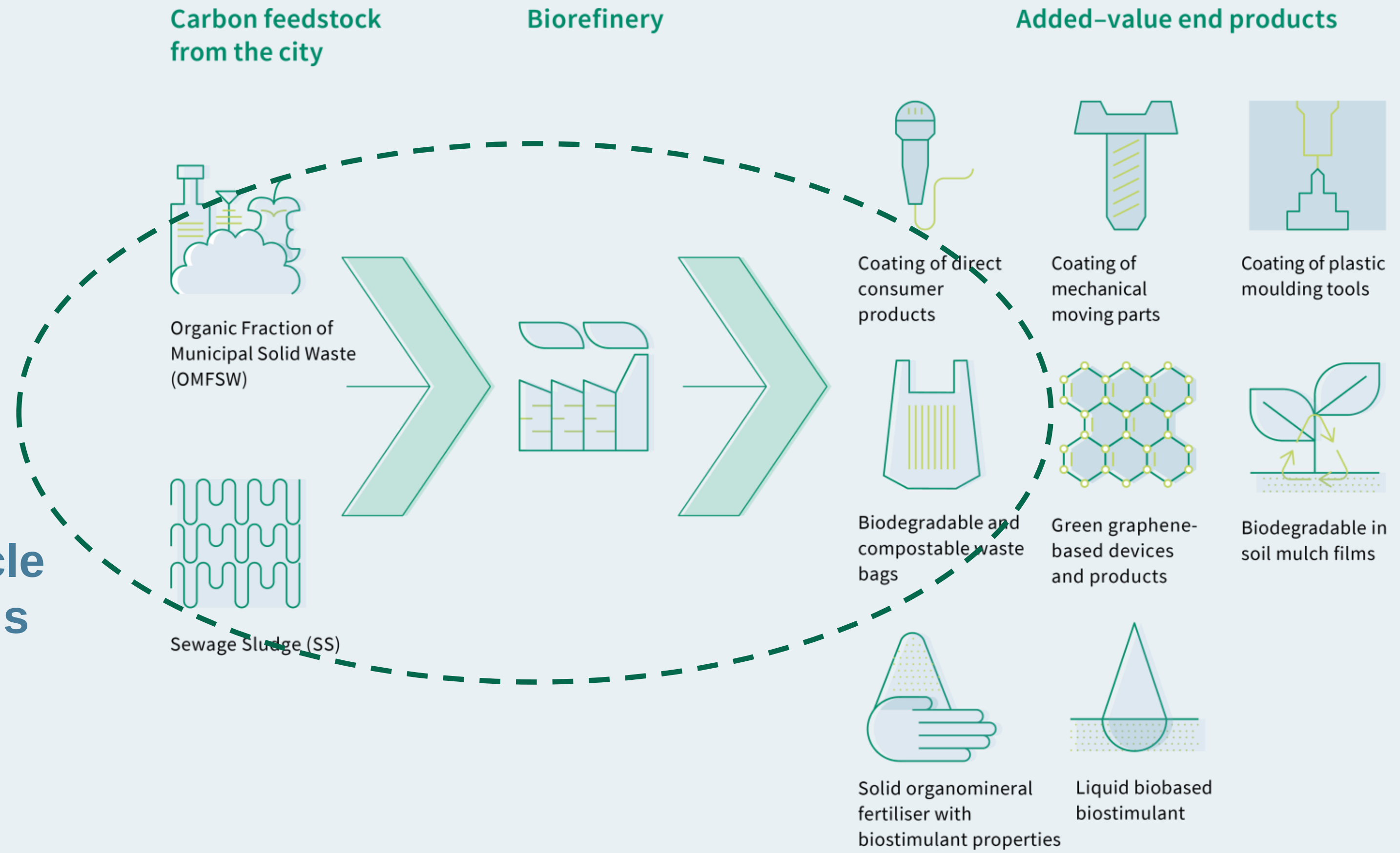
CIRCULAR BIOCARBON Project

Turning carbon of complex organic urban waste streams into value-added products



CIRCULAR BIOCARBON Project

Turning carbon of complex organic urban waste streams into value-added products

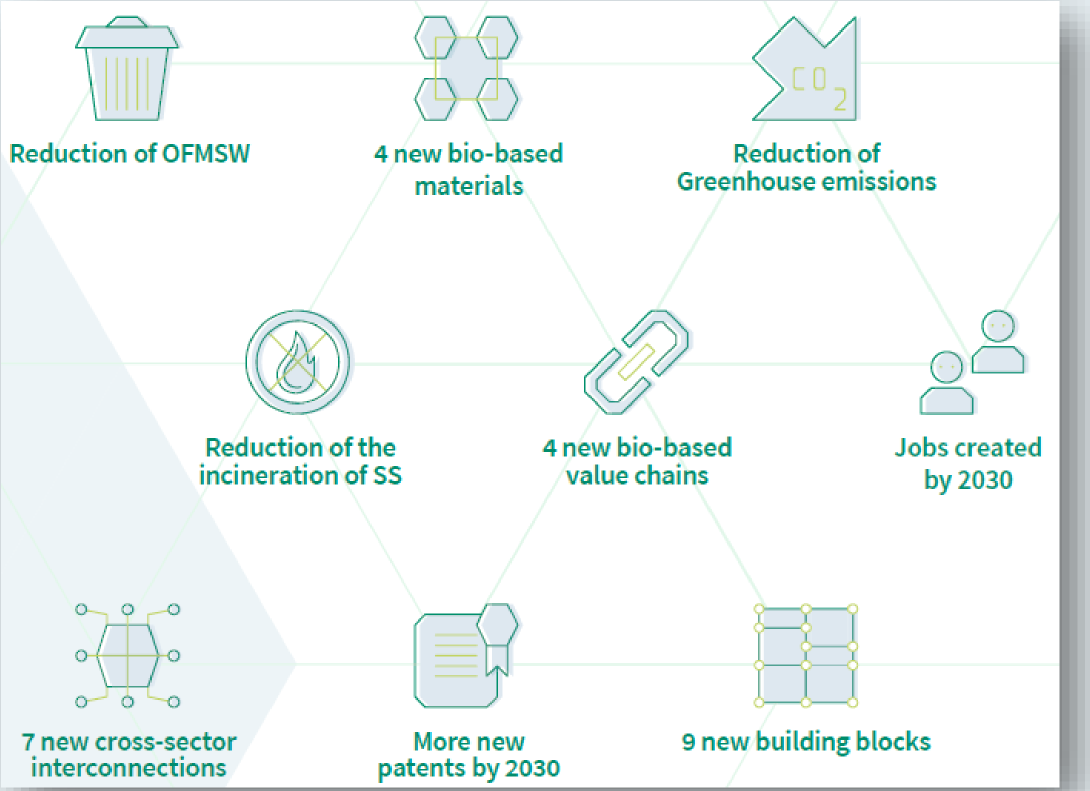


closing the cycle of the materials

zero waste

CIRCULAR BIOCARBON Project

Expected impacts



CIRCULAR BIOCARBON Project

Follow us and keep up to date!

@circbiocarbon

circularbiocarbon.eu

CIRCULAR BIOCARBON

/company/circbiocarbon

Stay in the loop!

Newsletter

Don't miss any news and important infos on the project. Subscribe to our newsletter and stay updated.

Email address* | Name, Surname* | Organisation* | Area*

CIRCULAR BIOCARBON Project

For a sustainable, innovative and competitive transition to a bio-based economy.

17th November 2022

CIRCULAR BIOCARBON

Turning carbon of complex organic urban waste streams into value-added products

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CIRCULAR BIOCARBON

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Mesa Redonda sobre aplicaciones industriales

Sostenibilidad e innovación en la industria aeronáutica

Alejandro Ibrahim Perera
Director General Aeropuerto Teruel

AEROPUERTO DE TERUEL

Aplicaciones industriales: sector aeronáutico

“Sostenibilidad e Innovación en la industria aeronáutica: el aeropuerto de Teruel”

Alejandro Ibrahim Perera

Director General Aeropuerto Teruel

Dr. Ingeniero Aeronáutico

Presidente Clúster Aeroespacial de Aragón, AERA

17 nov 2022

Nuevas Infraestructuras Inversión 2022-2023: 30 mill. €

1. Introducción
2. Sector. Características
3. Actividades / operaciones
4. Hangar capacidad 2 A380
5. 3 Naves, nave 2.000 m2 y 5.000 m2
6. Pavimentación campa Fase IV
7. Estacionamiento aeronaves zona industrial
8. Proyectos Europeos I+D
9. Nuevo PIGA 200 ha
10. Sostenibilidad aeronáutica

Operaciones 2013 -2022, 10 años creciendo

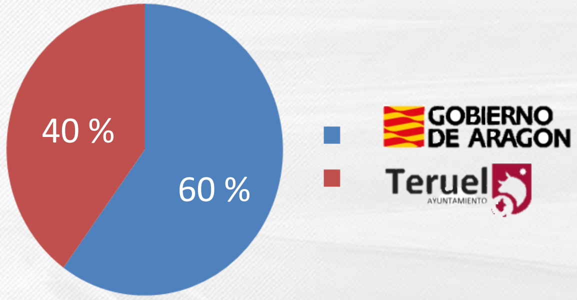
Operaciones 2013 -2022, 10 años creciendo

Introducción

Primer A380, 25 de abril 2020

Introducción

- El Aeropuerto de Teruel es un hub aeronáutico industrial Internacional. Pertenece al Gobierno de Aragón y al Ayuntamiento de Teruel.



GOBIERNO DE ARAGON

Teruel AYUNTAMIENTO

Características principales

- 550 Hectáreas, 4º más grande de España
- El mayor centro **MRO y estacionamiento** en Europa
- Parking larga estancia para más de **400** aeronaves
- Espacio aéreo libre de congestión
- Aeropuerto **Internacional**
- Personal técnico alta **cualificación**
- Diferentes negocios aeronáuticos

Responsabilidad medioambiental, RSA y Calidad

Medidas implantadas por el aeropuerto:

- **Sellos gestión Calidad ISO9001 y Ambiental ISO14001.**
- Respetuoso y participe de reconversión **medioambiental.**
- **Sello PLATA de Excelencia Empresarial**.
- **Ahorro energético→ Plantas fotovoltaica autoconsumo**; bombillas de bajo consumo; sistemas control encendido
- **Responsabilidad social de Aragón** desde 2017, 18, 19 +, 20 +, 21 + y 22 +
- **Reducción** consumibles y combustibles.

