Eco-design of bio-based and recyclable composite materials

Bari, 24 November 2023

Luigia Longo
Materials and Structures Technology Department

- **Research and Technology Organization (RTO)**
- Applied research, experimental development and technology transfer in the field of **advanced materials**, **ICT** and **product development**.

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Research and Technology Organization

Technical structure

65+ Employees: Researchers, engineers, designer & manager

15 Labs

Offices and laboratories extended for over 3.500 m^2

1. Virtual Reality Centre
2. 3D printers, prototyping, ergonomics
3. Electronics and robotics
4. Visual Tech Lab
5. Exhibit Design
6. Non-destructive controls
7. Composite ovens
8. Composite lamination
9. Composite welding
10. Smart Materials and Structural Monitoring
11. Building materials
12. Molding of polymers and composites
13. Physical thermal analysis
14. Chemical Analysis
15. Mechanical characterization

Research
Fields of application

Materials engineering

- Materials and characterization
- Technologies and processes
- Modelling and simulation
- Diagnostics and civil engineering

Computer engineering

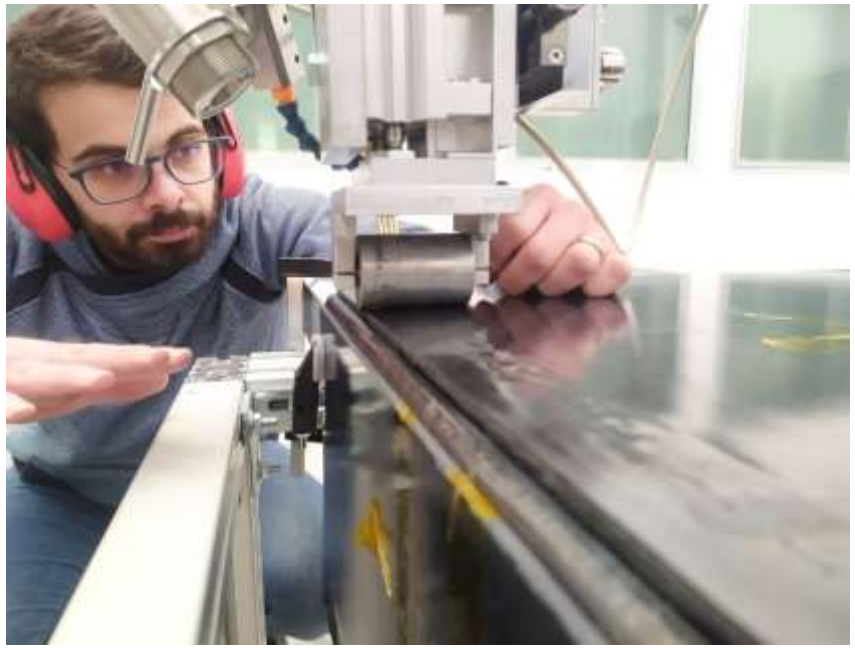
- Information systems and Knowledge Management
- Automation and control
- Virtual, Augmented reality and Multimedia

Industrial design

- IPR, Design management and Strategic Design
- Concept Design, Engineering and Prototyping
- Ergonomics, UI e UX design

Advanced Materials & Processes Department

Areas of expertise



AMP Department supports companies in **innovation** and **technology transfer processes** through calibrated consulting activities on company's specific needs.

4 INTERCONNECTED BUSINESS UNITS IN THE FIELD OF:

- Composite materials
- Plastic materials
- Modelling & Simulation
- Civil Engineering

New Technologies & Design Department

Areas of expertise

NED Department conducts applied industrial research **developing software** at different levels of programming and **integrating product design engineering with digital technologies** (augmented reality, virtual reality, virtual systems), to help companies to improve processes and increase their business.

3 INTERCONNECTED BUSINESS UNITS IN THE FIELD OF:

- Automation & Information System
- Virtual, Augmented Reality & Multimedia
- New Product Development

Technology transfer
Projects

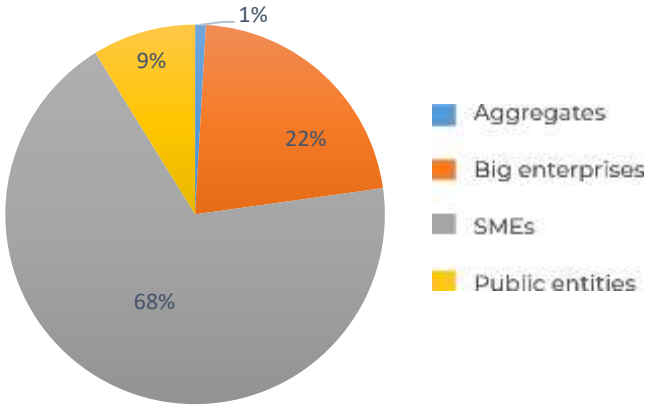
TECHNOLOGY TRANSFER

1354 Total projects
2917 Total proposals
127 Research projects
20 Advanced training projects

Total Budget
€ 186Mln

107 TECHNOLOGY TRANSFER ACTIVITIES IN 2022

Turnover by enterprise size



HIGHLIGHTS

Applied development with the most advanced digital technologies

Augmented Reality for cultural valorization

Development for new products with advanced materials and technologies

Consulting and Research on innovative materials and processes

Innovative solutions for circular economy

Product development with advanced materials

Sustainability of composite materials

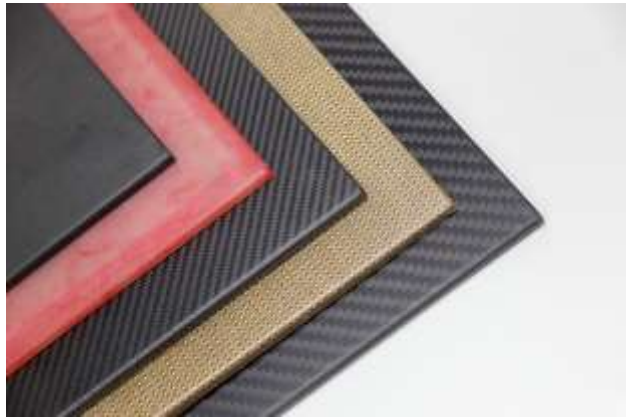
Relevant topic increasingly discussed at an international level.

The challenge of using **innovative and sustainable materials** in the logic of circularity in the use of resources.

