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Design sustainable composites

ICCM23
31st July 2023
Belfast

Funded by
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Plan

RESILIENCE 01-11 - TOPIC DESCRIPTION

TOPIC ANALYSIS / PROPOSAL

SUSPENS CONSORTIUM

SUSPENS TECHNOLOGIES

FOCUS ON NOVEL PYROLYSIS APPROACH

CONCLUSION

TOPIC DESCRIPTION - *HORIZON-CL4-2022-RESILIENCE-01-11*

European Commission

Topic: Advanced lightweight materials for energy efficient structures

Type of action: Research and Innovation Actions - TRL3 to 5

Observation: The overall life-cycle benefits of lightweight composite materials are often reduced by the manufacturing phase (energy consumption) and inherent challenges to regain the high-value components (fibre and matrix) at industrial scale.

Keywords:

- Fast curing bio-resins
- Recycling technologies for polymer composites
- Renewable fibres
- Reduce energy consumption
- Multifunctional composites
- Combinations of virgin and recycled fibres

SUSPENS Approach

Source: EconCore & Flaxco

Lightweight structures

Composite Sandwich & Hollow parts

giving

Highest stiffness to weight ratio

leading to

Reduced energy consumption in the transportation sector

Demonstrated on

3 applications / industries

Environmental impact reduction & sustainability

- **Ingredients**
  - Bio-based
  - Recycled
  - Fast-cure
- **Manufacturing process**
  - Energy-efficient
  - Multi-functionnal
- **End-of-Life**
  - Separable
  - Reprocessable