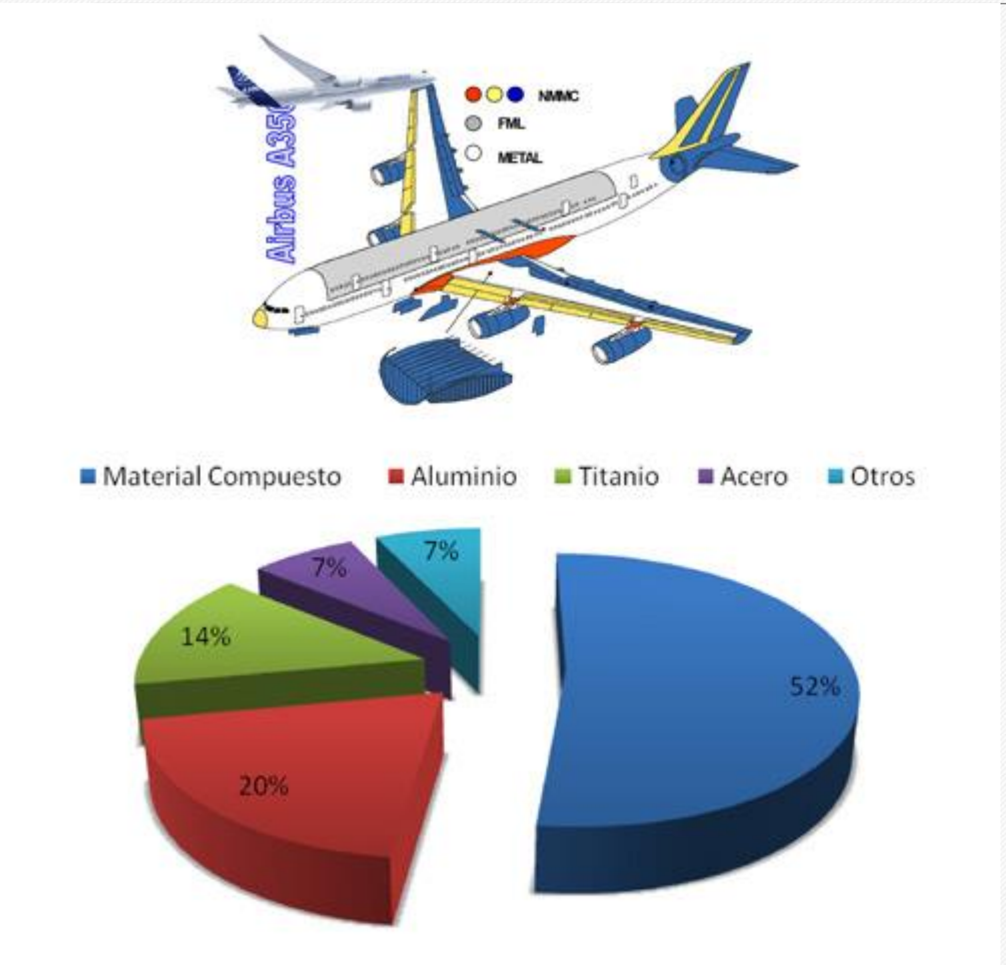
Actividades

1) Parking de aeronaves de larga estancia
2) Reciclaje de aeronaves
3) Mantenimiento, MRO
4) Servicios de pasajeros
5) I+D aeronáutico
6) Logística aeronáutica
7) Centro de excelencia de UAVs , drones
8) Escuelas de vuelo
9) Test de aeronaves y vuelo
10) Pruebas de motores cohete
11) Aviación general y ejecutiva
12) Transformación de aeronaves
13) Publicidad y rodaje cinematográficos
14) AERA, Plataforma aeroespacial, UNIZAR, Cátedra UNED, …

Materiales compuestos industria aeroespacial

- **Fibra de carbono muy generalizada en el sector aeronáutico y espacial.**
- **La separación y recuperación de las fibras y polímeros que componen estos materiales son procesos complejos.**
- **La fibra de carbono reciclada tiene propiedades mecánicas inferiores.**
- **Utilizar la fibra reciclada en sectores menos exigentes, ej. reposabrazos o raquetas de pádel.**

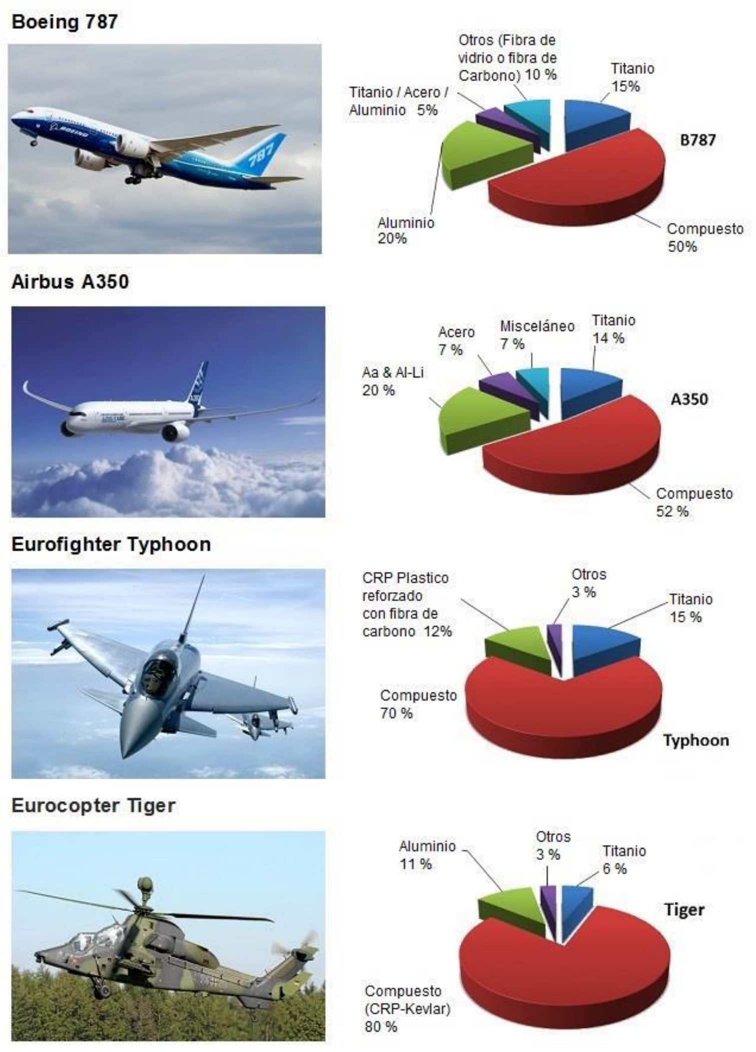
Materiales compuestos industria aeroespacial



Aplicaciones de materiales reciclados plásticos en drones

Fabricación aditiva con materiales compuestos reciclados

Materiales compuestos industria aeroespacial



fabricación aditiva 3D de material compuesto a partir de **desechos de CFRP** (polímero reforzado con fibra de carbono) foto: FIDAM

Actividades

- Mantenimiento, estacionamiento y reciclado aeronaves
- Naves Logísticas materiales compuestos
  y ensayos no destructivos
- JETA1 and AVGAS aviation fuel supply
- Pruebas de motores cohete
- Desarrollo e innovación de UAVs
- Aplicaciones y formación de drones
- Reciclado de plásticos de aeronaves

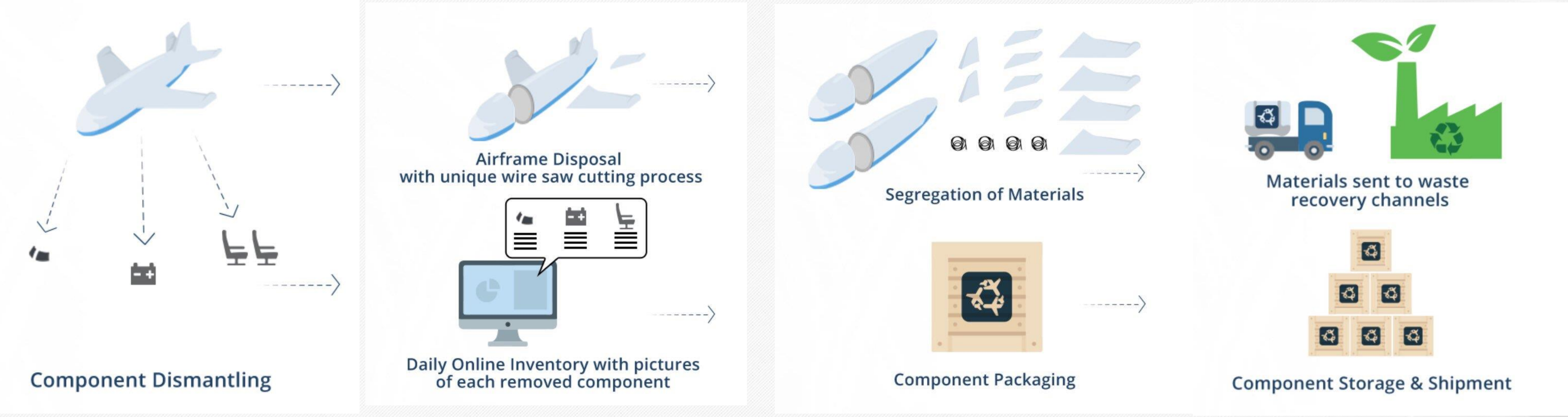
Eco-oil

Actividades

Principal cliente → TARMAC ARAGON

Compañía de estacionamiento de aeronaves más grande de Europa, es el líder aeronáutico dedicado exclusivamente al mantenimiento, estacionamiento y reciclado con respeto medioambiental

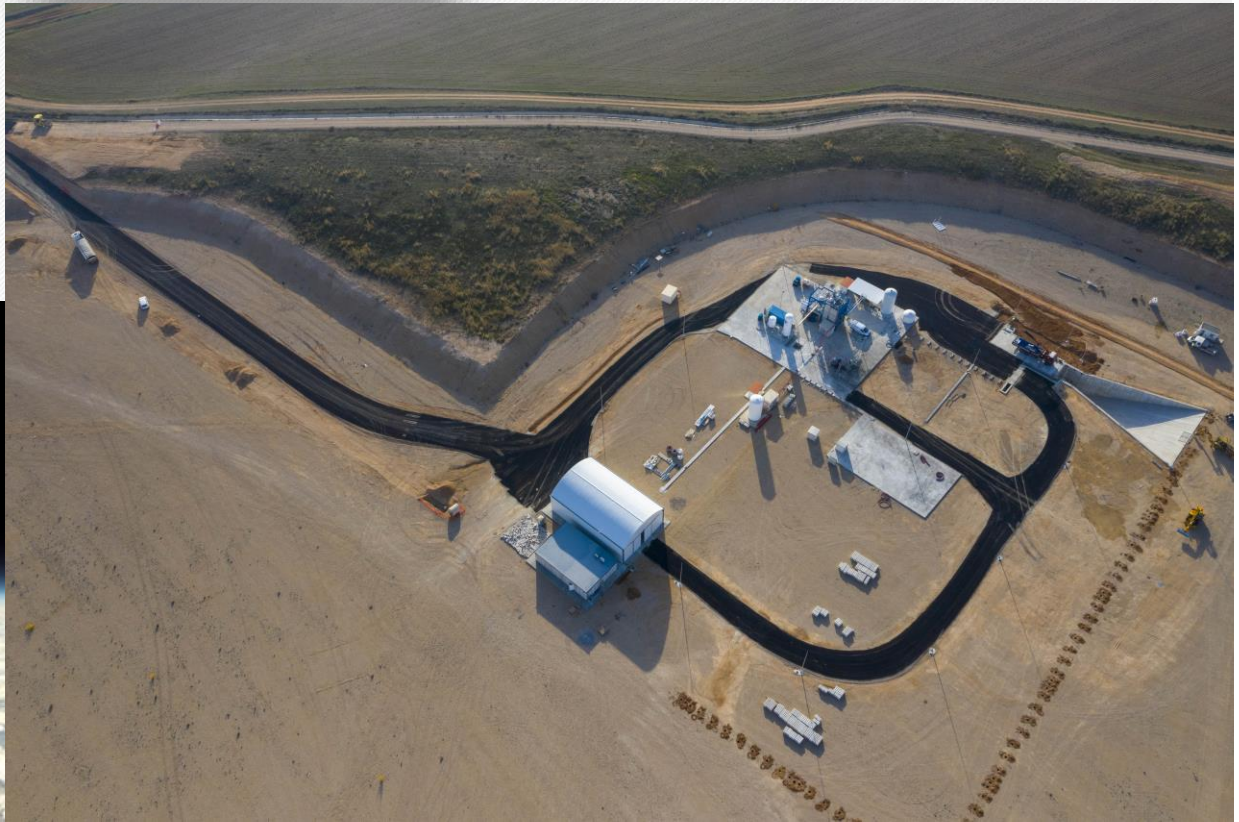
Actividades



Actividades

BANCO DE PRUEBAS DE MOTORES COHETE

- Pruebas 1º motor cohete líquido comercial
- PLD SPACE creada en 2011
- Ensayos de motores cohete en zona Campa
- Financiación CDTI + entidades privadas
- Desarrollo pionero y estratégico



PLATA SPAIN
Plataforma Aeroportuaria - Teruel

Premio Mundial Innovación 2019

Corporación de Ciencia y Tecnología Aeroespacial de China, en Pekín
China Academy of Space Technology