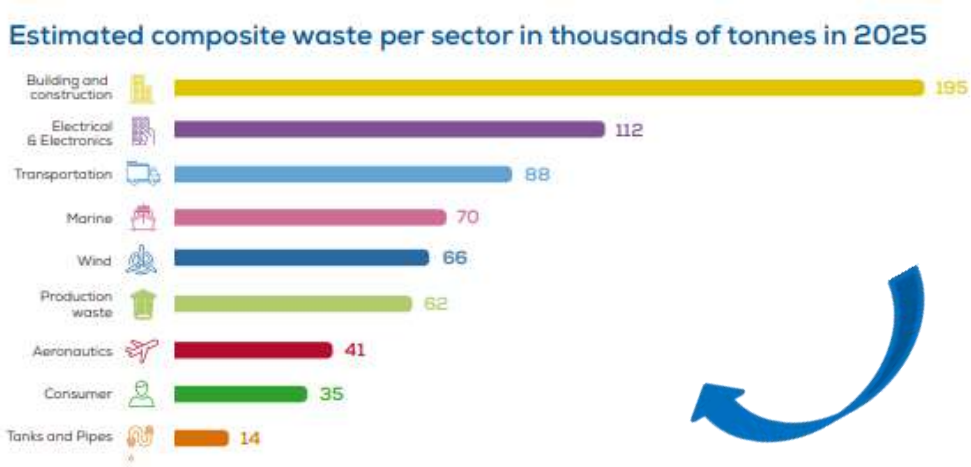
Composite materials

Waste

PERFORMANCE > USE > WASTE



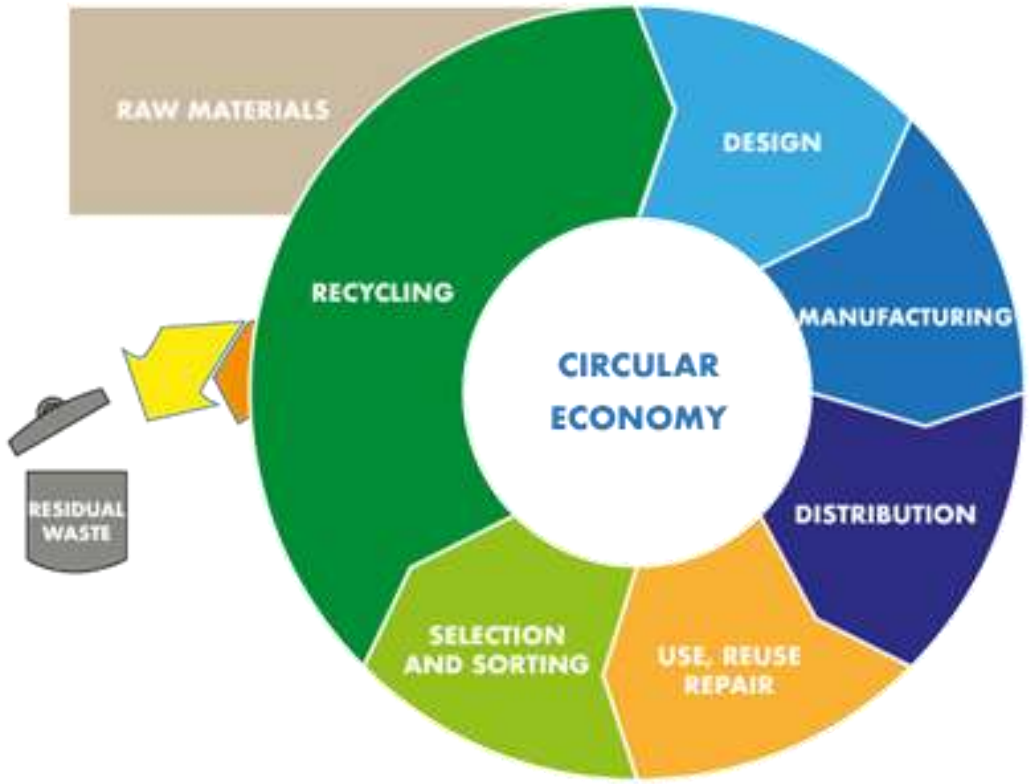
It is estimated that, by 2025, in Europe alone, around 680 thousand tonnes of **waste** will be generated from this type of material, with a plant recovery capacity of 100 thousand tonnes.



Composite materials
Recycling

Priority

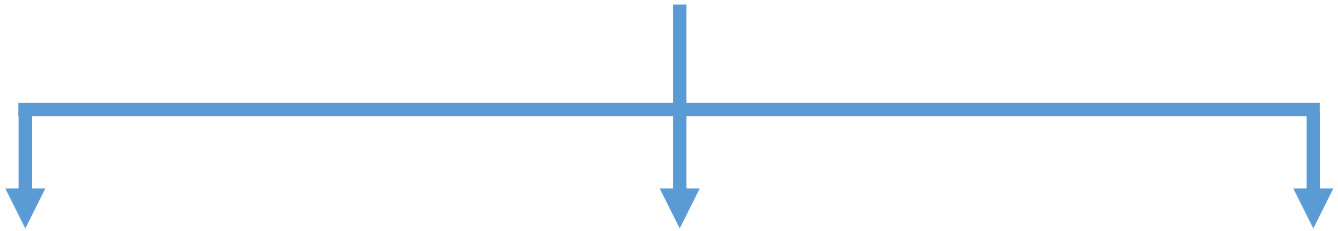
the activation of circular economy models based on **recycling**



Composite materials

Impact

The **impact** of a composite material is determined by the 3 main phases of its life cycle:



Production phase

choice of raw materials (resin, fibres, fillers, etc.) and production process

Use phase

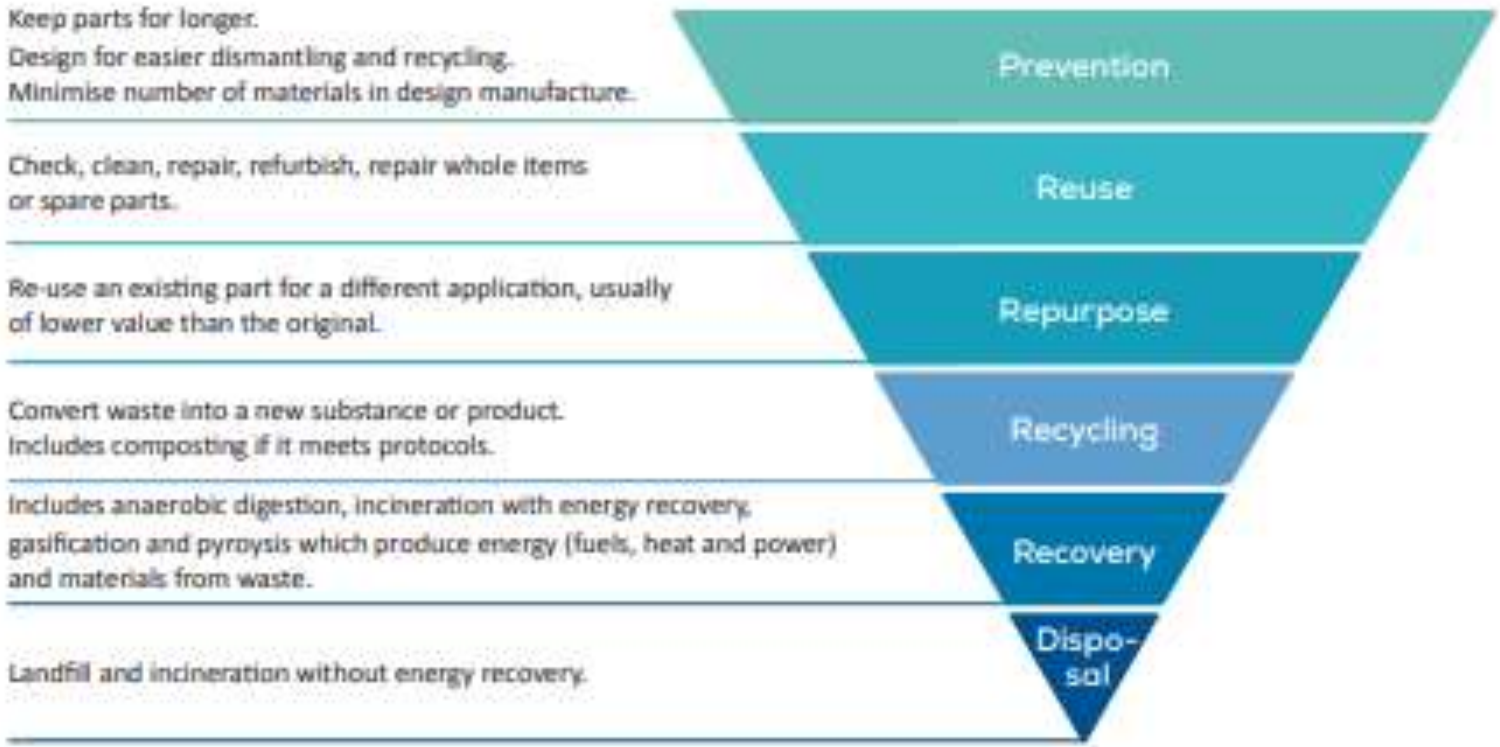
choice of materials (weight, durability and maintenance characteristics)