Cost efficiency

Partners

EMC2

FORVIA faurecia

IRT JULES VERNE ◀ Coordinator

UNIVERSITÉ CÔTE D'AZUR

apm composites

CENTEXBEL

IRES Innovation in Research & Engineering Solutions

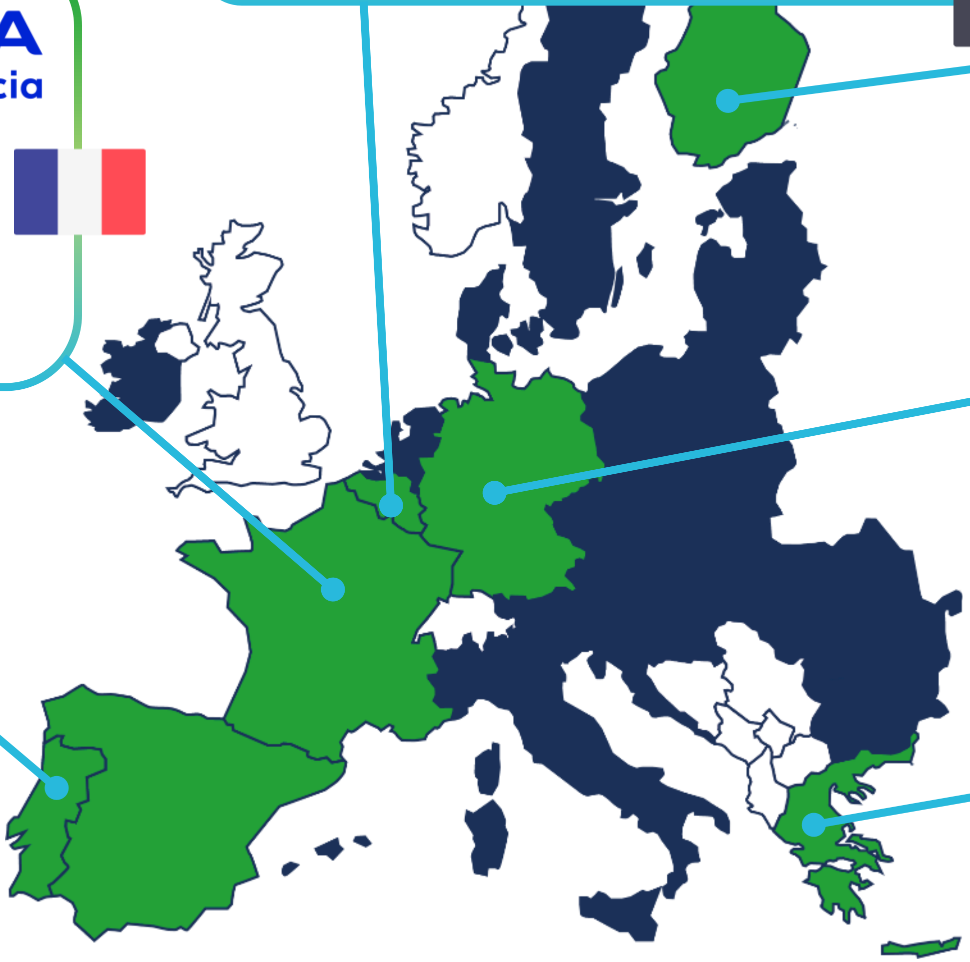
ORINEO original renewables

A! Aalto-yliopisto

LIPEX WH

ΕΘΝΙΚΟΝ ΜΕΤΣΟΒΙΟΝ ΠΟΛΥΤΕΧΝΕΙΟΝ

MEGARA RESINS ANASTASSIOS FANIS S.A.



Bio-sourced resins

Highly bio-based Epoxy matrix

Epoxidised linseed oil + bio-hardener

Epoxy with >95% bio content
3 formulations for Infusion, RTM and SMC

Styrene-free bio Polyester

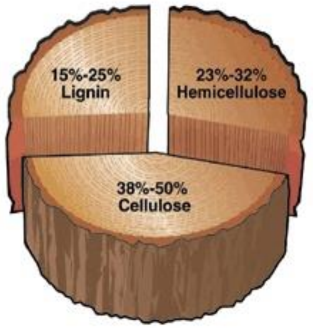
UPR Synthesis from bio-based unsaturated/saturated components & diols

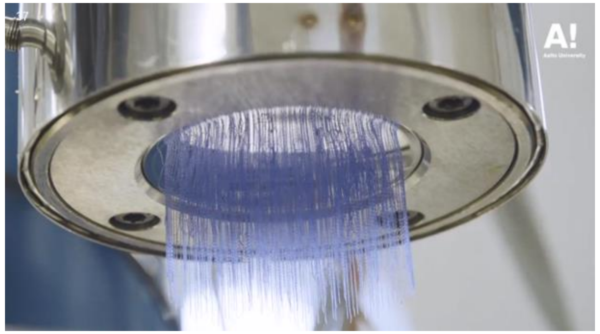
Substitute Styrene by bio-based diluent
Resin infusion + Curing time < 30min

