This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101096858.

REFRESH: from end-of-use blades to new products

Daniel Grisenti
Project Coordinator

ACI's European Wind Blade Recycling Summit 2025
11-12 June, Berlin

Photo by Nicholas Doherty on Unsplash

The REFRESH consortium

Horizon Europe
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11 partners from **5 countries:**

- Waste recycling and remanufacturing companies
- Engineering and consulting companies
- Research and development companies
- Access to stakeholders in the composites sector manufacturers

RINA is the project coordinator

EuCIA leads communication & dissemination activities

Methodology – The REFRESH concept

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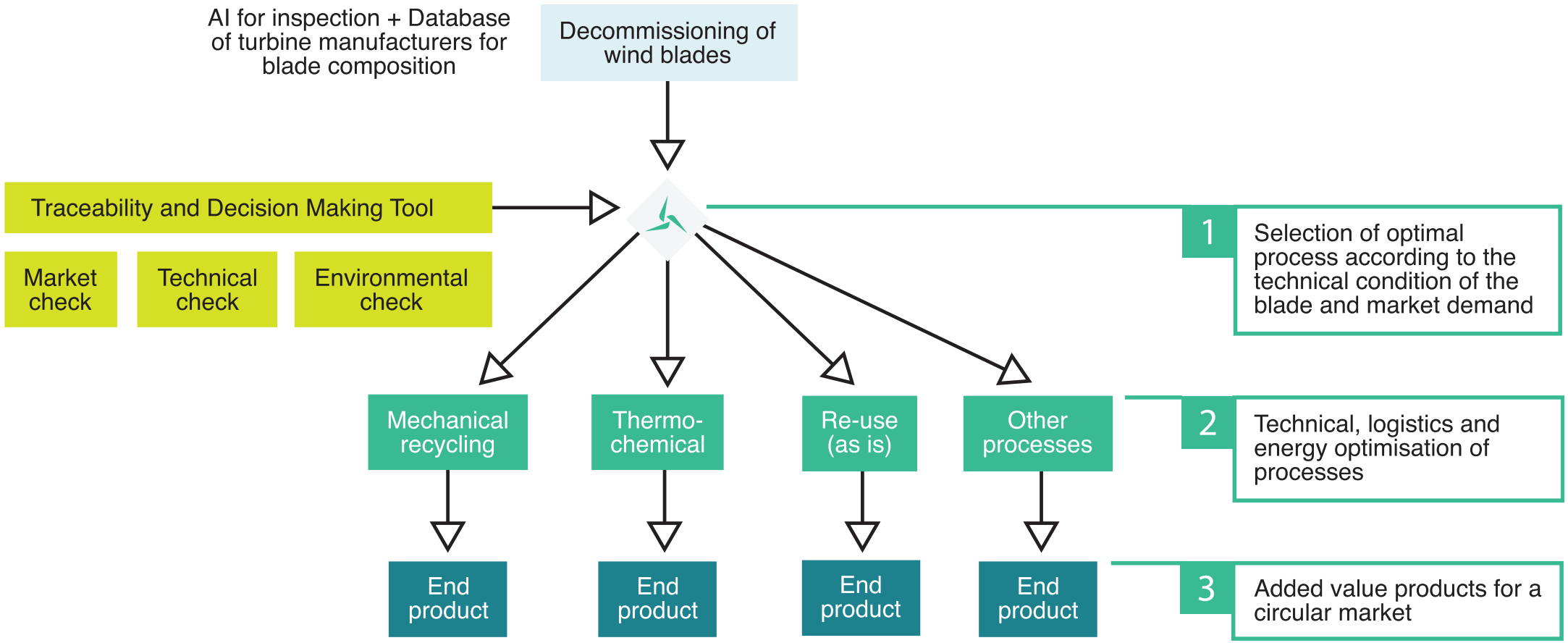

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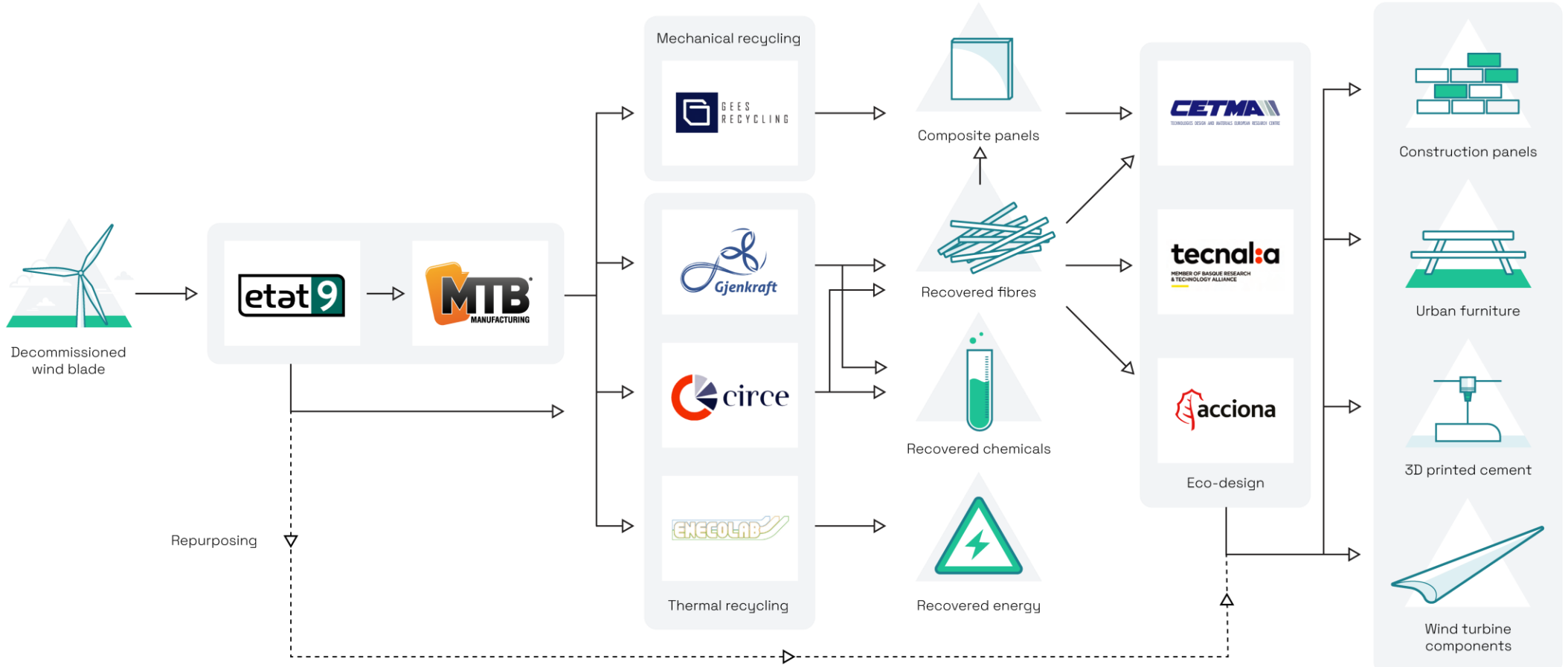
Methodology – The REFRESH value chain