End-of-use phase

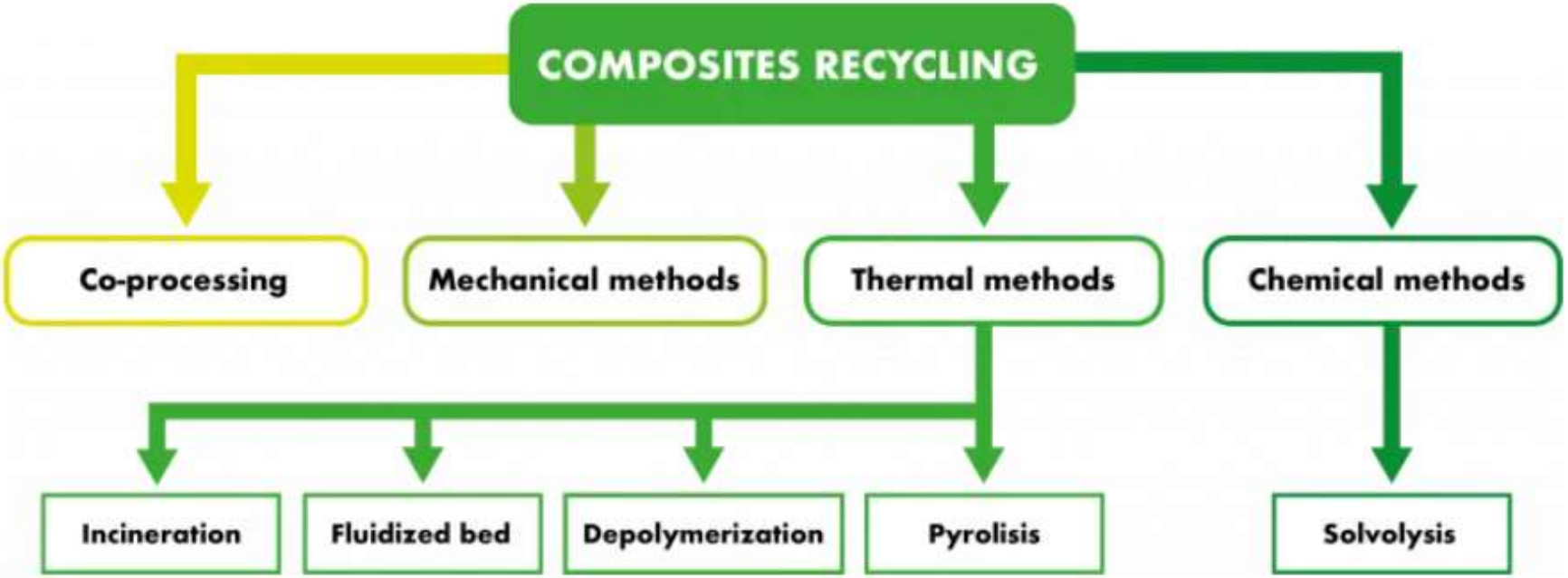
reuse / recycling / recovery / disposal

Composite materials

Waste treatment hierarchy

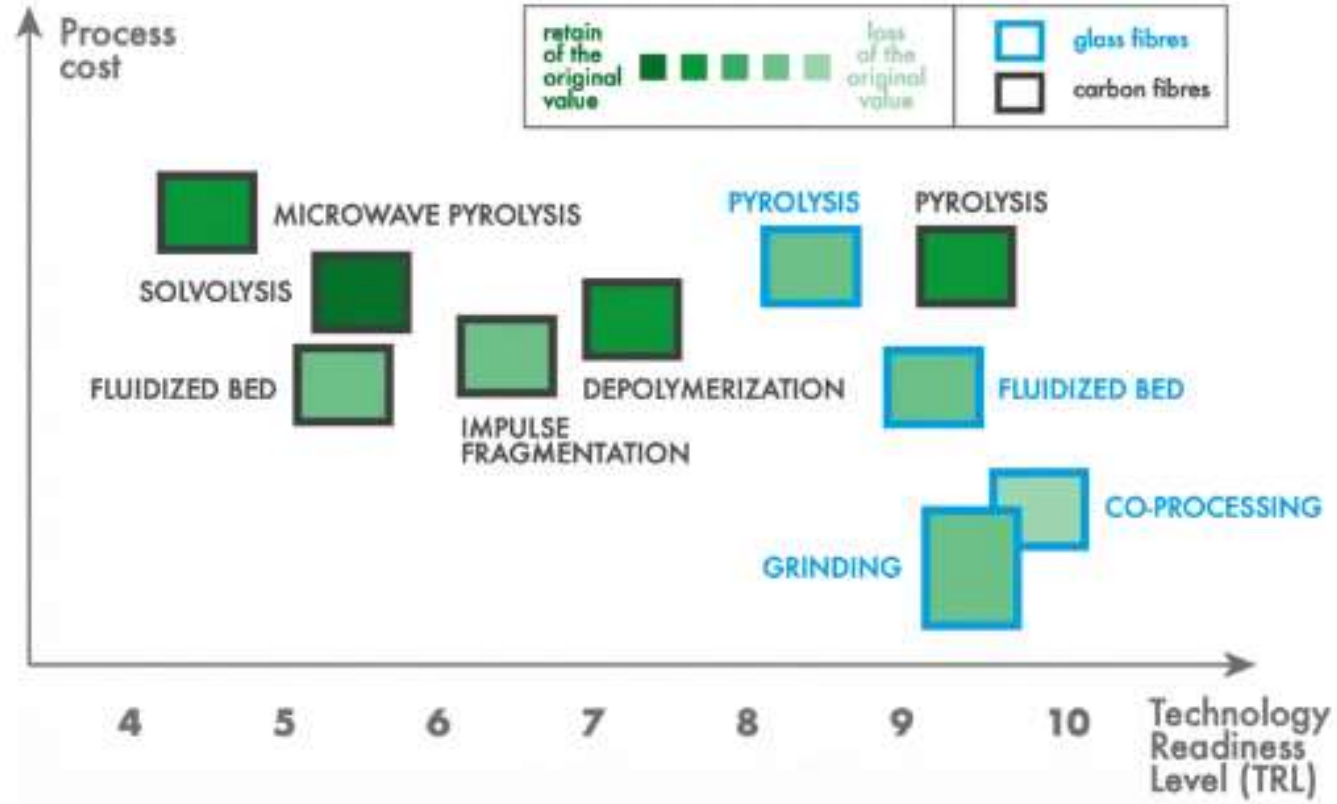


Composite materials
Recycling



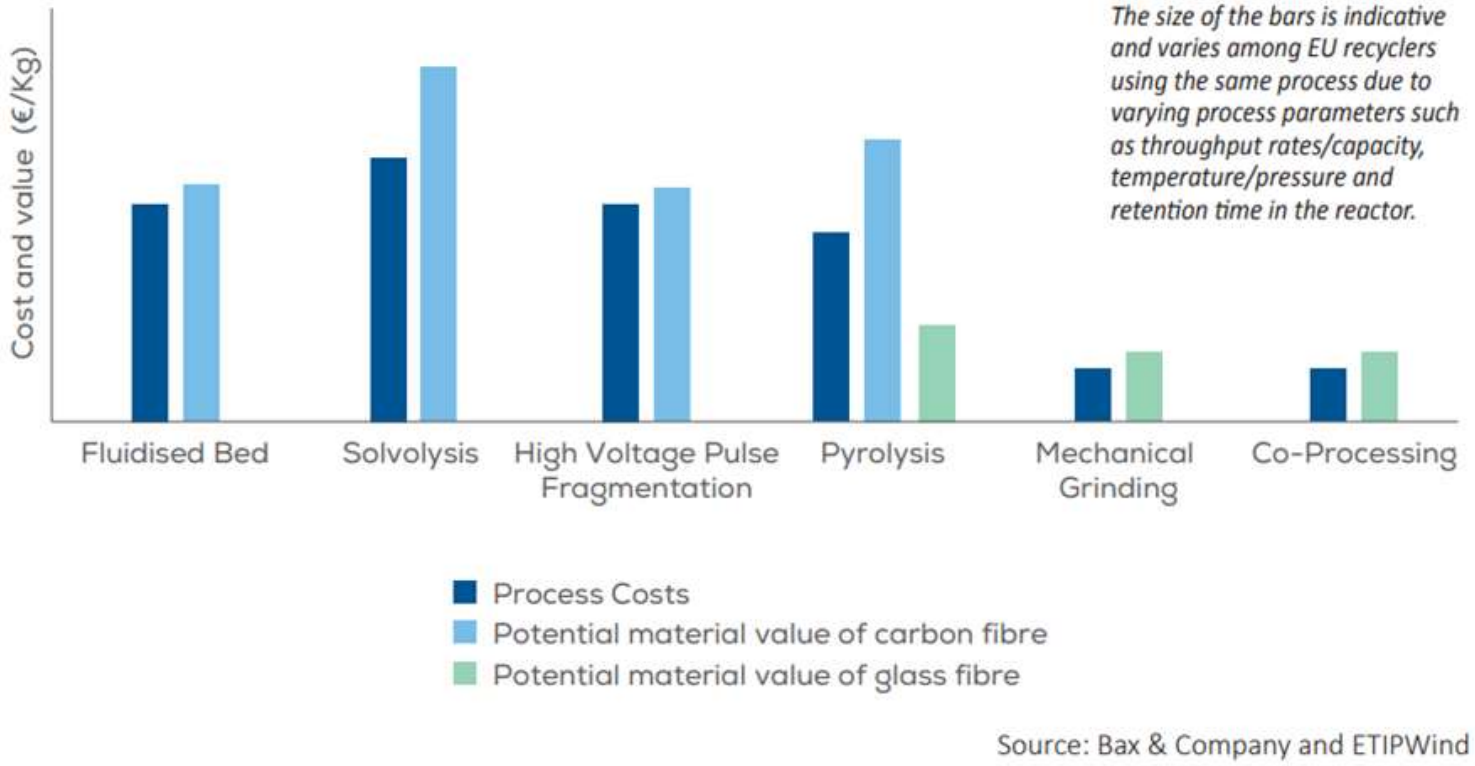
Composite materials

Recycling



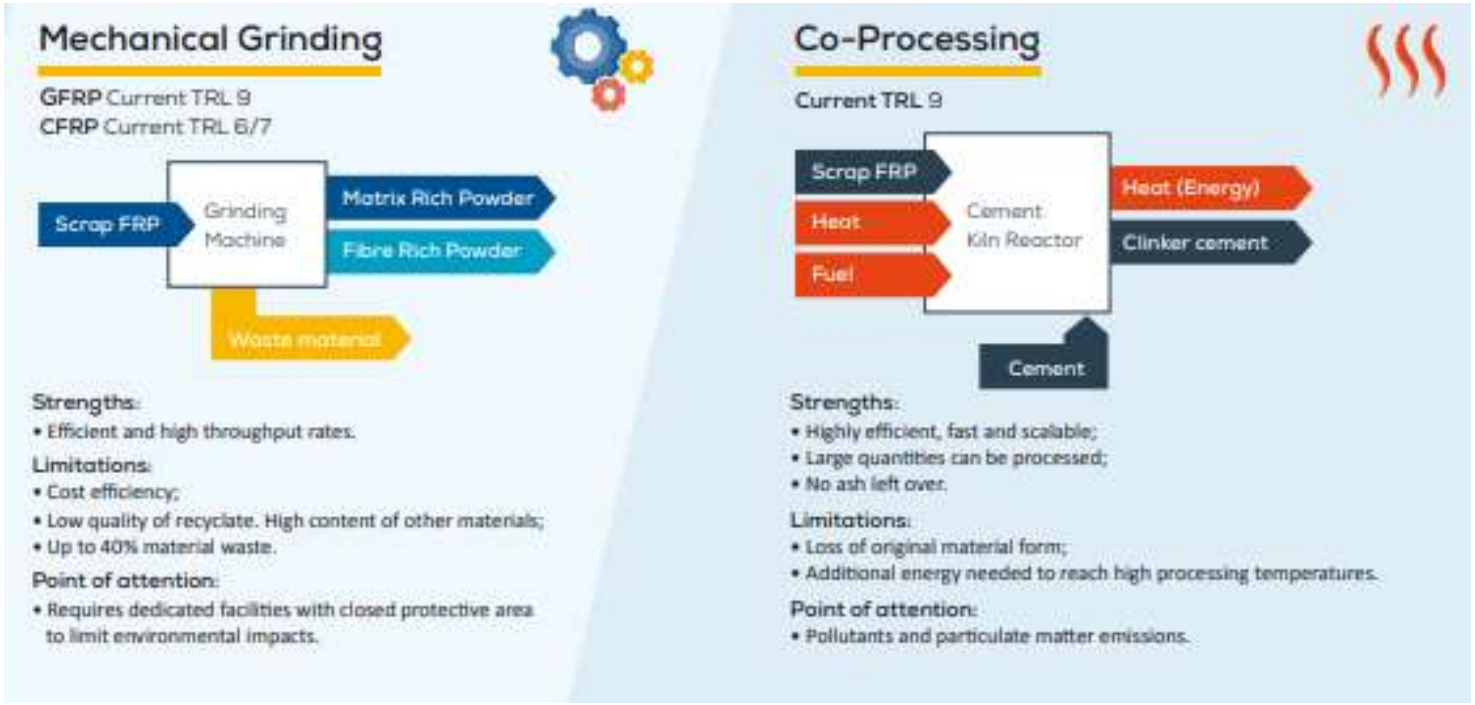
Composite materials

Recycling



Source: Bax & Company and ETIPWind

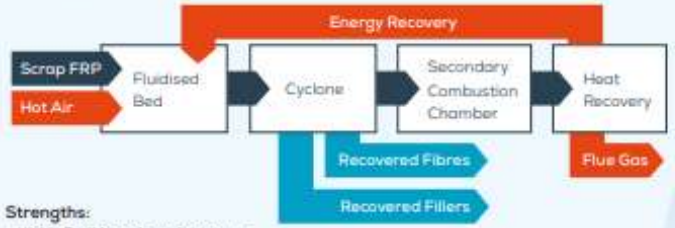
Composite materials
Recycling/Recovery



Composite materials
Recycling/Recovery

Gasification (Fluidised Bed)

Current TRL 5/6



Strengths:
- Highly flexible and simple process;
- Recovery of energy and potential precursor chemicals;
- High efficiency of heat transfer.

Limitations:
- Recovery of low-quality material;
- Economically viable at > 10,000 t/year;
- Fluidised bed can locally collapse.

Point of attention:
- Process-related emissions.

Solvolysis

Current TRL 5/6

Strengths:
- Recovery of clean fibres in their full length;
- Recovery of resin which can be re-used.

Limitations:
- Low efficiency;
- High energy consumption due to the high-temperature and high-pressure;
- Large amounts of solvents required.

Point of attention:
- Human health impacts and ecotoxicity from gas emissions.

High Voltage Pulse Fragmentation

Current TRL 6

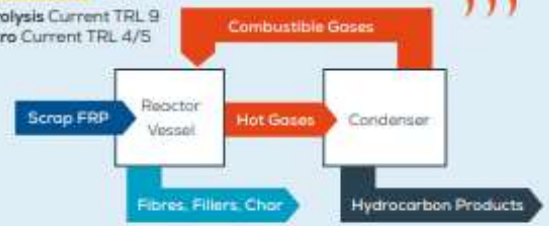
Strengths:
- Scalable to treat large amounts of waste;
- Low investments required to reach the next TRL.

Limitations:
- Only laboratory- and pilot-scale machines are available;
- Heavily decreased modulus of glass fibres.

Point of attention:
- Technology might be suboptimal to recycle the current stock of wind turbine blades.

Pyrolysis

Pyrolysis Current TRL 9
Micro Current TRL 4/5



Strengths:
- Pyrolysis gas and oil can be used as energy source in the same process or in chemicals production;
- Easily scaled up;
- Microwave Pyrolysis: easier control. Lower damage to the fibre.

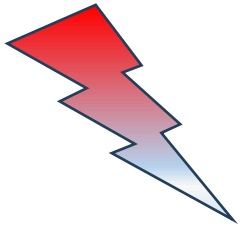
Limitations:
- Fibre product may retain oxidation residue or char;
- Degradation of the chemical structure of fibres;
- Not yet economically viable.

Point of attention:
- Potential leaks of gases from waste treatment chambers.

In principle …

- Regaining the **original precursors**, without loss of performance.
- Closing the **life cycle** of the component by producing another one for the same application.
- Not requiring the supply of **new raw materials**.

100% closed cycle circularity of the material is certainly a possible objective with composite materials.



The **economic feasibility** and **environmental impact** of the precursor recovery processes remain to be verified .

Urgent need:

Circular and sustainable review of the **design and production of composite materials:**

- wider use of raw materials and fibers with increased **recyclability or reusability**, to fully reuse these precursors in applications as close as possible to the original ones;
- design of the products and their assembly considering the need for **separation** for a differentiated treatment at the end of life.

European Project

FURHY

furhy
fully recyclable hybrid
bio-composite
for transport application

PROJECT	
Project number	101091828
Project name	FULLY RECYCLABLE HYBRID BIO-COMPOSITE FOR TRANSPORT APPLICATIONS
Project acronym	FURHY
Call	HORIZON-CL4-2022-RESILIENCE-01
Topic	HORIZON-CL4-2022-RESILIENCE-01-11
Project starting date	1 July 2023
Project duration	42 months

- FURHY is a **42-month EU project**, funded by Horizon Europe program, started on 1st of July 2023.
- Project Coordinator: **CETMA**
- The Consortium consists of **9 Partners across 5 countries**. An experienced and multidisciplinary group that will contribute the most towards achieving the project objectives.

FURHY
Project Summary

The project aims at the development of a **new, bio-based, smart and completely recyclable composite material**, obtained by fast and low energy consumption out-of-autoclave process.