2022

INVERSIÓN: 1M€

INVERSIÓN: 3M€

INVERSIÓN: 23M€

INVERSIÓN: 0,6M€

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022

HANGAR 2 A380

Proyecto	
Proyecto	Hangar 2 A380, oficinas y almacén
Presupuesto	278.000 €
Inicio	Junio 2019
Duración	4 meses

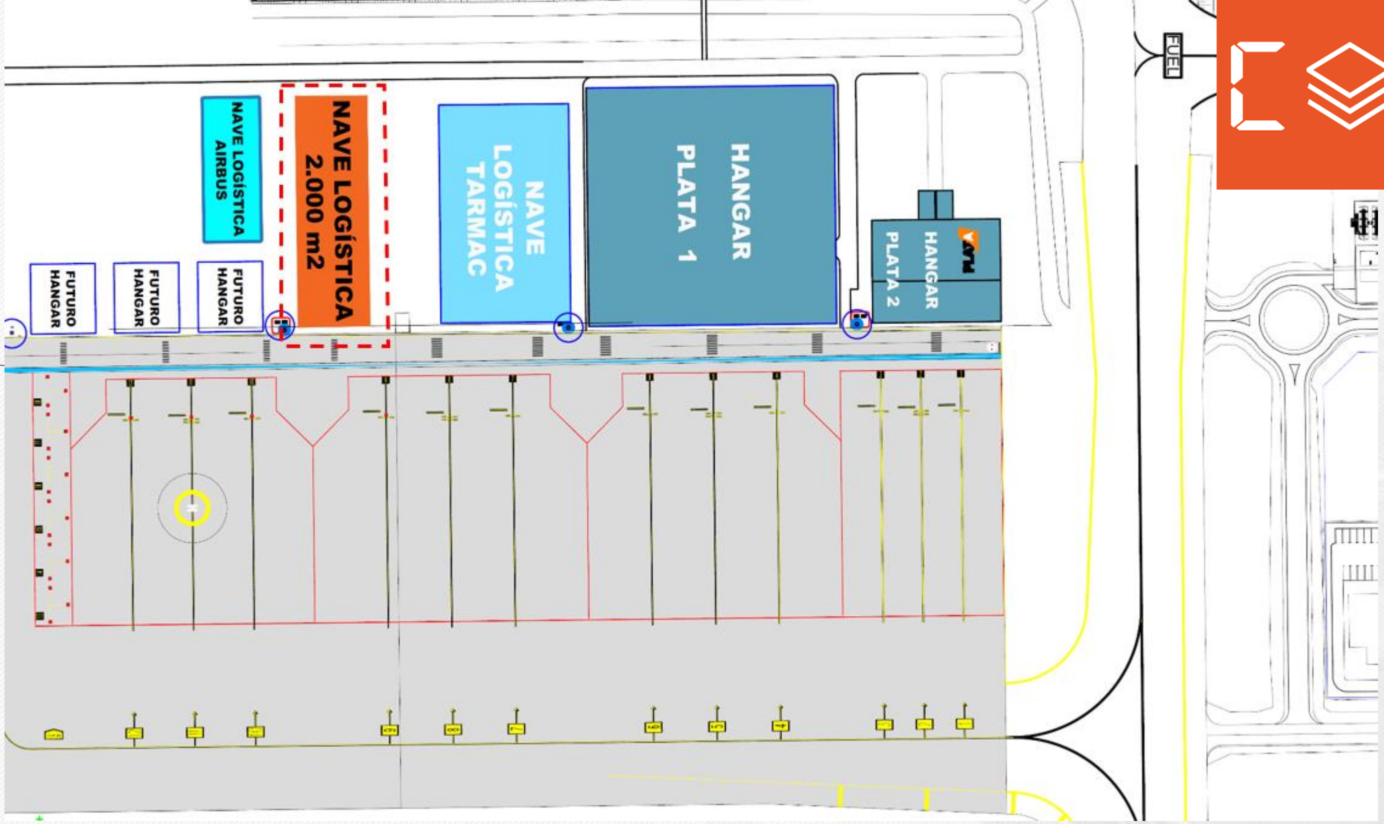
Obra	
Superficie hangar	16.200 m^2
Presupuesto	20.3 mill. €
Inicio	10 diciembre 2021
Duración	15 meses

Concesión	
Inicio previsto	Junio 2023
Duración	25 años

HANGAR 2 A380

PLATA SPAIN
Plataforma Aeroportuaria - Teruel

NAVES



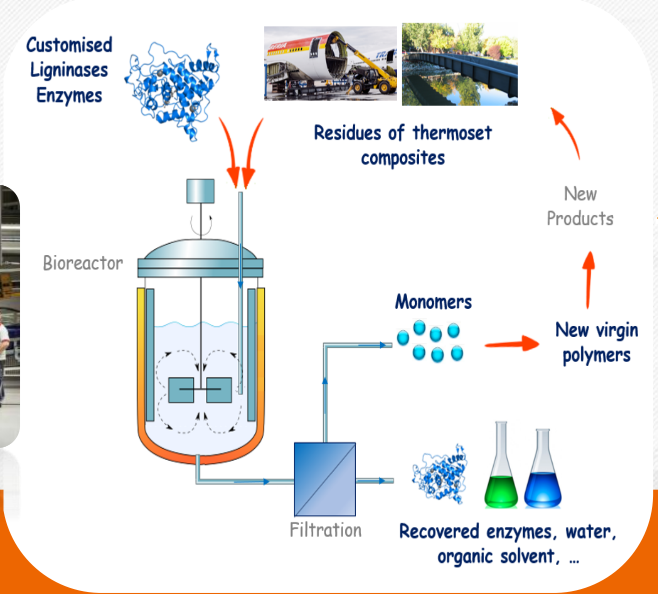
BIZENTE

Una solución innovadora para resolver el fin de la vida útil de los materiales compuestos termoestables en base al desarrollo de una nueva tecnología centrada en una biodegradación enzimática controlada.

10 Socios

Duración: 48 meses,

Mayo 2020 – Abril 2024



PLATA SPAIN
Plataforma Aeroportuaria - Teruel

Clean Sky
JOINT UNDERTAKING

Teruel
AYUNTAMIENTO

GOBIERNO DE ARAGON

HELACS

Holistic processes for the cost-effective and sustainable management of **E**nd of **L**ife of **A**ircraft **C**omposite **S**tructures.

PARTNERS

AIRBUS

PLATA SPAIN
Plataforma Aeroportuaria -

aitiip

ELG Carbon Fibre Ltd.

CENTEXBEL

VIBES

PARTNERS

IMPROVING RECYCLABILITY OF THERMOSET COMPOSITE MATERIALS THROUGH A GREENER RECYCLING TECHNOLOGY BASED ON REVERSIBLE BIOBASED BONDING MATERIALS

Duration: 48 months

- Consortium: 13 partners
- European countries: 7 (ES, FR, IE, DE, BE, IT y HE)
- Total budget: 5.299.800 €

EOLO HUBS

Wind turbine blades **E**nd **O**f **L**ife through **O**pen **HUBs** for circular materials in sustainable business models

<u>Duración</u>: 48 meses
<u>Comienzo</u>: 2023

- Socios : 18
- Países Euopeos: 7 (ES,UK,NL, DE, DK, IT y FR)
- Presupuesto total: 12.253.714 €

Nuevo Plan de Interés General Aragón, PIGA 200 ha

PLATA SPAIN Plataforma Aeroportuaria - Teruel

Teruel AYUNTAMIENTO

GOBIERNO DE ARAGON

2021

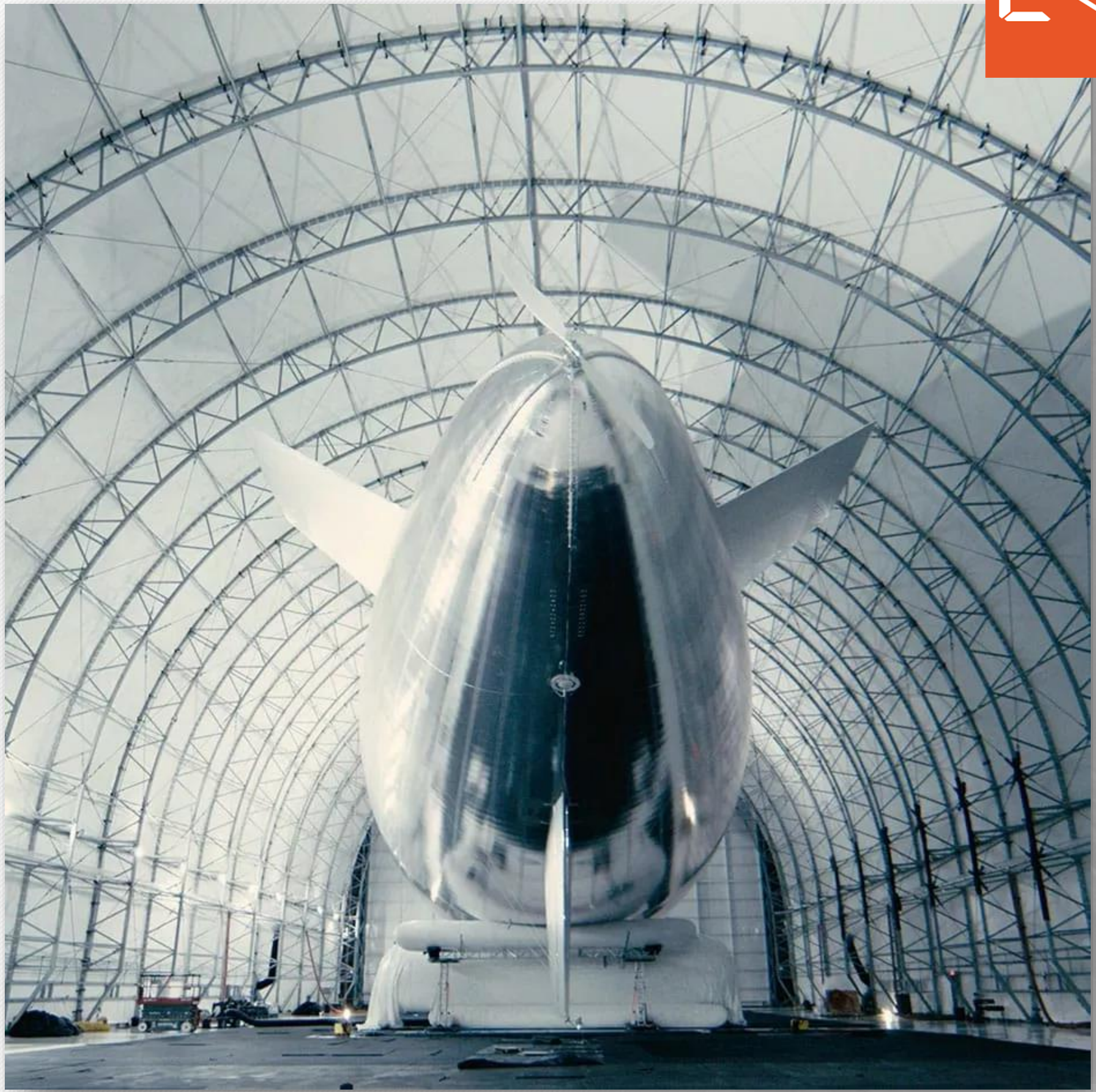
SCEYE

Proyecto	
Proyecto	Hangar y nave de producción
Presupuesto	350.000 €
Inicio previsto	Octubre 2022
Duración	6 meses

Obra	
Superficie hangar	14.000 m^2
Superficie nave producción	14.000 m^2
Presupuesto	25.000.000 €
Inicio previsto	2023

SCEYE

Proyecto y obra centro de control	
Proyecto	Centro de control HAPS, Nave y urbanización
Presupuesto	1.300.000 €
Inicio previsto	Enero 2023
Duración	10 meses