Methodology – The REFRESH timeline

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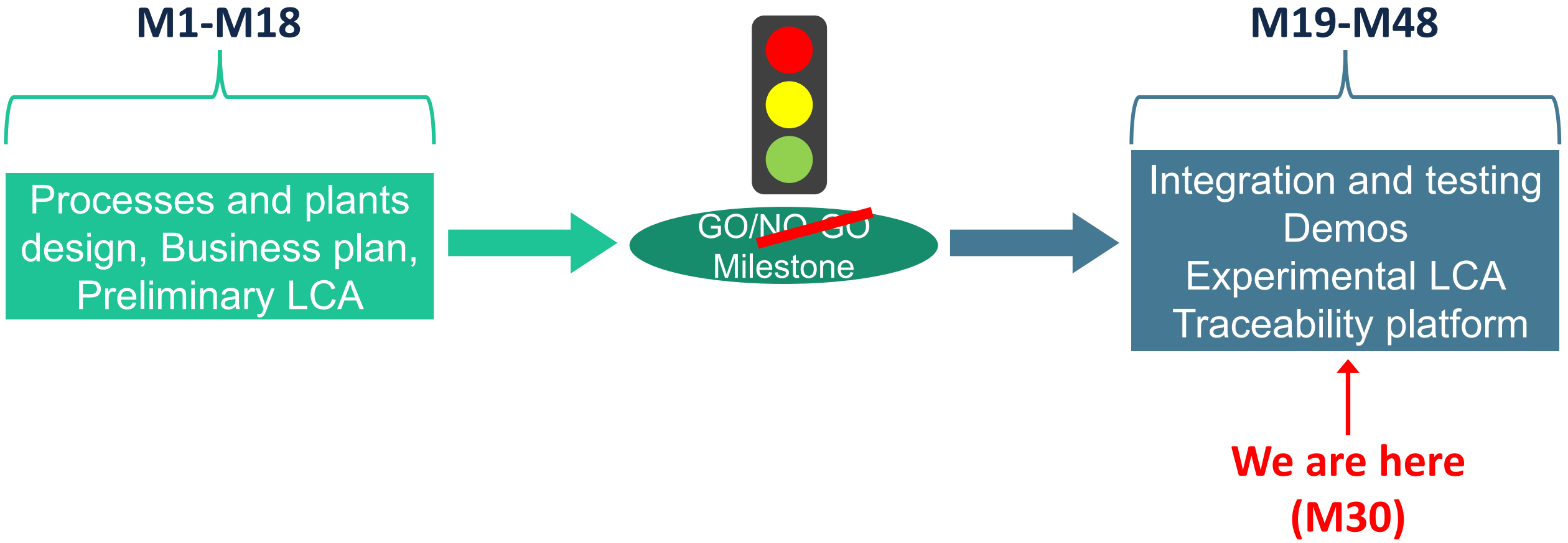

Dismantling and pre-cutting activities (ETAT 9)

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ETAT 9 activities focus on the **pre-cutting of blades.**

Dismantled blades

Circular saw cutting

Wire saw cutting

Dismantling and pre-cutting activities (ETAT 9)

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ETAT 9 activities focus on the **pre-cutting of blades**

Packaging

Temporary storage

Shipping

Shredding and sorting activities (MTB)

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MTB has developed a complete **range of shredding and mechanical sorting solutions** for the pre-treatment of wind turbine blades to obtain fractions that can be recycled downstream.

Shears solution

Complete wind turbine blades can be processed

Shredding & Granulation

From a few centimeters down to millimeters

Sorting

Various sorting solutions and engineering of complete pretreatment lines

Shredding and sorting activities (MTB)

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MTB feed the dismantled and cut wind blades from ETAT 9 into a **shear shredder**. The shredded pieces are downsized to be carried to the **sorting process**.