- The **matrix** will be made by a **new bio-based epoxy resin formulation filled by expanded graphite (EG)**, that will have a multiple role in the enhancement of both material and manufacturing process, providing smart-functions.
- A **hybrid composite** will be developed, by the use of **hemp and recycled carbon fibers (rCFs)**, thus maximizing the environmental benefits with a life-cycle perspective. The hybridization will let to exploit the advantages offered by both fibers, minimizing the relevant drawbacks.
- The **manufacturing process** will consist in a **low energy version of the prepreg compression moulding (PCM)**.
- **Aeronautics and automotive** fields are the main **sectors** of interest.

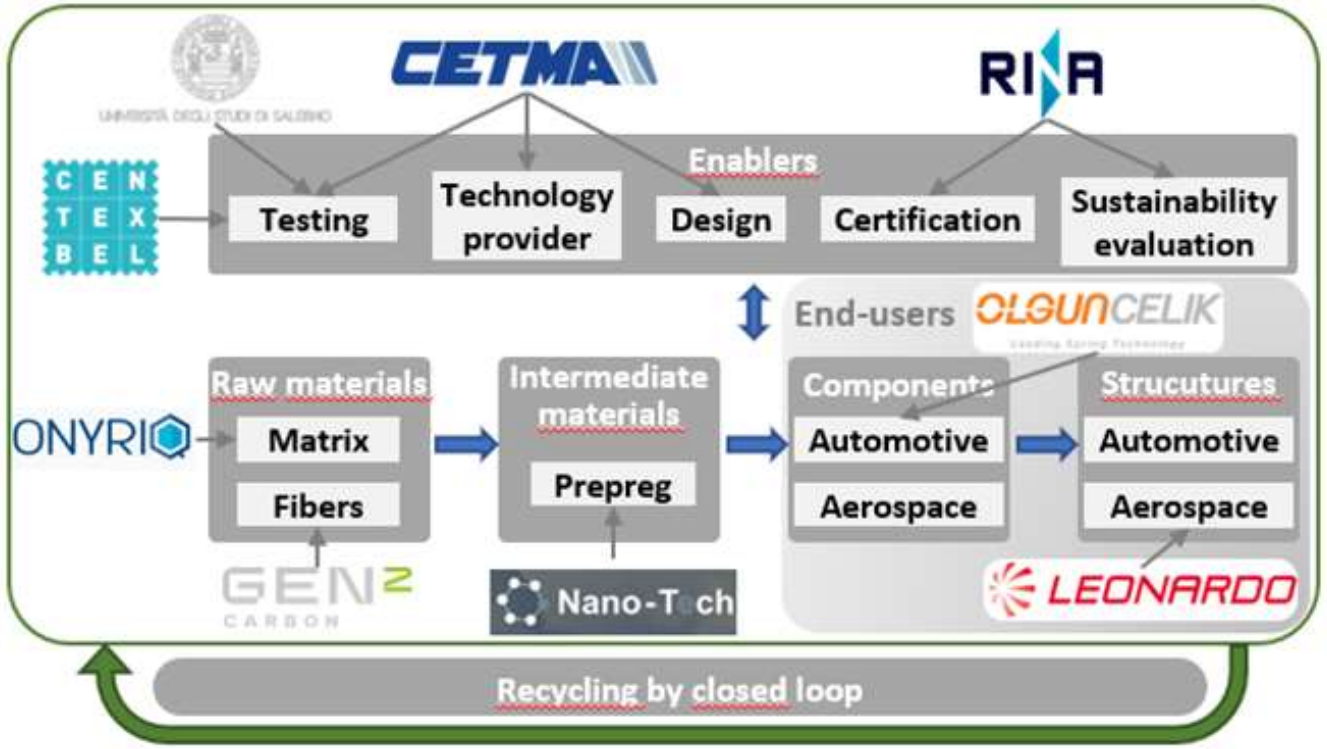
furhy
fully recyclable hybrid bio-composite for transport application

FURHY
Consortium

- 8 partners come from 4 different European countries;
- 1 associated partner from UK.

N.	Role	Legal name	Short name	Type	Country
1	COO	CETMA - CENTRO DI RICERCHE EUROPEO DI TECNOLOGIE DESIGN E MATERIALI	CETMA	RTO	Italy
2	BEN	ONYRIQ LABS, SL	ONY	SME	Spain
3	BEN	LEONARDO - SOCIETA PER AZIONI	LND	LE	Italy
4	BEN	RINA CONSULTING SPA	RINA-C	LE	Italy
5	BEN	OLGUN CELIK SANAYI VE TICARET ANONIM SIRKETI	OLGUN	LE	Turkey
6	BEN	UNIVERSITA' DEGLI STUDI DI SALERNO	UNISA	HE	Italy
7	BEN	NANO-TECH SPA	NANO	SME	Italy
8	BEN	CENTRE SCIENTIFIQUE & TECHNIQUE DEL'INDUSTRIE TEXTILE BELGE ASBL	CTB	RTO	Belgium
9	AP	GEN 2 CARBON LIMITED	GEN2C	SME	UK

FURHY
Consortium



- All the **expertise** necessary to finalize the project activities in the best way;
- A strong **complementary** in the know-how and equipment of the partners involved.

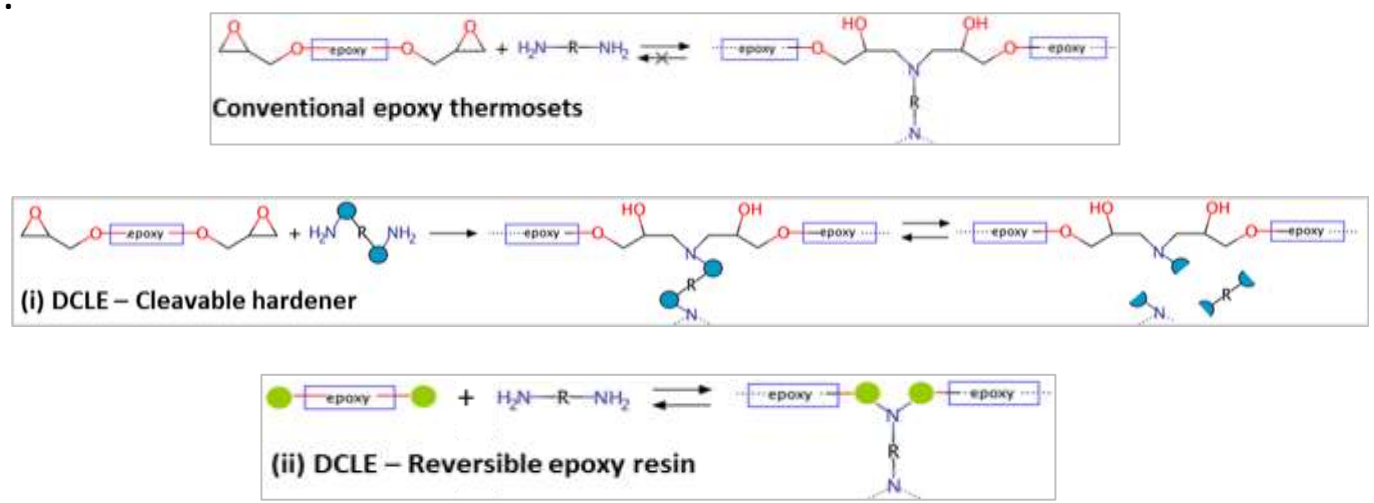
The consortium covers all the key stages of the manufacturing value chain, thanks to the presence of 5 production industries, and includes also the key “enablers”, thus ensuring a real high **industrial exploitation potential** of the project outcomes.