NUEVOS NEGOCIOS Y RETOS

Mantenimiento Digital MRO

Astropuertos, spaceport

Aeronaves cero emisiones

Taxis aéreos

Drones carga aérea

Dirigibles

DESCARBONIZACIÓN DE LA MOVILIDAD AÉREA

- Airbus Zero-e

- Eviation “Alice”, avión comercial eléctrico pax 9, alcance 1046 km
  - Empresa israelí, Eviaiton Aircraft
  - 95% de materiales compuestos con 3 motores de hélice
  - Baterias de Li-ion, 900 kWh

- Embraer, Eve Urban Air Mobility
  - Cero emisiones
  - Despegue y aterrizaje vertical

- HAPS, High Altitude Platform Station
  - No tripulados a gran altitud > 20 km
  - Globos, UAVs y dirigibles

Eviation Alice
9 pax MTOW
6.350 kg

CONSORCIO DEL AEROPUERTO DE TERUEL
Polígono de Tiro, 4
44396 Teruel, Aragón, España
T: + 34 978 617 742 F: +34 978 617 538
Consultas comerciales: info@airportofteruel.com
www.aeropuertodeteruel.com

Aeropuerto de Teruel

Gracias por su atención

PLATA
Plataforma Aeroportuaria - Teruel
SPAIN

@aeropuerteruel
@TeruelAirport

La Economía Circular en Saint-Gobain

Fernando Pardo Cobo
Responsable Economía Circular Placo® e Isover

SAINT-GOBAIN

LA ECONOMÍA CIRCULAR EN SAINT-GOBAIN

Fernando Pardo Cobo

isover SAINT-GOBAIN

placo SAINT-GOBAIN

ACH

AGENDA

1. SAINT-GOBAIN GROUP
2. ESTRATEGIA EN ECONOMÍA CIRCULAR
3. ACCIONES RELEVANTES

● El GRUPO SAINT-GOBAIN

UN FUERTE GRUPO GLOBAL

Más de

167,000

Empleados y sobre
100 nacionalidades representadas

Uno de los 100 más innovadores grupos del mundo

Fundada

Hace **350** Años

Alrededor de

1,000 fábricas en el mundo, operando en **70** países

Compromiso:
Neutralidad en cabono en 2050

Volumen de negocio en 2020

38.1kM€

Alrededor de

4,000

Puntos de venta

Líder mundial o europeo en la mayoría de nuestros negocios

2.9kM€

Ingresos de explotación en 2020

Nuestra organización

4 regiones consolidadas

America

Sur de Europa, Oriente medio, Africa

Norte de Europa

Asia-Pacífico

Y una entidad global

High Performance Solutions

SAINT-GOBAIN

DESEMPEÑO NO FINANCIERO RECONOCIDO

100 %
de las compras comerciales cubiertas con la firma de **carta a proveedores, y 90.6% para las compras no comerciales**

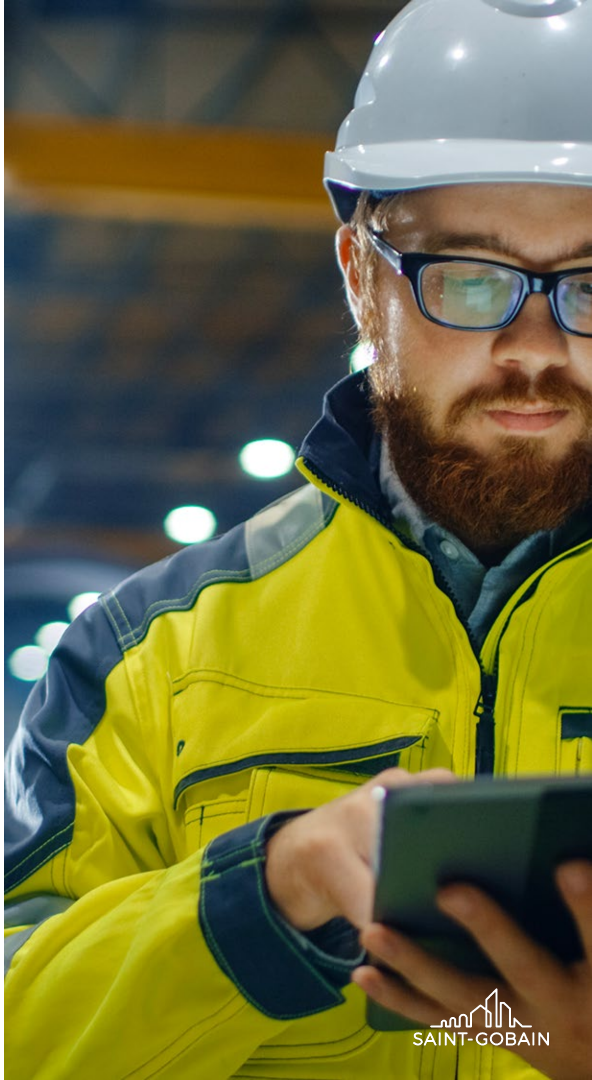
2050
Comprometida para lograr la neutralidad de carbono para 2050

3rd año
consecutivo en el **Índice de Igualdad de Género de Bloomberg**

10,100,574
toneladas de materias primas naturales vírgenes no extraídas (arena, yeso) gracias a las acciones de Saint-Gobain a favor de la **economía circular**

1.8
Tasa de frecuencia de accidentes

2020
Lanzamiento de un ambicioso programa de **protección social**, "**CARE by Saint-Gobain**"



● ESTRATEGIA EN ECONOMÍA CIRCULAR

SAINT-GOBAIN

NUESTROS VALORES

NUESTROS VALORES EN LA BASE DE NUESTRO ENFOQUE DE RESPONSABILIDAD

Cambio Climático
Contribuir al surgimiento de una economía baja en carbono capaz de preservar el bien común

Creación de valor local e inclusiva
Ser un ciudadano corporativo en todos los países

Inclusion & diversidad
Tener una amplia diversidad dentro de los equipos para construir una cultura corporativa abierta y atractiva.

SAINT-GOBAIN

Contribuir al desarrollo responsable y sostenible

Seguridad y salud
Nuestra primera responsabilidad es garantizar la salud y la seguridad de nuestros empleados y de nuestros grupos de interés

Business ethics
Share our values with our stakeholders to build together over the long term

Economía Circular
Cambiar la forma en que diseñamos, producimos y distribuimos nuestros productos y soluciones para desarrollar la economía circular

SAINT-GOBAIN

Qué es para Placo la Economía Circular

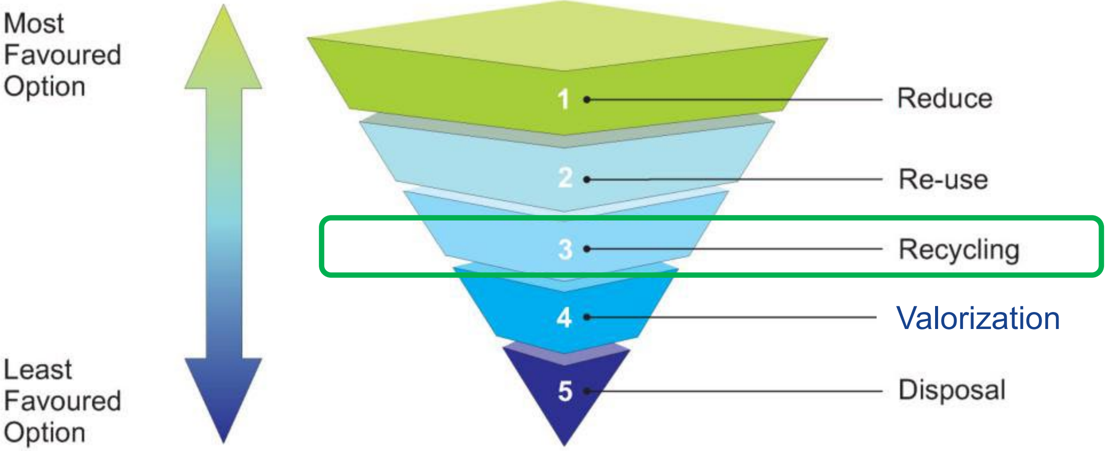
Estrategia de Responsabilidad Social Corporativa

SAINT-GOBAIN

Estrategia Economía Circular

RSC

Objetivos



1. Reducir
2. Reutilizar
3. Reciclaje
4. Valorización

SAINT-GOBAIN

ACCIONES RELEVANTES

SAINT-GOBAIN

Acciones relevantes

Reciclaje de placas de yeso laminado

Madrid, Comunidad de Madrid — Nacional

Ámbito de acción y relevancia de la BPEC en EC

- Desarrollo de productos y bienes que sustituyan sus materias por otras más sostenibles.
- Medidas de/o que fomenten el reciclado: recuperación de materiales de los residuos para reprocesarlos en nuevos productos, materiales o sustancias, ya sea para el propósito original o para otros propósitos.
  Recogida separada del textil, residuos de aparatos eléctricos y electrónicos (RAESS), plásticos, residuos de construcción y demolición, neumáticos, etc.

Objetivos

1. Fomentar la circularidad del sector de la construcción.
2. Educar y sensibilizar al sector de la construcción sobre la reciclabilidad de los productos de yeso.
3. Diseñar productos más sostenibles aumentando el % de uso de materias primas secundarias.
4. Disminuir la cantidad de residuos que terminan en el vertedero.
5. Demostrar que el reciclaje de productos de yeso es posible.
6. Involucrar a todas las partes interesadas (promotor, arquitecto, distribuidores de material de construcción, constructores, etc.) en el reciclaje de los residuos de yeso y su consumo responsable, fomentando la construcción sostenible (sellos sostenibles como LEED, BREEAM, VERDE, LEVELS…)."

Descripción

Para cerrar el círculo de los productos de placa de yeso laminado se diseñó el siguiente plan de acción:

1. Diseño y construcción de una planta de reciclaje para transformar los residuos de construcción de placa de yeso laminado en yeso secundario.
2. Fomento, educación y sensibilización del sector de la construcción para la segregación en obra de este tipo de residuos, y su logística inversa hacia los centros de producción.
3. Trasformación de estos residuos en materia prima secundaria en aquellas instalaciones autorizadas para la operación R5 (reciclaje).
4. Consumo de la materia prima reciclada en nuestros centros de fabricación de productos de yeso, para lo cual es necesario la adaptación de todos los procesos y controles de calidad asociados a la introducción de esta nueva materia.

Resultados Clave

- Competitividad, Potencial de ingresos, Innovación
- Empleo, Conocimiento, Desarrollo sostenible
- Materiales, Residuos, Biodiversidad

Principios de EC

2 3 6 7

Objetivos ODS

9 11 12

Dificultades o retos identificados

- Cooperación con las autoridades.
- Cambio de comportamiento/falta de conciencia o cooperación.
- Reconocimiento de subproductos/materias primas secundarias.
- Bajo retorno de inversión.
- Otros.