Composite « fine » mix

Composite « medium » mix
67% glass fiber composite
29% carbon fiber composite

Composite « gross » mix
87% glass fiber composite
10% carbon fiber composite

Mechanical recycling (GEES Recycling)

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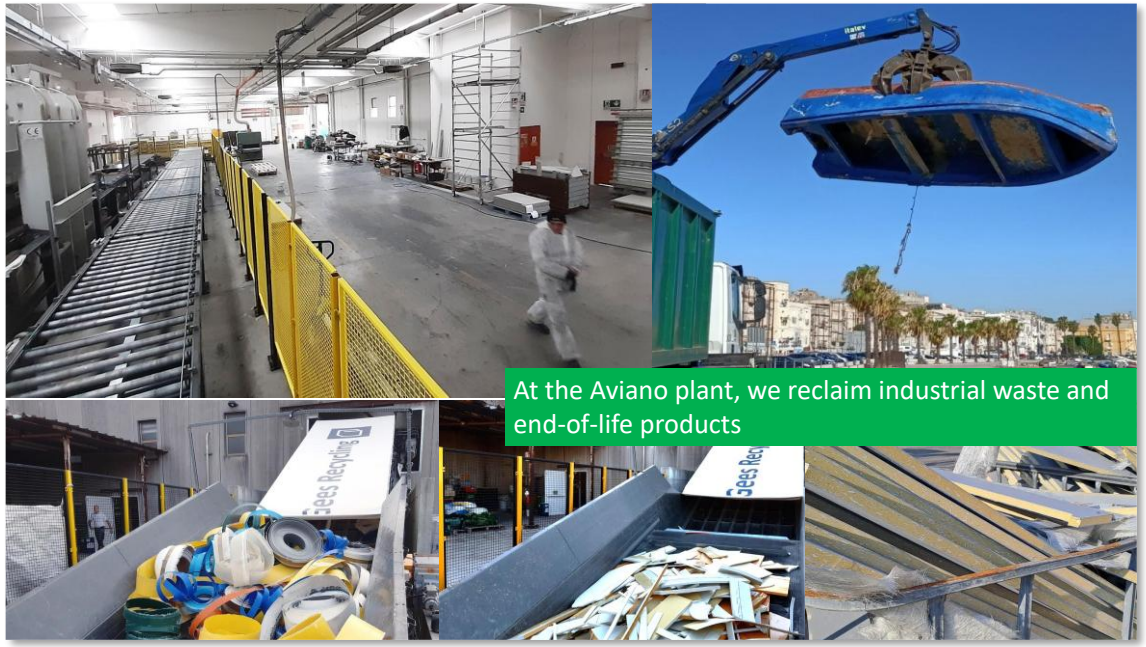
Gees Recycling has developed a **mechanical recycling process** for composites of any kind, rigid foams, core materials and other waste. Currently **>1800 t/y** are processed; in the REFRESH project this number will be increased to **>5500 t/y**.



At the Aviano plant, we reclaim industrial waste and end-of-life products

We convert waste management challenges into tailor-made construction materials

We convert waste management challenges into secondary raw materials and fillers

Thermo-chemical recycling (EnEcoLab)

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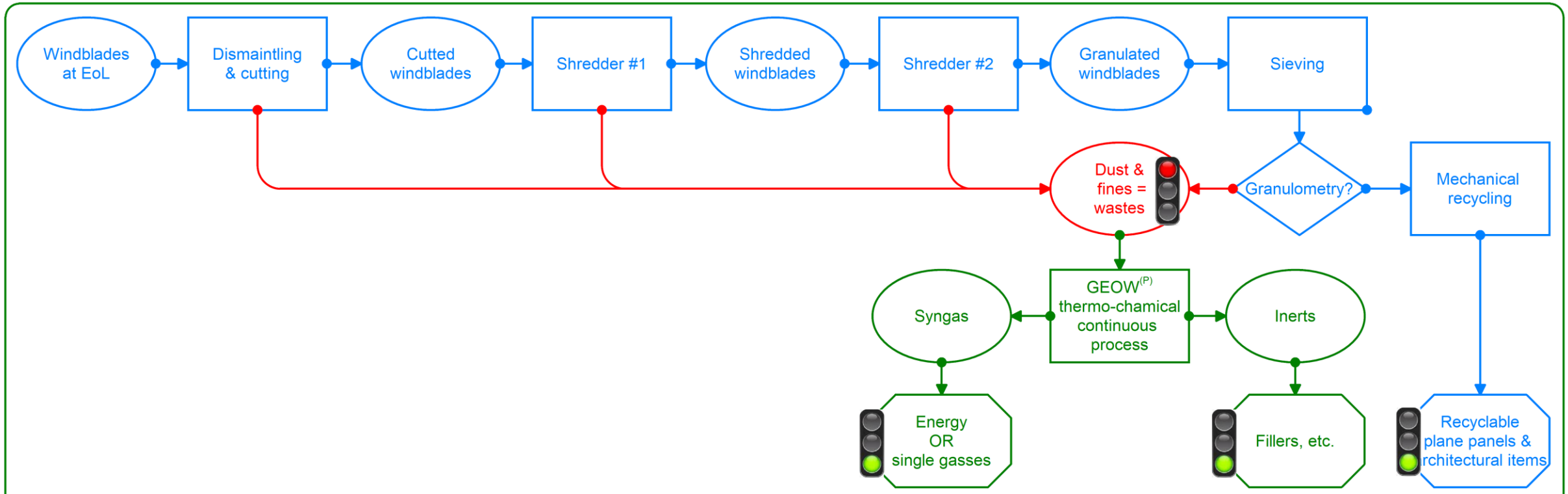
EnEcoLab has developed a **thermo-chemical recycling process** to close the EoL cycle of decommissioned wind blades, turning in syngas and inerts the not re-usable and not-recyclable dusts and fines generated by the previous mechanical treatments.