Bio-sourced continuous fibres

Tailored cellulosic fibres

Aalto University





Develop a Lyocell fiber for technical applications

Blended Lignin-based precursor

CENTEXBEL

Improved spinnability by blending

Lignin stabilisation carbonisation line

Increase carbonisation yield

-60% CO2 vs ex-PAN CF

Recycled continuous fibres

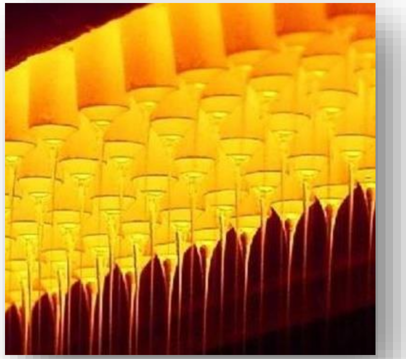
Continuous rCF yarn

Cost-competitive rGF

Photo Credit: MARK RALSTON/AFP / JCMA

Staple yarn

Photo Credit: PortEsberg / Carbon River LLC /



>90% CF continuous staple yarn
>90% Properties of new carbon fibre

Cost equivalent to new GF
with >50% rGF

LIPEX WH
GLASS AND BASALT FIBRE TECHNOLOGY

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3 demo cases

HIGH PERFORMANCE LIGHTWEIGHT APPLICATIONS

One-shot manufacturing processes for sandwiches and hollow parts

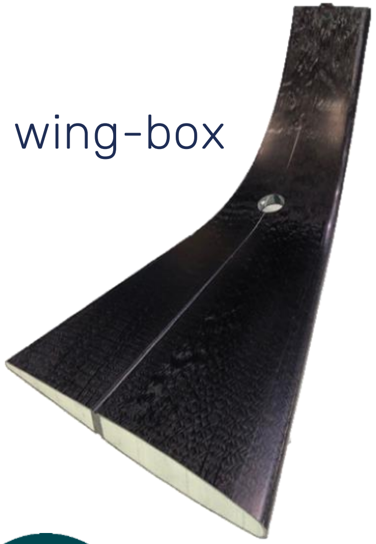
Battery pack for electric vehicle

FORVIA faurecia

Sailing boat hull and deck

apm composites

Aircraft wing-box



IRT JULES VERNE

One-shot processes

One-shot processes for sandwich parts

Bio Epoxy & UPR + rGF Fabric

SMC s/w Press molding

Liquid Compression Molding

Bio UPR + Cellulose & rGF

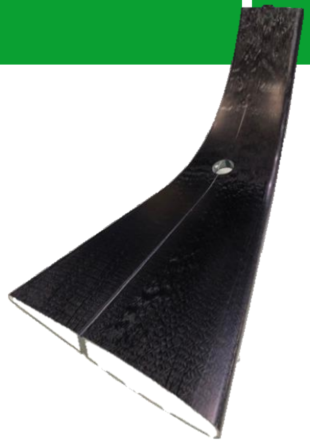
Vacuum infusion

One-shot processes for hollow parts

Bio-Epoxy + rCF & Ex-lignin CF

TFP

RTM



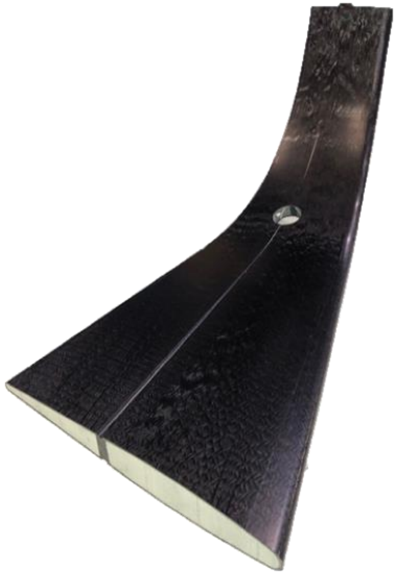
Material separation processes & LCA

Solvolysis of Epoxy in bio-based solvent

UNIVERSITÉ CÔTE D'AZUR

Matrix Pyrolysis from carbonisation gases

Source: Orineo



IRES Innovation in Research & Engineering Solutions

Source: Vartega

Reclamation of lignin-based Cf, rCF & rGF through solvolysis
Novel pyrolysis process using carbonisation gases

Pyrolysis vs Other Recycling Technologies

Mechanical Recycling

Grinding

+ Neither atmospheric nor water pollutants production during the process/No chemicals are used
+ Considerably lower energy demands
+ No need for expensive and high-end technical equipment
+ Processing of large amounts of waste at higher rates
- Downgrading/low quality of the recycled fibers
- Commercial or industrial exploitation remains very limited

(Thermo)Chemical Recycling

Solvolysis, Hydrolysis

+ Cleaner recycled fibers of high quality
- not yet commercialized
- significant environmental as well as cost issues
- significant energy consumption

Thermal Recycling

Conventional Pyrolysis, Fluidized Bed Pyrolysis, Microwave Pyrolysis

+ Well-established and conventional recycling process for CFRPs/ commercialized
+ Effective for most of CFRPs/ high recycled fiber properties achieved
- Requires continuous feed of inert gas and considerable amounts of energy to achieve high temperatures (>500-800°C)
- Long operation time (i.e. 6 hours) to separate the CFs from the polymer matrix.

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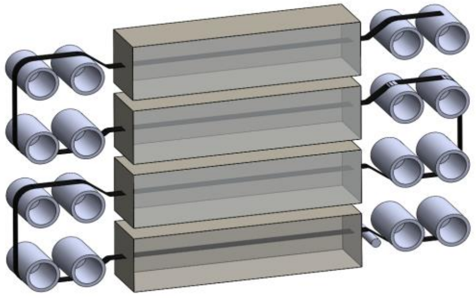
Markatos, et. al, A holistic End-of-Life (EoL) Index for the quantitative impact assessment of CFRP waste recycling techniques, https://doi.org/10.1051/mfreview/2021016