Entidad

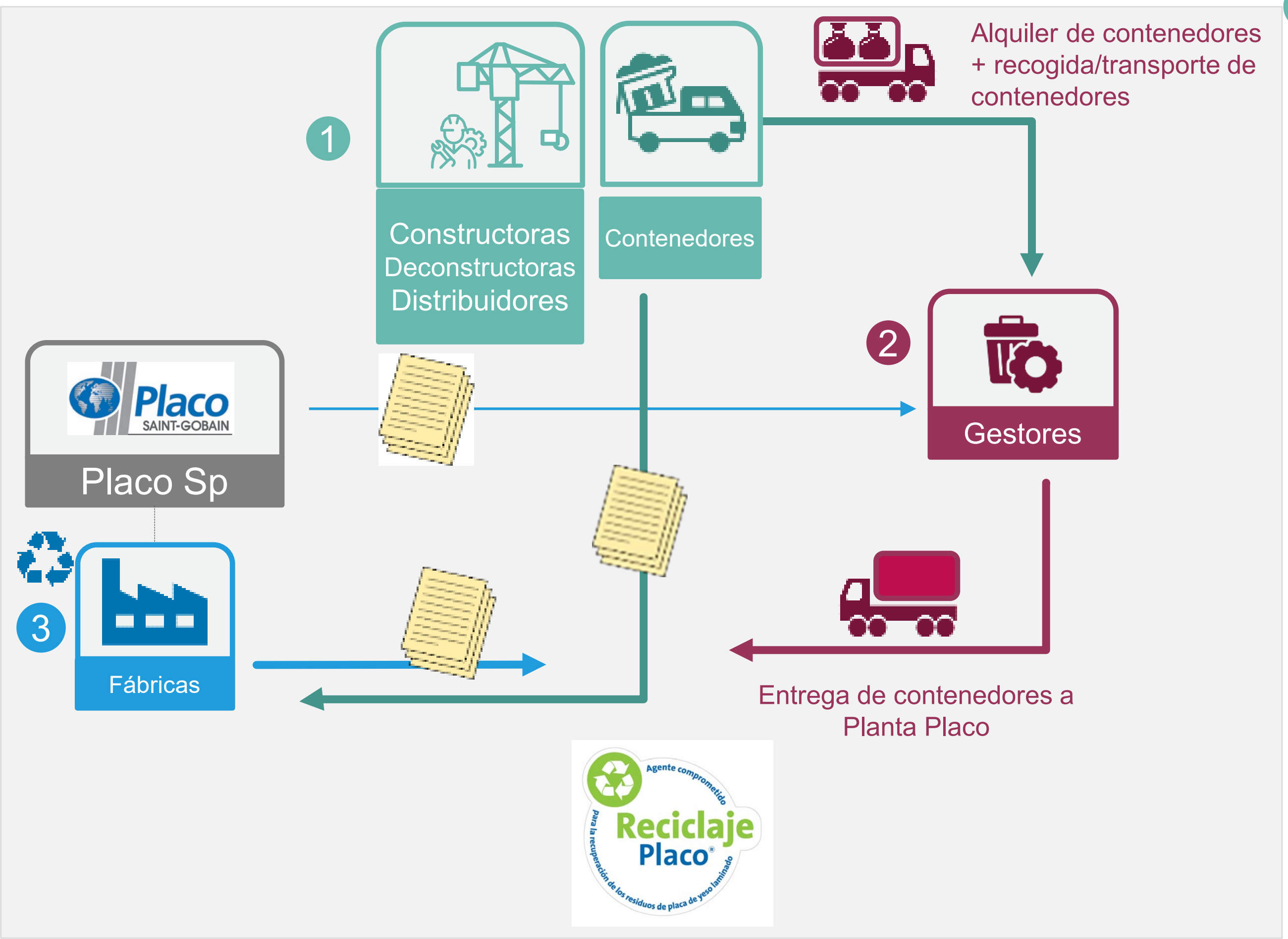
Saint-Gobain Placo Ibérica en colaboración con el Ayuntamiento de Getafe.
Fernando Pardo Cobo (fernando.pardo@saint-gobain.com).

Más información: www.placo.es

https://www.placo.es/sostenibilidad/reciclaje-de-placa-yeso-laminado
https://www.servimedia.es/noticias/1228902
https://www.adip-as.com/campus-acciona-reciclaje-pyl-placo/

SAINT-GOBAIN

Servicio de Reciclaje Placo



1

El Gestor organiza la recogida de los residuos de yeso clasificados y cobra al propietario de los residuos por este servicio. Placo no interfiere.
Destino 1: Al Gestor
Destino 2: Directo a Fábricas de Placo

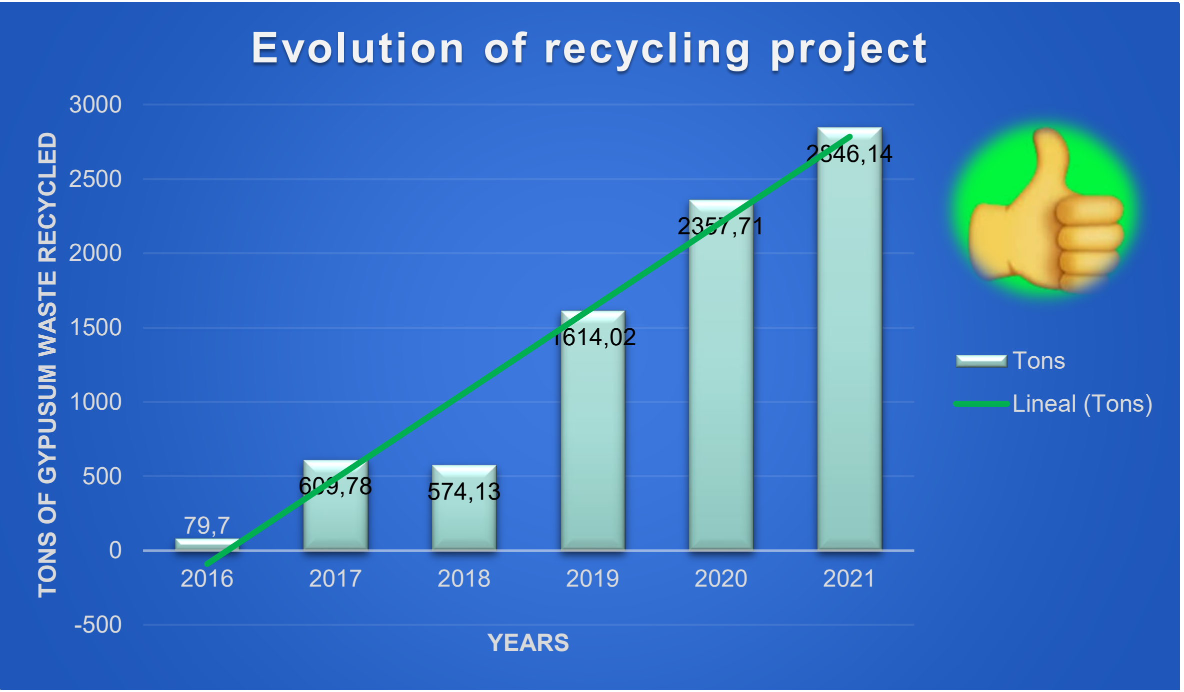
2

Placo tiene contratos individuales con gestores y constructutoras para la entrega de residuos de yeso de construcción o demolición limpios a nuestras plantas de reciclaje. Placo no paga y nadie paga Placo.

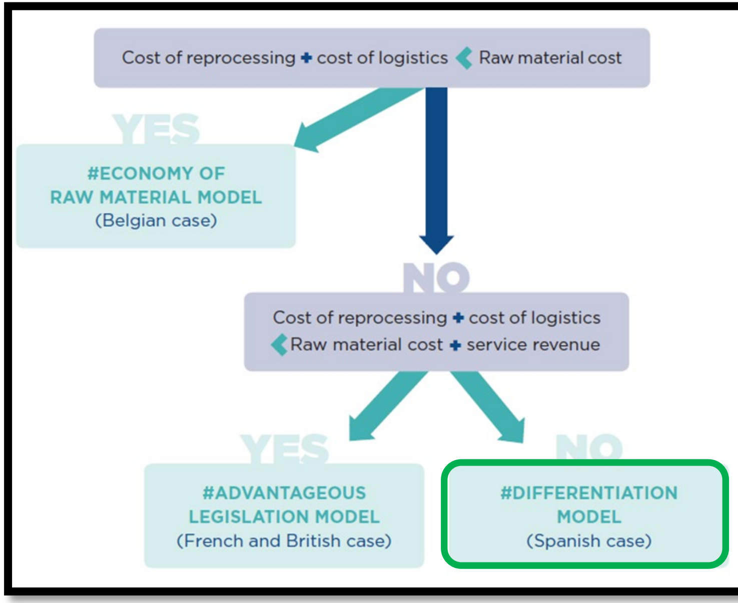
3

Fábricas Placo recibe los residuos, los recicla y los utiliza como materia prima en el proceso. Una pequeña cantidad de residuos se entregan a Gestores de residuos

SERVICIO DE RECICLAJE PLACO

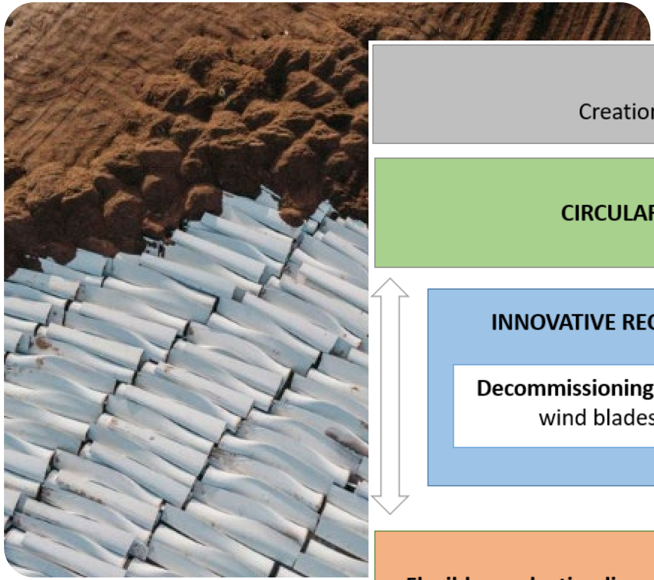


Modelo de funcionamiento



EOLO PROJECT

Secondary raw material from waste from wind turbine blades



KNOWLEDGE HUBS
Creation of the knowledge hub, Dissemination & communication activities.

CIRCULAR DESIGN

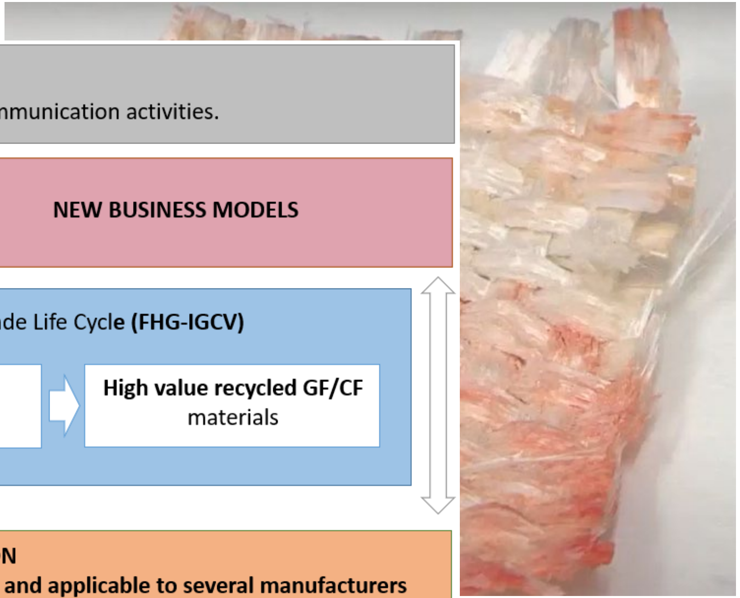
NEW BUSINESS MODELS

INNOVATIVE RECYCLING TECHNOLOGIES for the complete Blade Life Cycle **(FHG-IGCV)**

- **Decommissioning** of EoL wind blades
- **Flexible Recycling** components
- **High value recycled GF/CF** materials

LARGE SCALE DEMONSTRATION
Flexible production line, able to deal with a large amount of material and applicable to several manufacturers

- **First EoL WB waste material**. From production Scrap to Zero energy recycling processes.
- **Offshore decommissioning**. EoL WB to Zero waste recycling processes.
- **Onshore Decommissioning**. EoL WB to Green Chemical recycling processes.
- **Up-cycled recycled Materials** in composite Heavy sectors



Fuente: Universidad de Alicante

GRACIAS

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Director de Economía Circular