Thermo-chemical process of dusts and fines generated by the previous mechanical processes, Concept

Thermo-chemical recycling (EnEcoLab)

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Syngas composition, %:	
C_nH_m:	1,67
CH_4:	20,02
H_2:	21,54
CO:	35,12
CO_2:	16,82
O_2:	0,08
Other gasses:	4,76
LHV, Mj/Nm^3:	14,80
1 Nm^3 syngas = 0,413Nm^3 CH_4	
0,54 $l_{syngas}/gr_{material}$	

GEOW® continuous reactor, in progress to TRL 5

Residual solids, inert,
Ø 0 – 0,6 mm = 82 %

Initial material: GJENKRAFT, GRP dusts and fines from EoL wind blades, inert portion 31,23%

Final material: 56,33% in weight on the initial, process efficiency 81,90% (organic portion transformed)

MW-pyrolysis and solvolysis (CIRCE)

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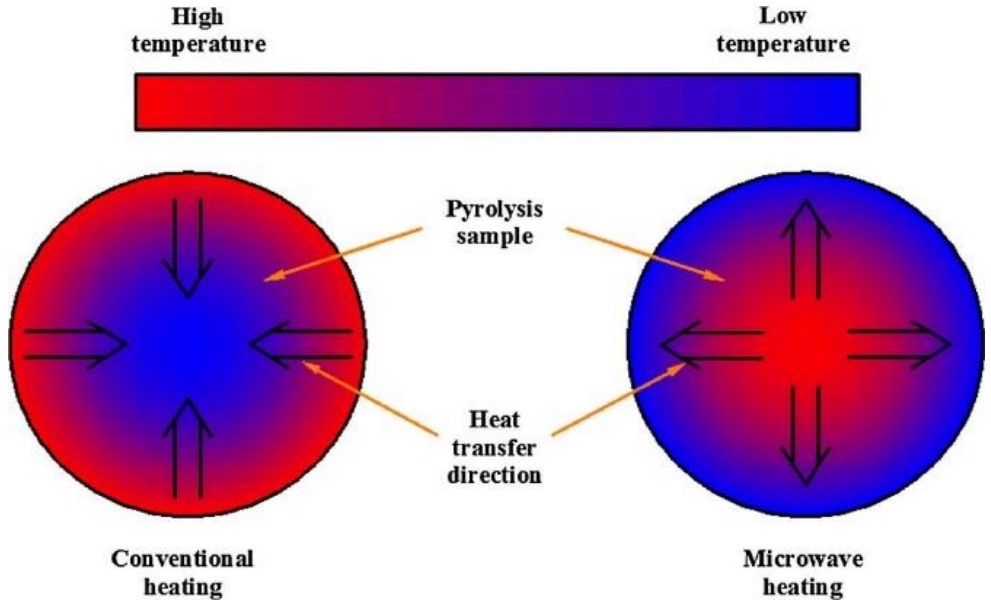
CIRCE develops two thermochemical routes for the valorization of wind blade waste based on **microwave-assisted pyrolysis** (MW-PYR) and **microwave-assisted solvolysis** (MW-SOL).

Technological benefits:

- Moderate energy consumption (**<10 MJ/kg FRP**)
- Preservation of mechanical properties (**lower T**)
- Resins recover for fuels, recycled resins or second-generation chemicals
- Fast and volumetric heating rates (**+ energy efficiency**)
- Potential power consumption from **100% renewable sources**



Microwave-assisted pyrolysis and solvolysis

Horizon Europe
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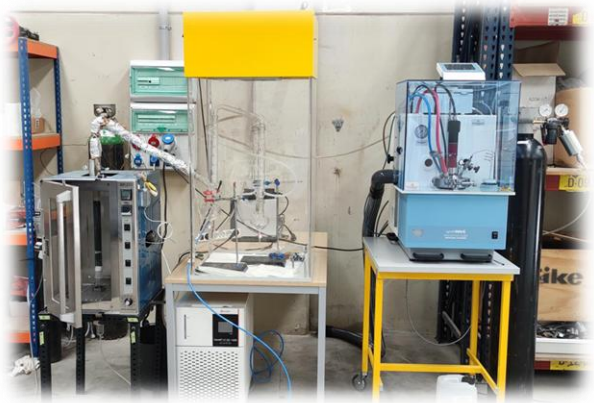
CIRCE develops two alternative energy-efficient thermochemical routes for the valorization of wind blade waste based on **microwave-assisted pyrolysis** (MW-PYR) and **microwave-assisted solvolysis** (MW-SOL).