Gain from energy intensive processes

CF production and pyrolysis are both energy intensive processes

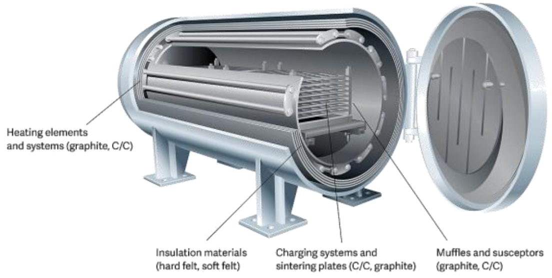
CF production

- Considerable amounts of inert gases
- Energy-intensive process of PAN-based CF
- Valorisation of carbonization gases is not yet achieved
- Costly procedure



CF production is one of the most energy-consuming processes, with max. consumption up to 704MJ/kg of produced CF, corresponding to 31.0 kg CO_2 eq. emissions.

- CFRPs Pyrolysis



- Further production of CO_2 emissions
- Long operation time
- Further consumption of energy for recycling
- No valorisation of co-products

The pyrolysis energy consumption varies from 2.8MJ to 30MJ per kg of CFRP waste recycling, resulting in GWP 2.88 kg CO_2 eq. emissions.

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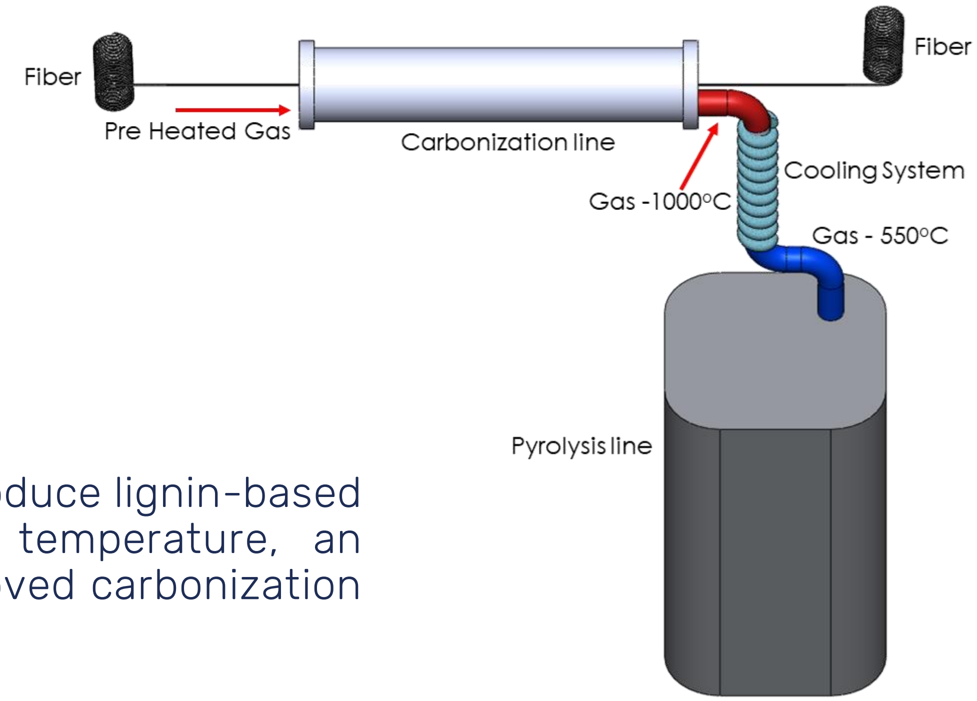
Combined CF production with CFRPs pyrolysis

Combine 2 energy intensive processes in 1 → lower-impact for industrial recycling process of CFRPs

The hot gases produced by carbonization can be exploited to pyrolyze CFRPs, and therefore reduce the energy consumption needed to achieve the required temperatures, as well as eliminate the extra vector gas needed for inert atmosphere.



Goal 1:

- An optimized stabilisation and carbonization process to produce lignin-based precursor fibres, leading to a reduced carbonization temperature, an increased carbon atomic content in the fibre and an improved carbonization mass yield.

Goal 2:

- A combined pyrolysis process, operating with the gas waste streams derived from the carbonisation process of the CFs, exploiting the heat energy of the waste gases, saving the inert gas, and leading to lower energy consumption.