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SAINT-GOBAIN

Innovation to Circular Economy Service

Raúl Gallego
Responsable de materiales avanzados
Grupo Antolín

Innovation to Circular Economy service

17th November 2022

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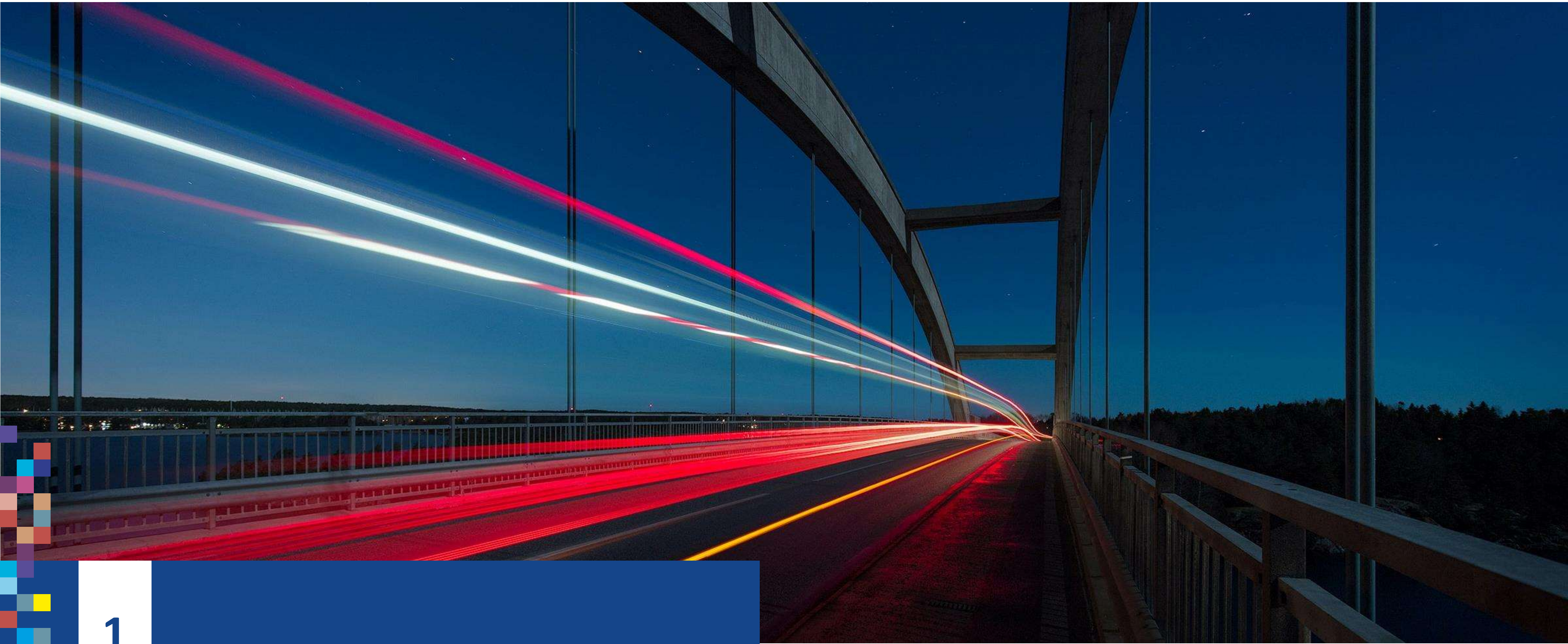
AGENDA 2030

GRUPO ANTOLIN



1

Compañía global con pilares sólidos

De un vistazo

Datos 2021

Nuestro Negocio

Ventas consolidadas
Millones de euros
4.055

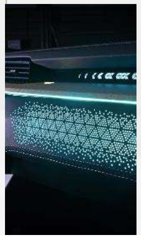
Innovación
% sobre ventas en 2020
3%

Inversión
Material e inmaterial
Más de 217mills

Techos

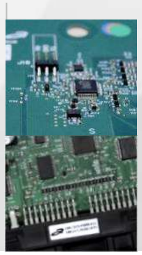
Puertas

Iluminación y HMI



Cockpits

Sistemas electrónicos



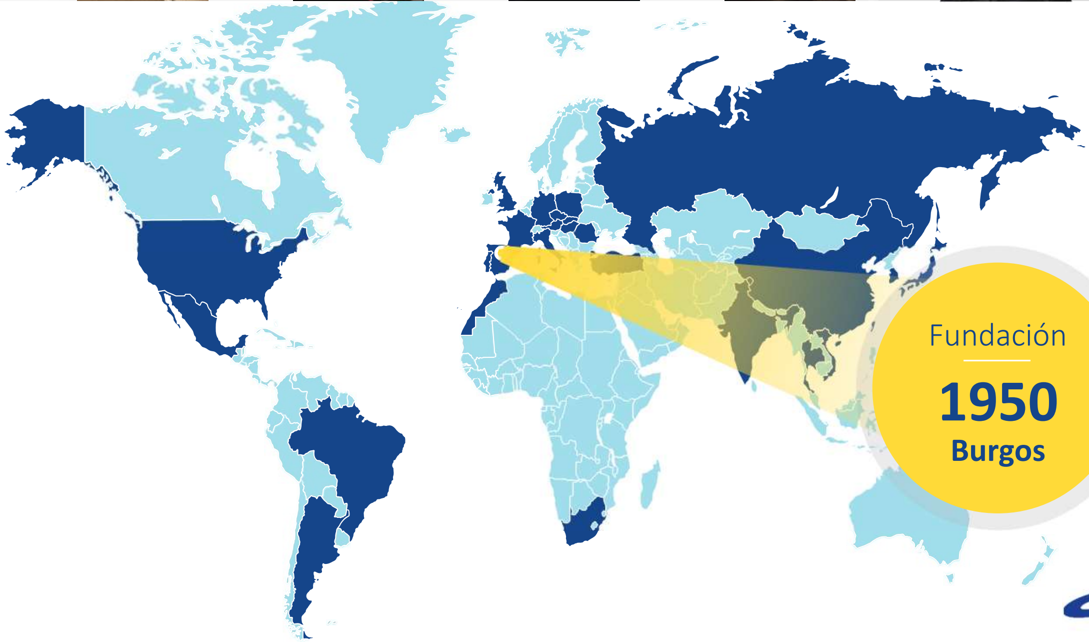
EBITDA Consolidado
millones de euros
282

Gestión del entorno
reducción de emisiones CO_2 alcance 1 y 2
27%

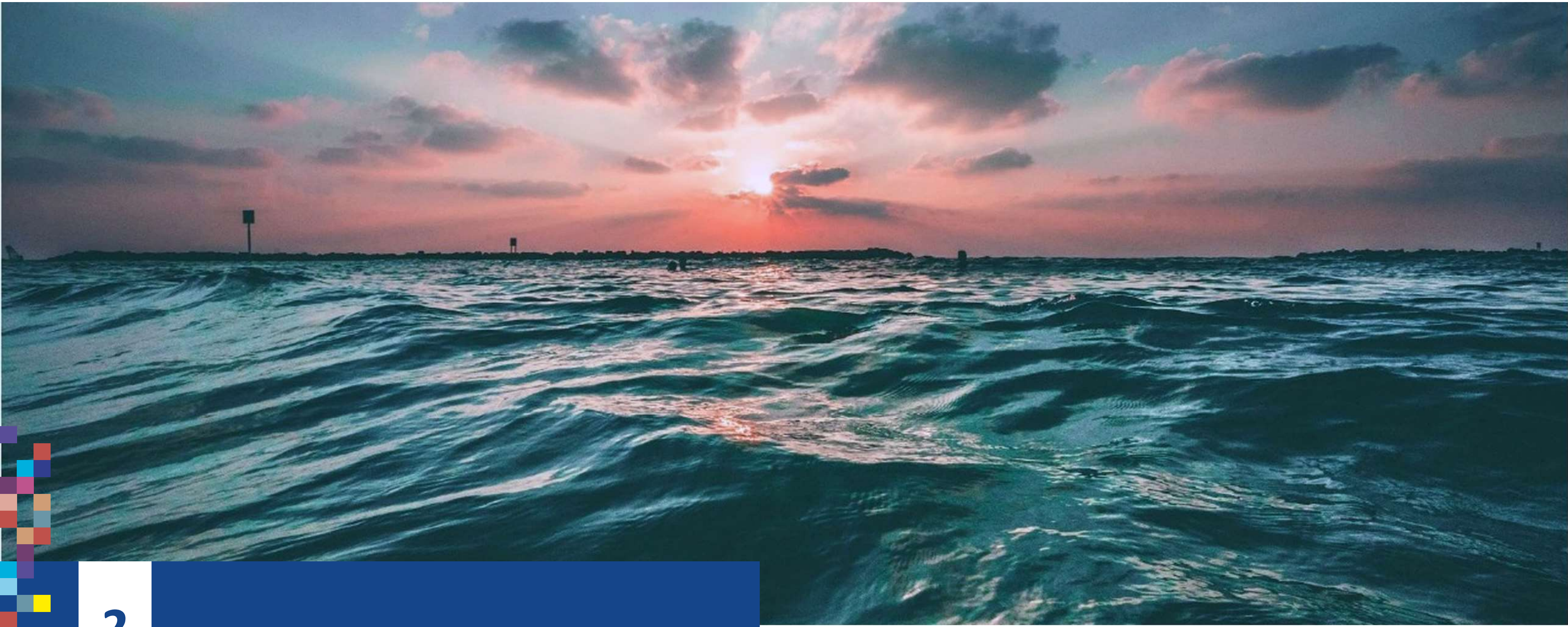
Colaboradores
Número de personas
+25.000

Con casi
140 plantas
en **26 países**

112
 # Nacionalidades



Fundación
1950
Burgos



2

Comprometidos con la Sostenibilidad

Construyendo una movilidad sostenible

Alineados con Objetivos de Desarrollo Sostenible

Prioridades de actuación

OBJETIVOS DE DESARROLLO SOSTENIBLE

17 OBJETIVOS PARA TRANSFORMAR NUESTRO MUNDO

1. FIN DE LA POBREZA
2. HAMBRE CERO
3. SALUD Y BIENESTAR
4. EDUCACIÓN DE CALIDAD
5. IGUALDAD DE GÉNERO
6. AGUA LIMPIA Y SANEAMIENTO
7. ENERGÍA ASEQUIBLE Y NO CONTAMINANTE
8. TRABAJO DECENTE Y CRECIMIENTO ECONÓMICO
9. INDUSTRIA, INNOVACIÓN E INFRAESTRUCTURA
10. REDUCCIÓN DE LAS DESIGUALDADES
11. CIUDADES Y COMUNIDADES SOSTENIBLES
12. PRODUCCIÓN Y CONSUMO RESPONSABLES
13. ACCIÓN POR EL CLIMA
14. VIDA SUBMARINA
15. VIDA DE ECOSISTEMAS TERRESTRES
16. PAZ, JUSTICIA E INSTITUCIONES SÓLIDAS
17. ALIANZAS PARA LOGRAR LOS OBJETIVOS

Compromiso de futuro

Marcar la diferencia por nuestros valores y compromisos, para **ser reconocidos como una empresa de referencia en el ámbito de la sostenibilidad** dentro del sector de componentes de automoción **y extender ese objetivo a toda nuestra cadena de valor**.

Accionistas

Equipo

Clientes

Proveedores

Inversores

Sociedad

Construyendo una movilidad sostenible

Alineados con Objetivos de Desarrollo Sostenible

La **Agenda 2030 para el Desarrollo Sostenible** se compone de 17 objetivos y 169 metas. Para su seguimiento, se diseñaron 232 indicadores que pueden medirse a través de los datos estadísticos que aquí se recogen. La actualización de estos indicadores, que constituyen una operación estadística recogida en el Programa anual vigente, es continua e incluye información tanto del INE como de otras fuentes oficiales que se irán incorporando de forma progresiva.