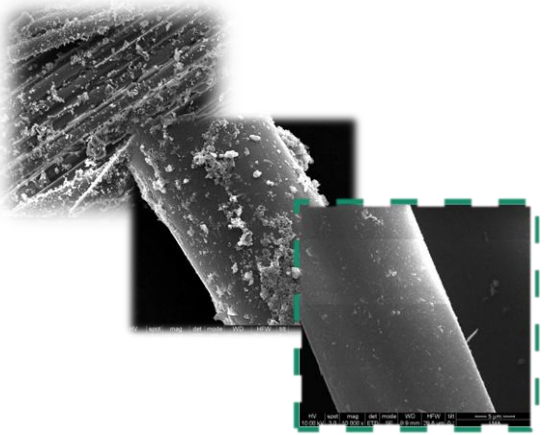
Bench MW-reactors

Continuous pilot MW-pyrolysis unit

EXPERIMENTAL ASSESSMENT ON CHEMICAL WTB RECYCLING

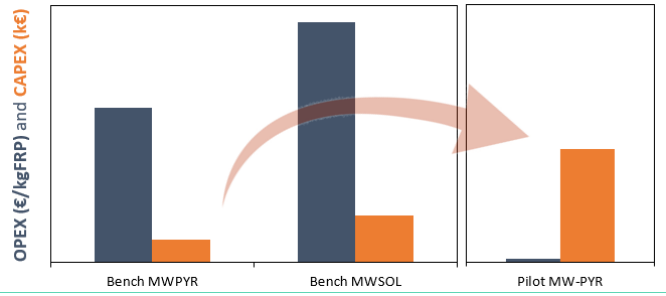
Shredded wind blade fiber-reinforced composites

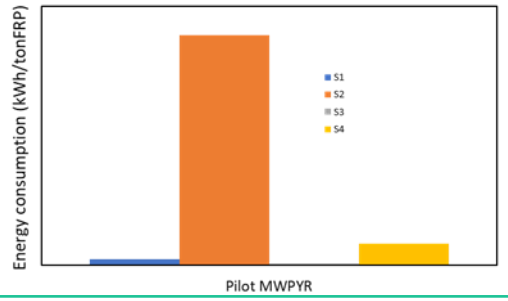
Recovered clean glass fibers without textural damage



Pyr-oils and syn-oils preserving building blocks

TECHNO-ECONOMIC ASSESSMENT (MWPYR vs MWSOL)





Thermal recycling – electrical pyrolysis process research and analysis (Gjenkraft)

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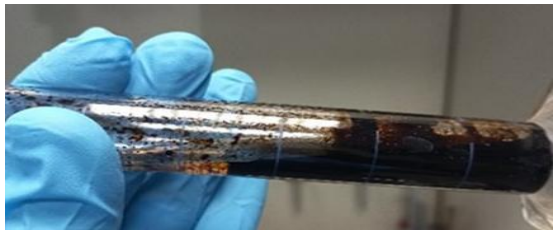
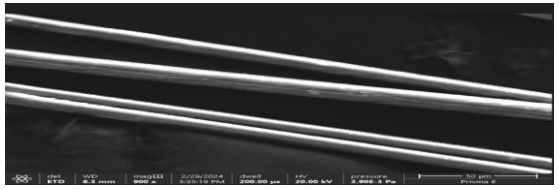
Progress

- Pyrolysis process research under various conditions
- Fiber cleaning: comparing methods for char/ash removal
- Mechanical property testing post-process
- Exploring fiber strength recovery techniques
- Scaling up: refining parameters in lab tests
- Defining final process parameters for implementation



Thermal recycling – large-scale machines design (Gjenkraft)

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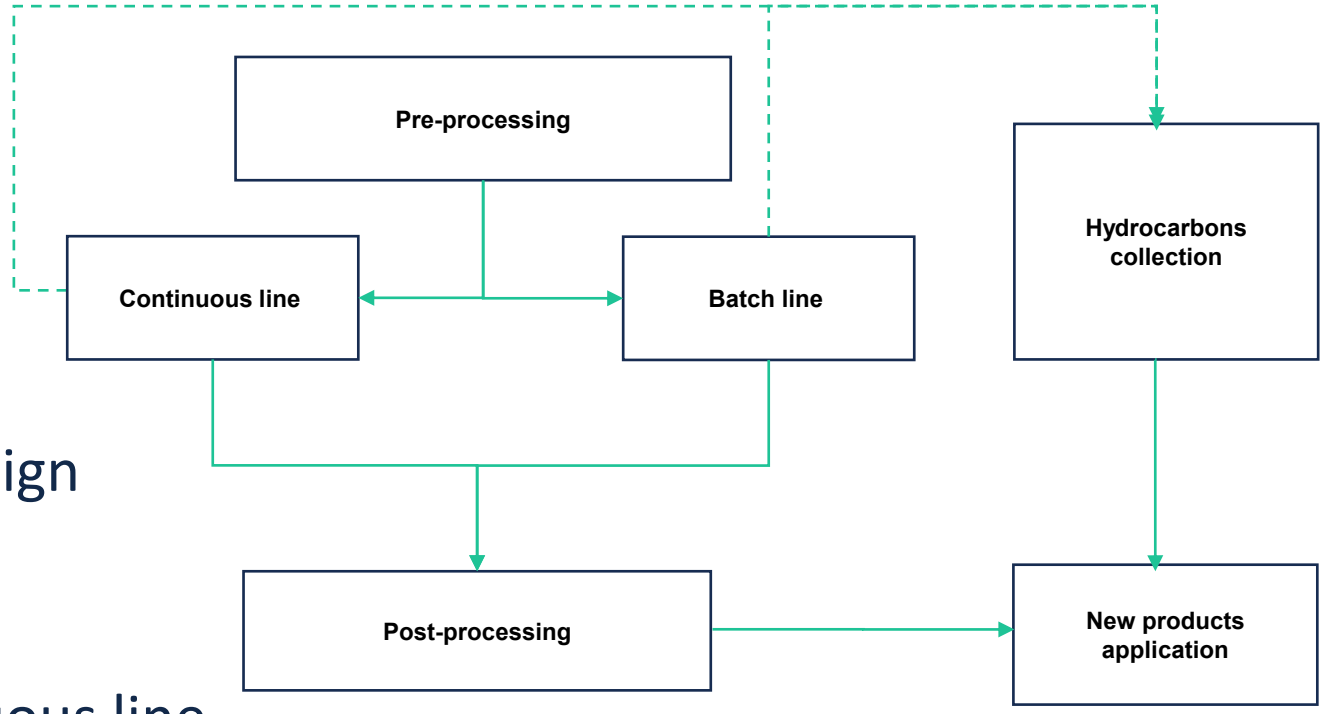
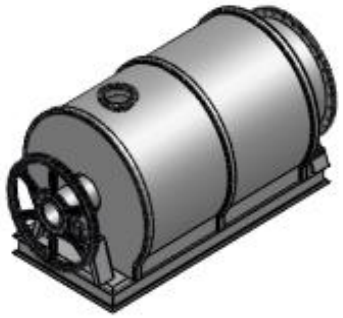
Progress