How this will be achieved?

Methodology:

1. The two processes will be designed in a way, where the gases, reaching the pyrolysis furnace, will have the desired temperature for pyrolysis.
2. The pyrolysis furnace will be preheated in the desired temperature in inert atmosphere, and when hot carbonization gases reach the furnace, the electrical heating and gas feeding will be reduced.
3. The energy and gas amount needed for pyrolysis is considerably reduced, resulting to a process that is more environmentally friendly and cost efficient.
4. Conventional epoxy composites (with GFs and CFs), as well as the bio-polyurethanes will be treated in the combined pyrolysis recycling process.
5. For each type of composites, the parameters will be adjusted (flow rates, desired temperature, etc.).
6. Simulation activities will be to represent energy flows during the different stages of the process (different energy sources, energy conversion, losses, comparison between different strategies including the reuse of the stream of waste gases)

Gases from carbonization process

Semi-inert gas needed for pyrolysis (Nitrogen and mono-/dioxides)

Required temperature to heat the pyrolysis chamber

The hot gases have exploitation potential to be used in thermal recycling of thermoset composites.

- Reduction of temperature needed to maintain the required temperature for long operation times
- Reduction of energy consumption due to continuous heating of the furnace

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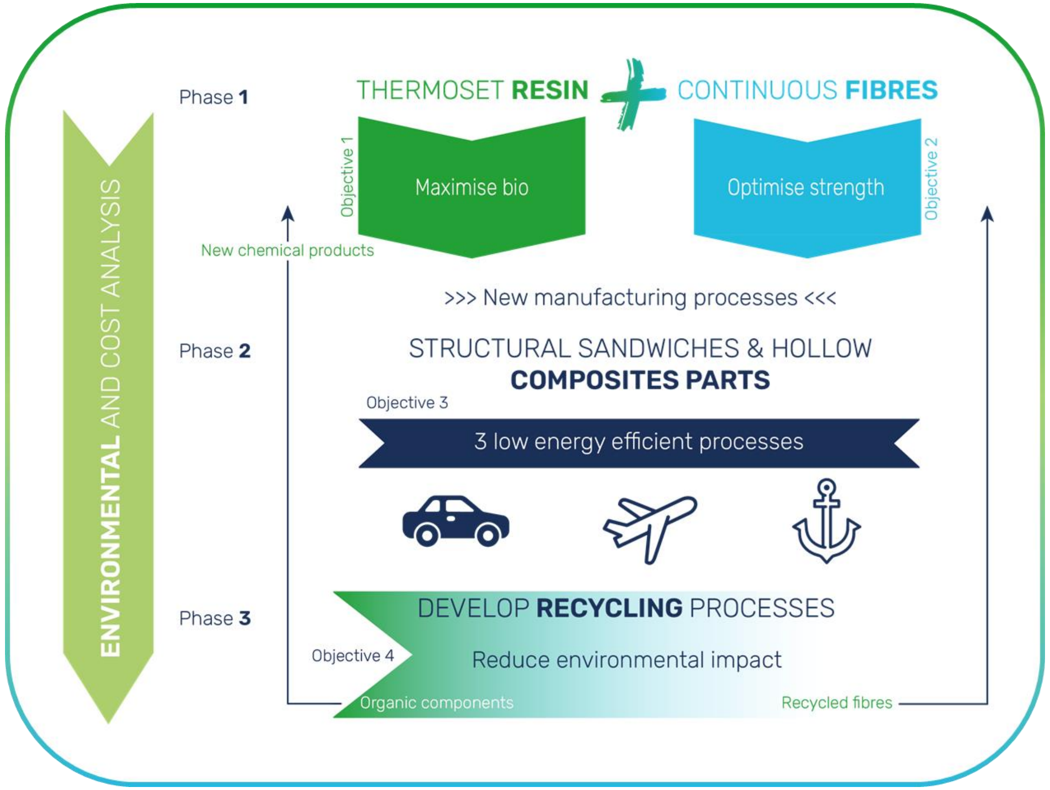
Conclusion



Check out the other RESILIENCE 01-11 projects!

r-LightBioCom

FOREST

repoxyble

BIO-BASED MULTIFUNCTIONAL RECYCLABLE COMPOSITES

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Thank you !

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