Clara Arpa (Presidenta del Pacto Mundial de la ONU España): "Quedan menos de diez años para alcanzar las 169 metas propuestas en los Objetivos de Desarrollo Sostenible (ODS) y todavía no hemos avanzado lo suficiente..............El Objetivo 9 de Industria, innovación e infraestructura de la agenda 2030 de Naciones Unidas deja constancia de que la innovación es esencial para la consecución de los Objetivos de Desarrollo Sostenible"

"La actividad de innovación del Grupo Antolin tiene como referente la contribución a los ODS. Trabajamos en nuevos materiales de origen natural y vegetal que permitan un desarrollo sostenible de los mismos, y en soluciones que permitan la reciclabilidad de nuestros componentes."

Javier Ignacio,
Director de innovación corporativa del Grupo Antolín

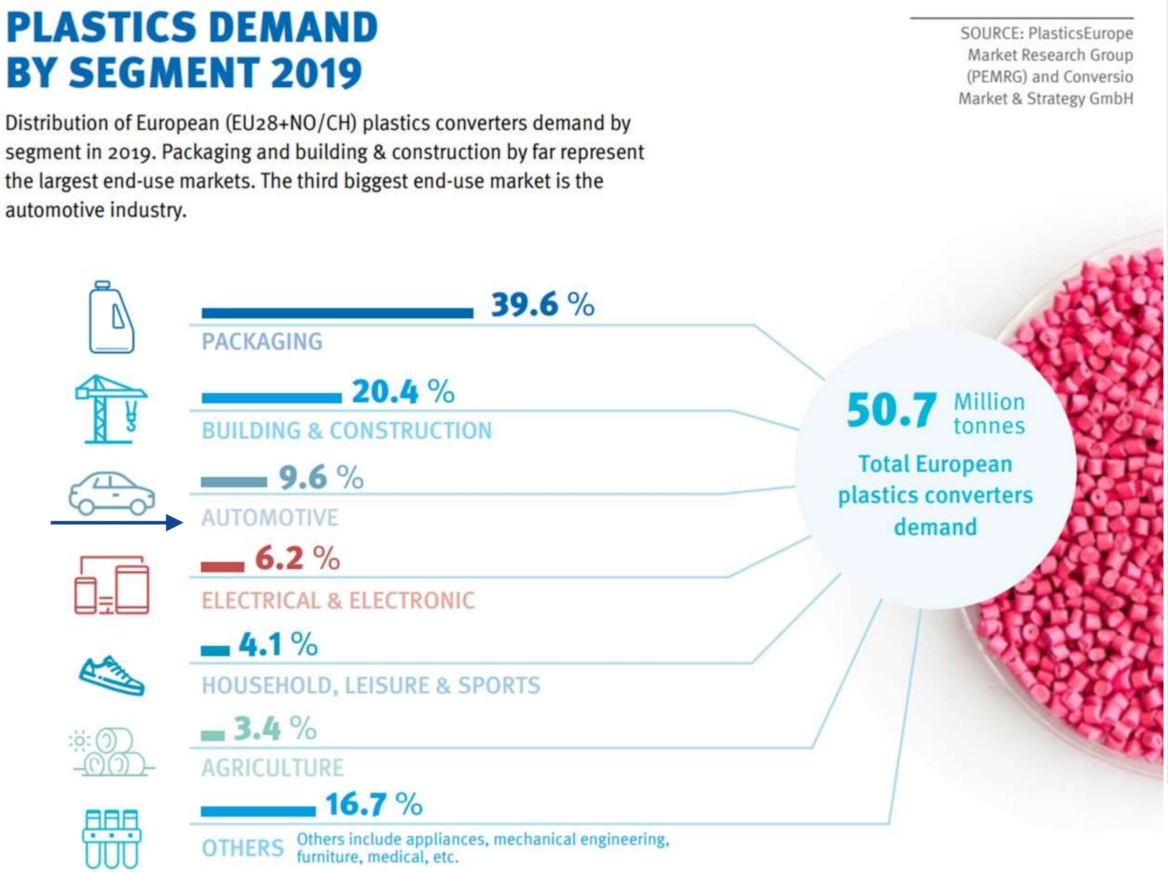
https://www.pactomundial.org/biblioteca/ods-ano-7-innovacion-para-lograr-la-agenda-2030/

3

Datos sobre Sostenibilidad en Automoción

Rompiendo con Ideas Preconcebidas

Plásticos en Automoción



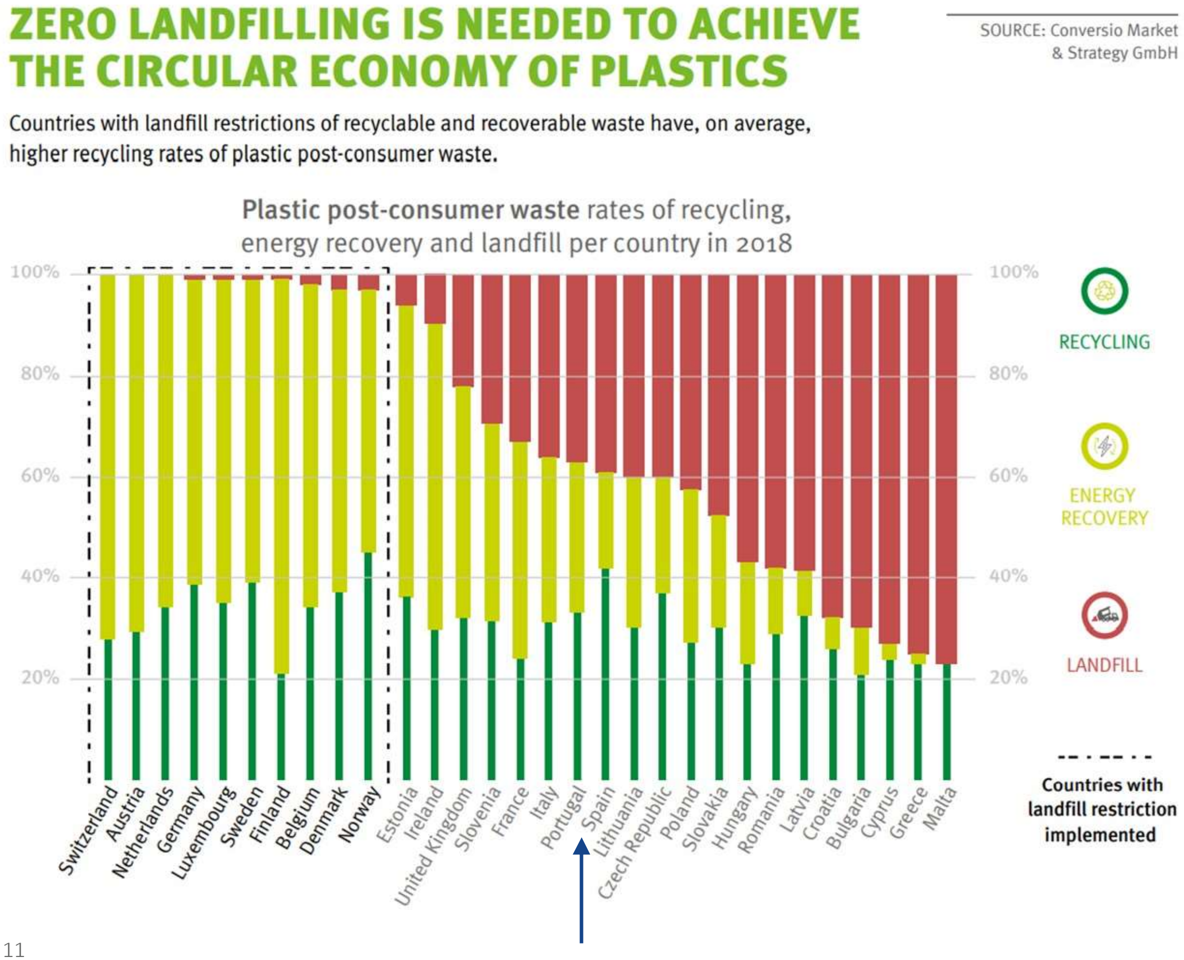
Los plásticos se encuentran **injustamente criminalizados**. Aportan grandes beneficios a la sociedad: conservación de alimentos y medicamentos, equipos de protección EPIs, ...

La industria de Automoción transforma **apenas un 10%** de la cantidad de plásticos procesados en Europa.

Sin el uso de plásticos **no sería posible alcanzar muchos de los objetivos medioambientales de las industrias de movilidad y transporte**: aligeramiento de peso de componentes, construcción de baterías y elementos electrónicos, ...

Rompiendo con Ideas Preconcebidas

Reciclado de Plásticos en España vs. UE



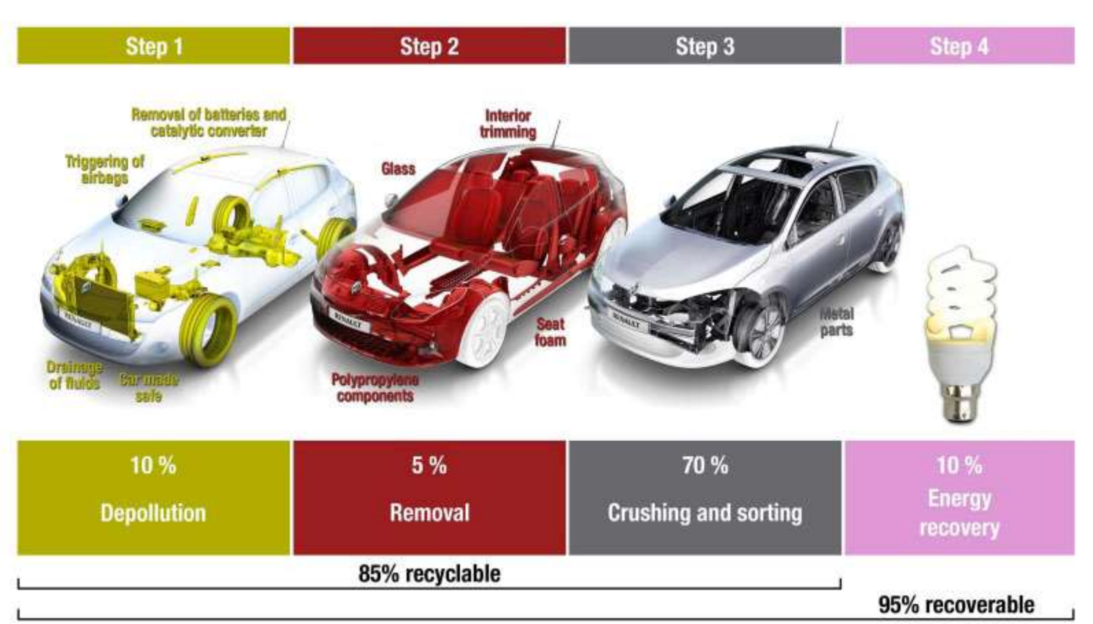
Las tasas de reciclado de residuos plásticos en España están **por encima de las del resto de países europeos** (tan sólo por detrás de Noruega)

Los países del norte de Europa (con mayor tradición y educación medioambiental) **apuestan por la valorización energética de los residuos plásticos** debido a su alto poder calorífico (comparable al del gasoil)

Esos países tienen **impuestas restricciones para el envío de los residuos plásticos a vertederos**

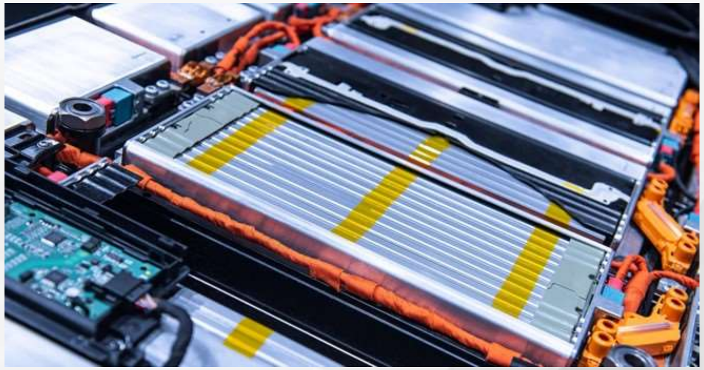
Regulaciones (UE)

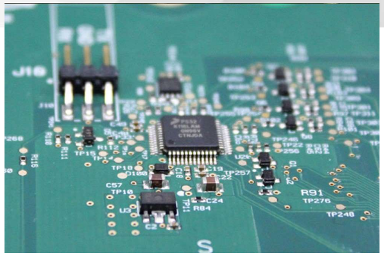
Tratamiento de Vehículos a Fin de Vida



La Directiva 2000/53/CE del Parlamento Europeo, relativa a los vehículos al final de su vida útil (ELV) es la norma aplicable a los vehículos, sus componentes y los materiales con que se fabrican.