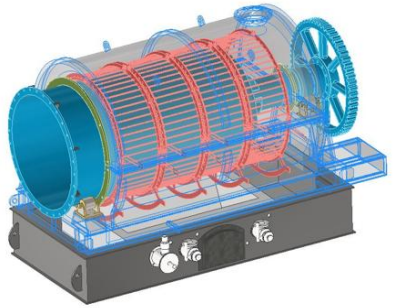
- LCA analysis & material balance
- Modification concept for existing batch reactor and installation
- Detailed machinery and equipment design

Next steps

- Installation & commissioning of continuous line
- Procurement & upgrade of existing reactor
- Fiber production (glass & carbon) for partner testing







REFRESH eco-design strategy (CETMA)

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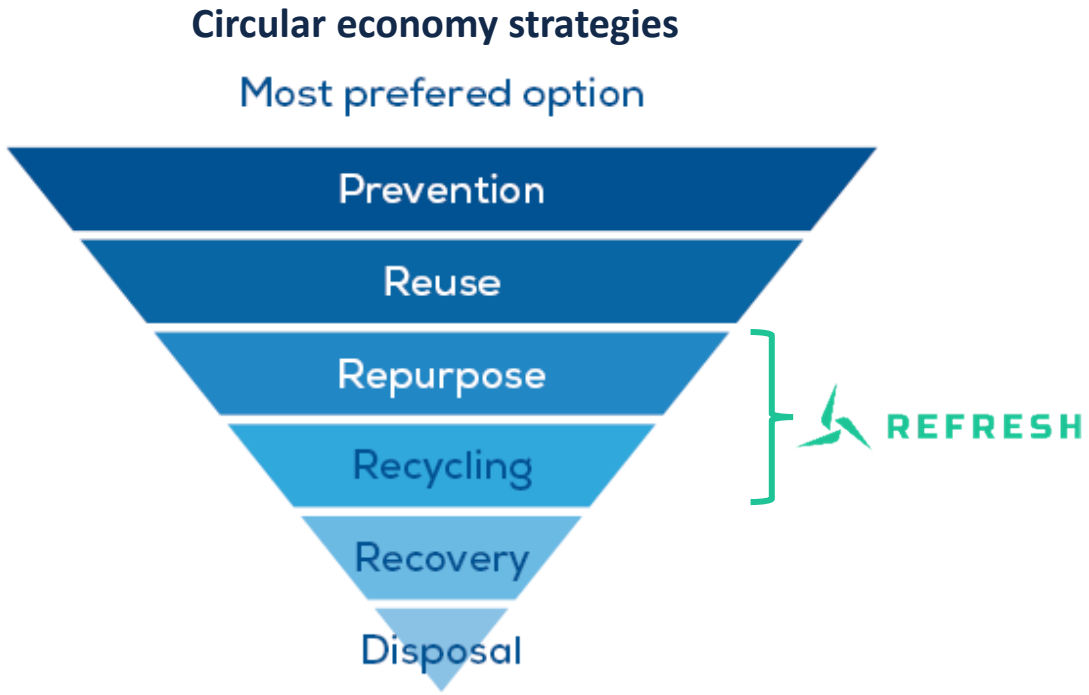