FURHY
Project objectives

OB1. To develop an optimized **bio-based, fast curing, recyclable epoxy resin**, filled with **expanded graphite (EG)** that will promote electro-curing and will provide multifunctional and self-monitoring capability and a list of enhanced properties to the final composite material.

KPIs:

- Percentage of components coming from renewable resources in the epoxy resin: up to 80% with respect to the total components of the resin formulation.
- Glass transition temperature (Tg) of the final resin: 200°C - the target Tg of unfilled epoxy resin will be 150°C, increased of more than 30% thanks to EG.



Scheme of the two approaches of the Depolymerizable Closed Loop Epoxy (DCLE) system, compared with conventional epoxy thermosets

FURHY
Project objectives

OB2. To develop hybrid reinforcing fibers textiles by combinations of **bio-based virgin fibers and recycled carbon fibres**, including **appropriate fibre coatings** to maximize the fiber properties.

KPIs:

- Composite mechanical properties increase, given by the application of the coating to the fibers, of at least the 20% (both static and dynamic properties).
- Commingled hemp/rCF non-woven: fibre areal weight variation lower than +/-8% to ensure properties repeatability and correct closed mould processing.

Fiber architectures at ply level - (a) innovative hybrid commingled hemp/ rCF non-woven, (b) commercial rCF non-woven, (c) hemp fabric

FURHY
Project objectives

OB3. To develop a new effective and **reduced energy consumption out-of-autoclave process** for the new bio-based composite component manufacturing, consisting in prepreg compression moulding (PCM).

KPIs:

- PCM cycle time: <2 min for 3 mm thick laminates.
- Void % in the final composite material: <2%.

Hot-melt prepreg line for prepreg manufacturing at Nano Tech

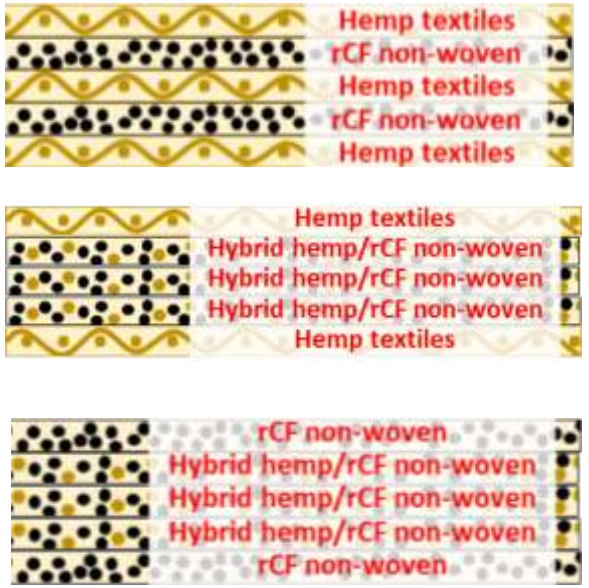
Pilot-scale (CETMA) press for PCM process development

FURHY

Project objectives

OB4. To design and develop a set of new composites, with **different lay-up**, thus providing the possibility to tailor functionality for a range of possible applications.

KPIs: New bio-based hybrid laminates with tensile modulus up to 30÷40 GPa and tensile strength up to 300÷400 MPa, with improved dumping properties.



Examples of interply hybrid laminates

FURHY
Project objectives

OB5. To demonstrate the potential of the innovative composite material by the design of 2 **aeronautic** and 2 **surface transport (automotive) application**.

KPIs: Design of N° 4 demo products.

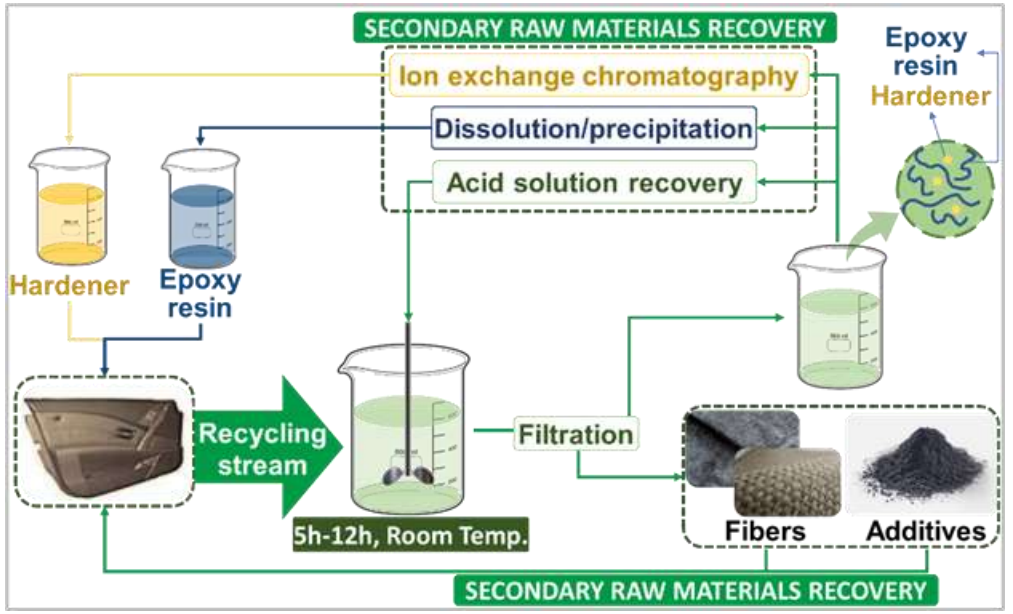
Components candidate to be selected for the aerospace (left) and the automotive (right) applications

FURHY
Project objectives

OB6. To develop a **new recycling technology** suitable for the **recovery of all the constituents of the composite structure**, providing secondary raw materials having properties similar to the virgin original materials.

KPIs:

- 85% of starting monomers recovered, 90% of EG recovered, 100% of reinforcing fibers recovered.
- 75% of mechanical performances (strength and modulus) retained for hemp fibers, 95% for rCF.