- Desde el 1 de enero de 2015, el porcentaje de reutilización y valorización de los vehículos al final de su vida útil debe ser como mínimo de un 95%, y el porcentaje de reutilización y reciclaje de al menos el 85%.





Directiva (UE) 2018/849 del Parlamento Europeo y del Consejo, de 30 de mayo de 2018, por la que se modifican la Directiva 2000/53/CE, la Directiva 2006/66/CE relativa a residuos de pilas y acumuladores y la Directiva 2012/19/UE sobre residuos de aparatos eléctricos y electrónicos.

Además de criterios de reutilización y reciclaje, **comienzan a imponerse otros aspectos de la sostenibilidad**:

- Diseños con **Vida Extendida** (*Extended Life Products*)
- Replanteamiento de la arquitectura de los componentes **para facilitar desensamblaje** (Designed for disassembly)
- Diseños con **vistas a la reparabilidad**

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4

Nuestra Aportación a una Movilidad Sostenible

Productos y Procesos Sostenibles

Light weighting

- Espumación Estructural
- Nuevos aditivos de carga para PP: µ–Talco, microcargas minerales
- Composites termoplásticos reforzados con fibras naturales
- Estructuras modulares: DHM Premium Concept
- Integración de funciones: Elevalunas plásticos PWR; Centralización de PCBs
- Tintas Conductoras en sustitución de cableado

Sustainable Processes

- Soldadura Láser de Materiales Plásticos
- NovaForm ®
- Double Slash Tech para revestimientos de PVC en cockpits
- e-Galvano ®
- Fabricación Avanzada para reducción de ciclos, consumos, emisiones y residuos
- Certificaciones Ambientales y Energéticas: ISO 14001 & 50001
- Eficiencia energética en plantas y medios productivos
- Mejora de Gestión Logística: Reducción de emisiones CO_2
- Certificación de Consumo de Energía Verde

Sustainable Materials

- Espumas Green PU (Poliol de origen vegetal) D25
- eBu ®: Textiles con fibras naturales
- Materiales 100% naturales para superficies decorativas
- Materiales disruptivos procedentes de fuentes renovables
- Biopolímeros & Bioadhesivos
- Velos de fibras naturales en sustitución de fibra de vidrio

Energy Management & Harvesting

- Baterías y Condensadores flexibles integrables en componentes y procesos de fabricación
- Valorización Energética de residuos de fabricación de techos
- Sistemas de Gestión Térmica/Confort en EVs

Circular Economy

- Textiles y tejidos a partir de reciclado (rPS/rPET)
- Materiales reciclados (PC/ABS) para revestimientos interiores
- Insertos decorativos a partir de pulpa de celulosa procedente de residuos de industria papelera
- Materiales plásticos procedentes de Reciclaje Químico
- Coretech ® Composites elaborados con residuos de revestimiento de techos

Eco - Design

- Diseños con vistas a **recuperación de componentes, reparabilidad y criterios de vida extendida**, …
- Arquitecturas ligeras y de fácil desensamblaje en ELVs
- Procesos de adhesión con cintas para facilitar operaciones de desensamblaje de componentes
- Sustitución de módulos retroiluminados por sistemas de proyección de luz

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Algunos Ejemplos

Altos contenidos de material reciclado: NovaForm®

NovaForm®

- Tecnología **propiedad de GA** basada en extrusión, deposición sobre molde y termoformado en prensa, que **permitir el procesado de materiales con altos contenidos de materia reciclada**.
- Se aplica a la **fabricación en serie de medallones de puerta** en los que se hace uso de **más del 50% en peso de un material reciclado** homologado por el cliente (procedente del reciclaje de paragolpes)

GRUPO ANTOLIN

Algunos Ejemplos

Aligeramiento de Peso: DHM Premium y Sistemas Elevalunas PWR

Sistemas de Elevalunas de Plástico (PWR)

- Permiten un aligeramiento de peso de **400 gramos por pieza en sistemas de puerta delantera** (doble rail) y de **250 gramos por pieza en puertas traseras** (rail simple).
- Pueden contribuir a un ahorro de peso de **hasta 1,3 Kg por coche** con las consiguientes ventajas de ahorro de consumo y emisiones.

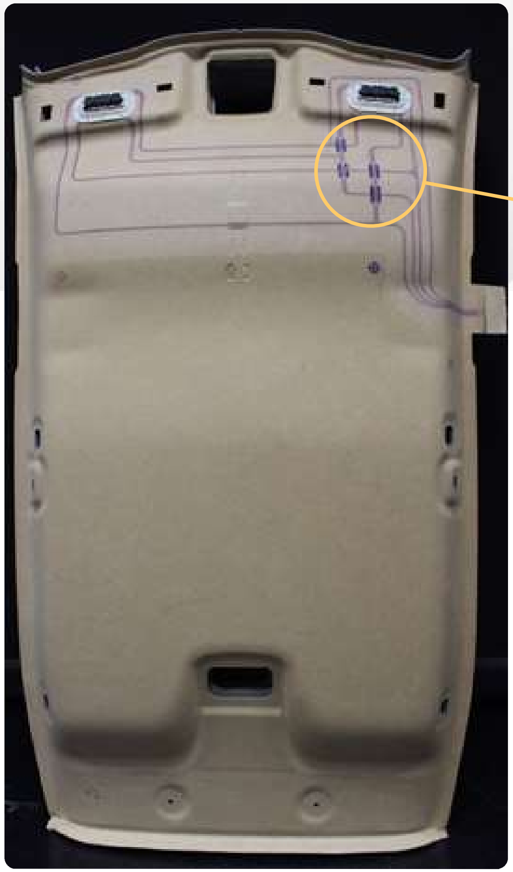
Sistema Modular GA DHM Premium:

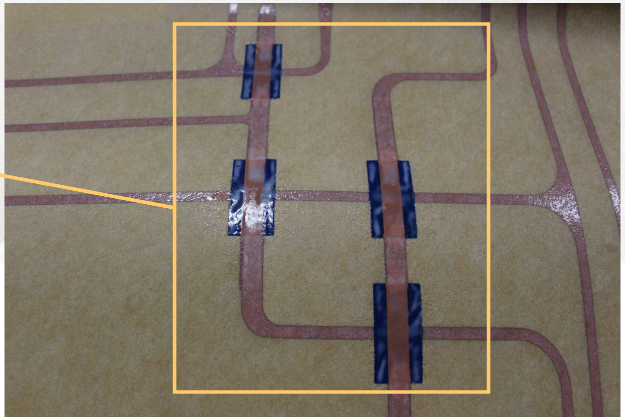
- Permite un **aligeramiento de un 42,5% en módulos integrales de puerta**.
- Se hace uso de **diferentes composiciones de PP y PP expandido (EPP)**, materiales compuestos de matriz PP así como de tecnologías para la **integración de carriles elevalunas plásticos** y de funciones de **aislamiento acústico**, de protección frente a **impacto lateral**, de **estanqueidad**, …

GRUPO ANTOLIN

Algunos Ejemplos

Aligeramiento: Impresión Funcional y Espumación Estructural



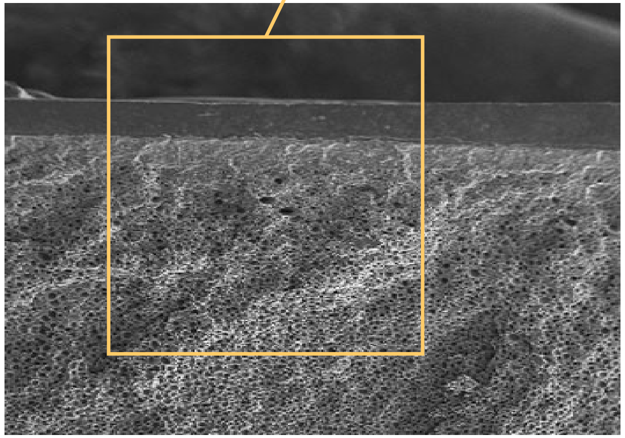


Circuitería Impresa:

- Uso de **Tintas conductoras y materiales dieléctricos** para la generación de circuitos sobre substratos de techo, en **sustitución de sistemas convencionales de cableado de cobre** (Ventajas de aligeramiento de peso y empaquetamiento funcional)

Espumación Estructural:

- Tecnologías de espumación **química**, **física** (MuCell) y **sintáctica** (microesferas de vidrio y poliméricas expandibles) para aligeramiento de componentes (núcleos espumados y piles rígidas).



Algunos Ejemplos

Economía Circular: Reutilización y Reciclaje de Residuos Industriales

Los materiales Coretech® ofrecen excelentes prestaciones de absorción acústica y de protección contra la humedad

GA **Coretech®** es una gama de materiales elaborados a partir del reciclaje de residuos procedentes del proceso de fabricación de revestimientos de techo.

Se trata de materiales certificados que puede aplicarse al recubrimiento de tejados, la protección de paredes contra humedad y el aislamiento térmico – acústico en la industria de la construcción.

Algunos Ejemplos

Economía Circular: Reutilización y Reciclaje de Residuos Industriales

This amazing achievement recognizes the first headliner substrate on the market produced by thermoforming different materials (PU foam, textile and plastic reinforcement) made from urban & post-consumer plastic waste and end of life tires

Grupo Antolin wins the Plastics Recycling Award Europe for its sustainable headliner for vehicle interiors | Grupo Antolin

CarMaker		Focused n Commitment	Key Date	Key Figure
VW GROUP	Plastics	Use of recyclates in plastics. It should contain the technically maximum proportion for the component (at least 20% material by weight)	2024	20%
STELLANTIS	Metals & Polymers	Increase Green material by 2030 in Stellantis products, at iso vehicle cost	2030	40%
FORD MOTOR CO.	Plastics & Polymers	20% renewable and recycled plastics by 2025	2025	20%
BMW Group	Thermoplastics	Use at minimum 30 % of recyclate in our carset package Use thermoplastics with an average of 40% recycled material by 2030.	2030	30%
MERCEDES BENZ Group (DAIMLER)	Metals & Polymers	Proportion of secondary raw materials per vehicle 40% in 2030 on average for the Mercedes -Benz car fleet without smart and vans	2030	40%
GM	-	30% Ecofriendly / sustainable materials in 2025 50% Ecofriendly / sustainable materials in 2030	2030	50%
RENAULT Group	Metals & Polymers	All new vehicles worldwide to be made with 33% recycled materials by 2030 (20% plastic content in 2025)	2030	33%
GEELY Group (VOLVO)	Plastics & Polymers	25% recycled plastics in cars from 2025	2025	25%

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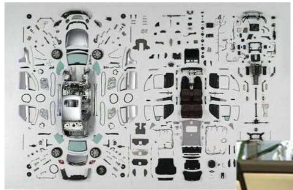
5

Innovación al servicio de una Movilidad Sostenible

Innovación al servicio de una Movilidad Sostenible

Ecodesign

Disassembly



Composites

Recycled

Plastic wastes

Natural

Vegetal wastes

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AGENDA 2030

GRUPO ANTOLIN

2022

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info@composiforum.com

Cátedra aitiip Universidad Zaragoza

AEMAC ASOCIACIÓN ESPAÑOLA DE MATERIALES COMPUESTOS