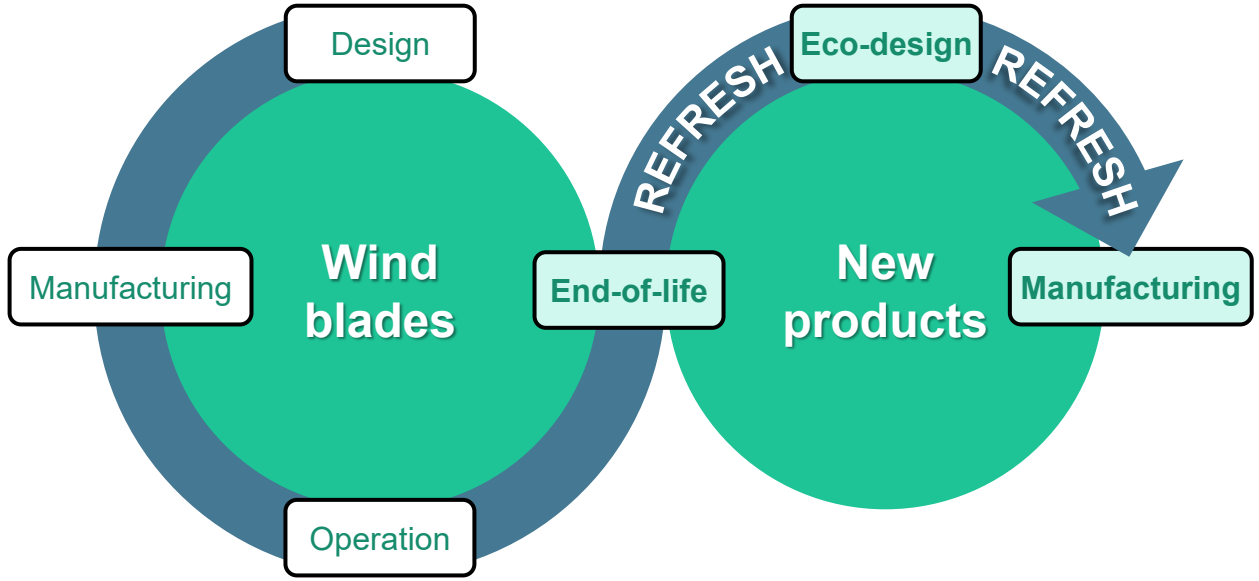

- Deployment of recycling technologies and repurposing strategies
- Development of recycled / repurposed products and markets

REFRESH eco-design strategy (CETMA)

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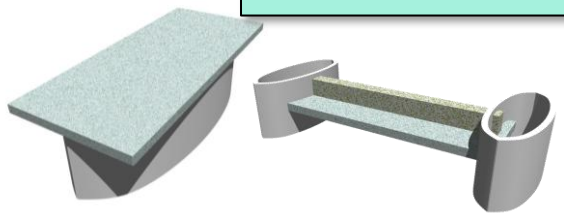
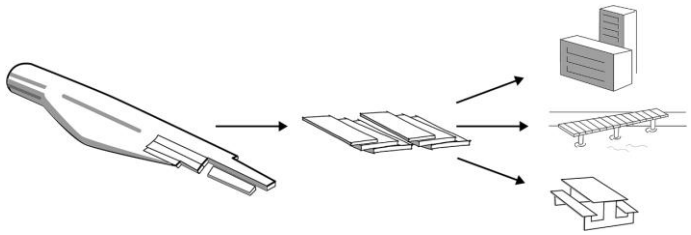
TRADITIONAL REPURPOSING APPROACH





ALTERNATIVE REPURPOSING APPROACH (JOUSTRA ET AL., 2021)

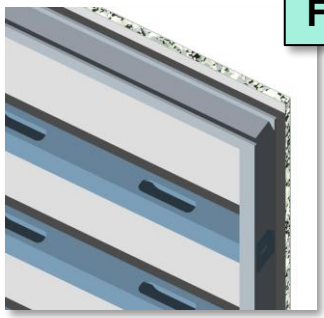
Repurposing of blade portions *with ETAT9*

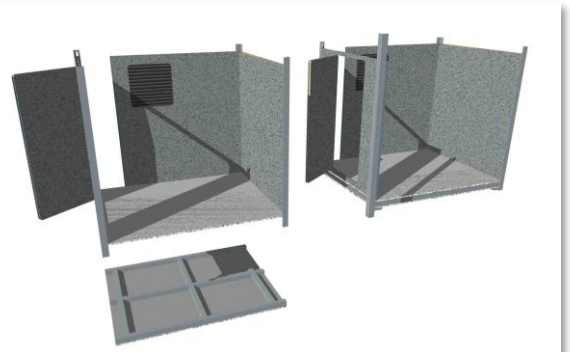
Mechanically recycled materials *with GEES*

Concrete structures *with TECNALIA*

Thermally recycled materials *with GJK*

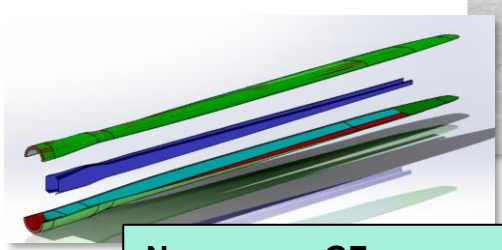
FORMWORK PANELS





EQUIPMENT SHELTER

NON-WOVEN GF INSULATION FOR BUILDING APPLICATIONS



NON-WOVEN GF MATT FOR WIND BLADE OUTER SKIN

ONSITE 3D PRINTED CONCRETE WIND TOWER

REFRESH preliminary LCA results (RINA-C)