Closed loop (synthesis + chemical recycling) for DCLE-based composite

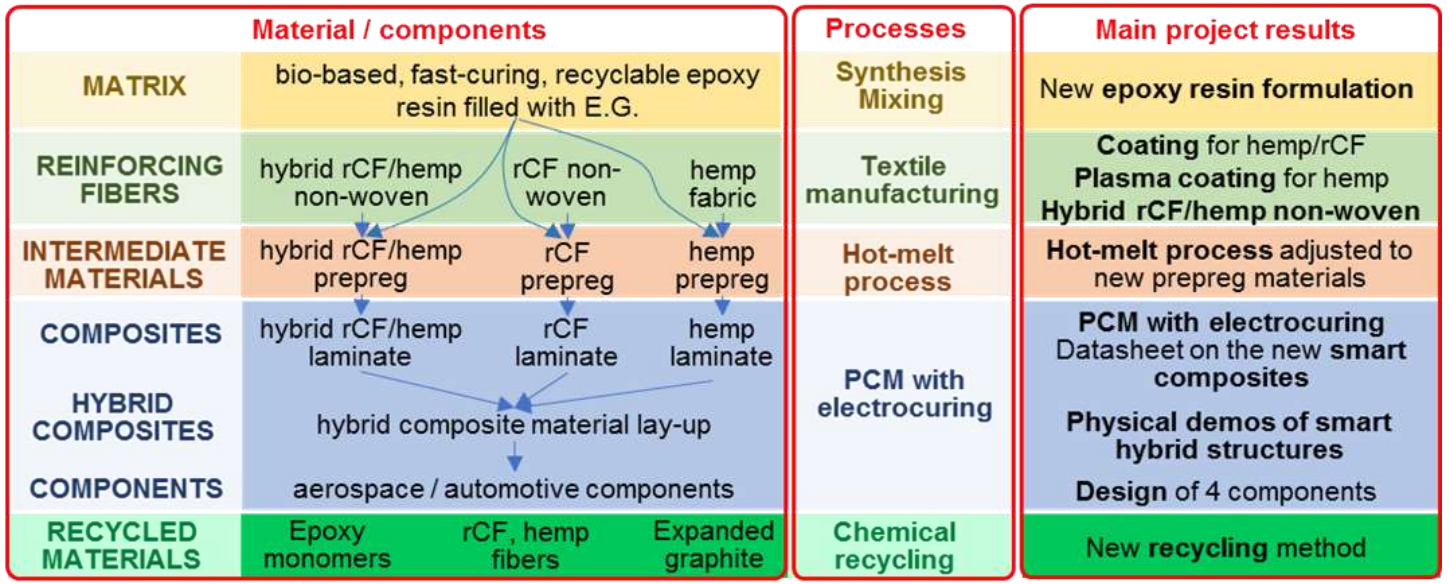
FURHY
Methodology

furhy
fully recyclable hybrid
bio-composite
for transport application

Innovative solutions in each stage of the product chain.

Real step **change** in the composite material sector.

FURHY
Methodology

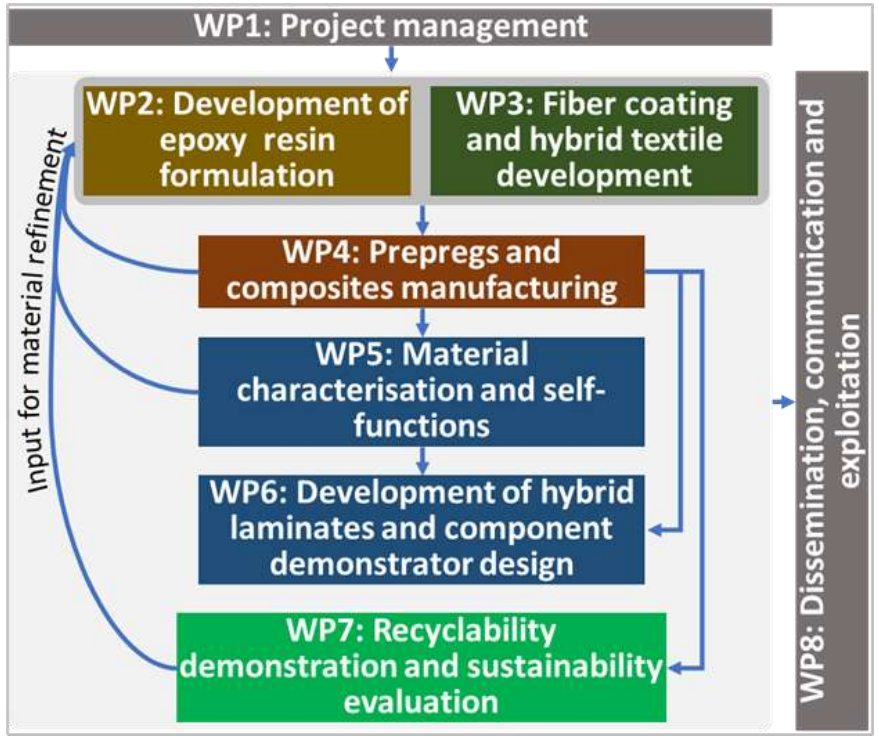


- **innovative materials and components** (matrix, reinforcing fibers, intermediate materials, final composite material, aerospace and automotive component demonstrators and recycled materials);
- **innovative manufacturing processes** (matrix synthesis and formulation, textile manufacturing, hot-melt process, PCM with electrocuring and chemical recycling);
- smart-functions and composite material **testing**.

FURHY

WPs and Work plan

Work Package n.	Work Package name	Lead Beneficiary	Start month	End month
WP1	Project Management	CETMA	1	42
WP2	Development of epoxy resin formulation	ONY	1	39
WP3	Fiber coating and hybrid textile development	GEN2C	1	39
WP4	Prepregs and composites manufacturing processes development	CETMA	7	39
WP5	Material characterization and self-functions analysis	UNISA	22	28
WP6	Development of hybrid laminates and component demonstrator design	OLGUN	29	42
WP7	Recyclability demonstration and sustainability evaluation	UNISA	19	42
WP8	Dissemination, communication and exploitation	RINA-C	1	42



FURHY
WP1 and WP4

WP1 – Project Management

To provide effective project management throughout the duration of the project; to accomplish all necessary **administrative tasks** and provide regular **progress reports** to the European Commission; to establish and maintain effective **communication** between project participants.

WP4 – Prepregs and composites manufacturing processes development

Development and optimisation of the holt-melt process for **prepreg manufacturing** and of the Prepreg Compression Moulding process with electrocuring for composite consolidation and **component manufacturing**; quantifying the energy saving of the proposed moulding process with respect to traditional processes.

Thank you!

CETMA

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