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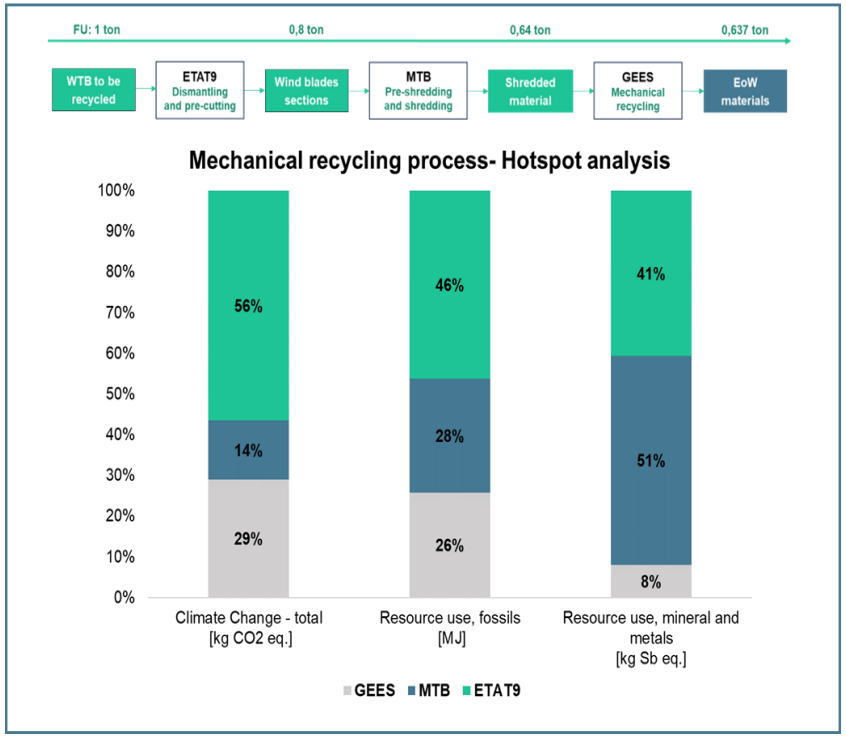
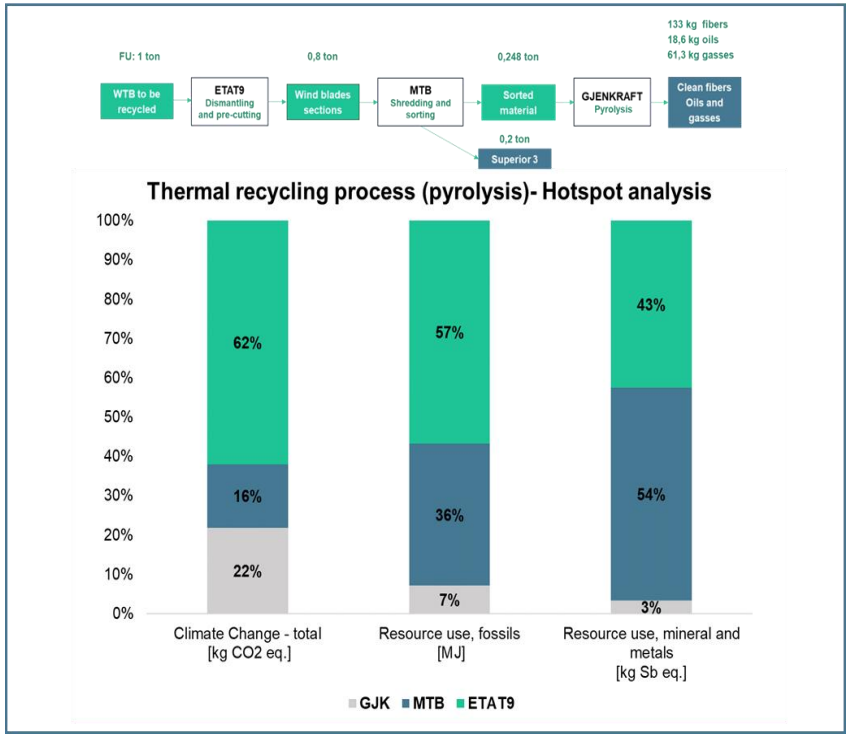
MECHANICAL



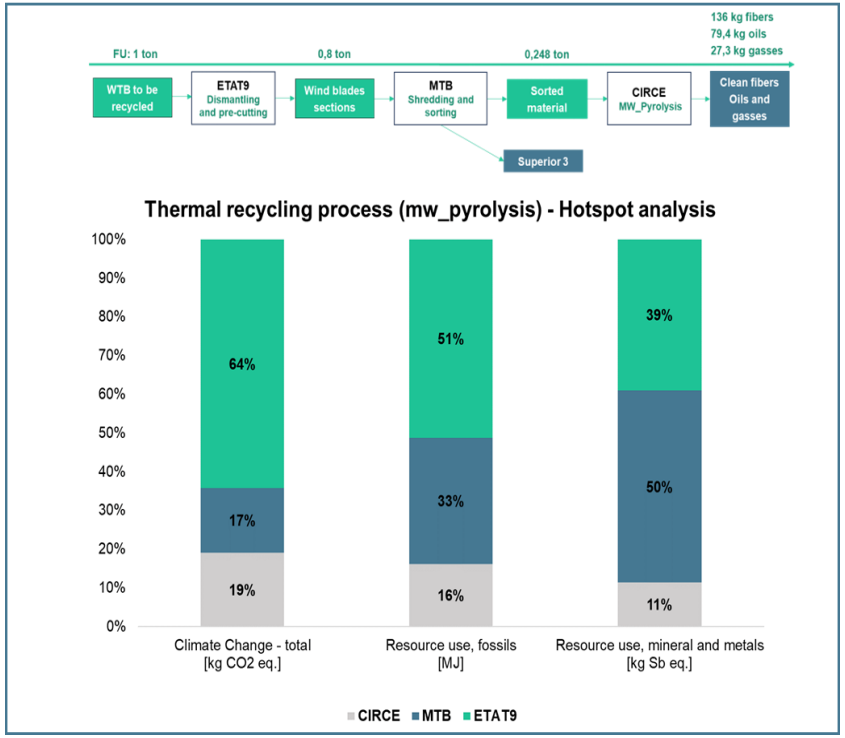
Environmental benefits of EoW materials (as ***substitute of epoxy resin materials***) from mechanical recycling value chain are ***3180 kg CO2eq.***

THERMAL E-PYROLYSIS



Environmental benefits of glass and carbon fibers (as substitute of ***virgin ones***) from thermal recycling value chain are ***1128 kg CO2eq.***

THERMAL MW-PYROLYSIS



Environmental benefits of glass and carbon fibers (substitute of ***virgin ones***) from thermal recycling value chain are ***1154 kg CO2eq.***

REFRESH smart tool for traceability (TECNALIA)

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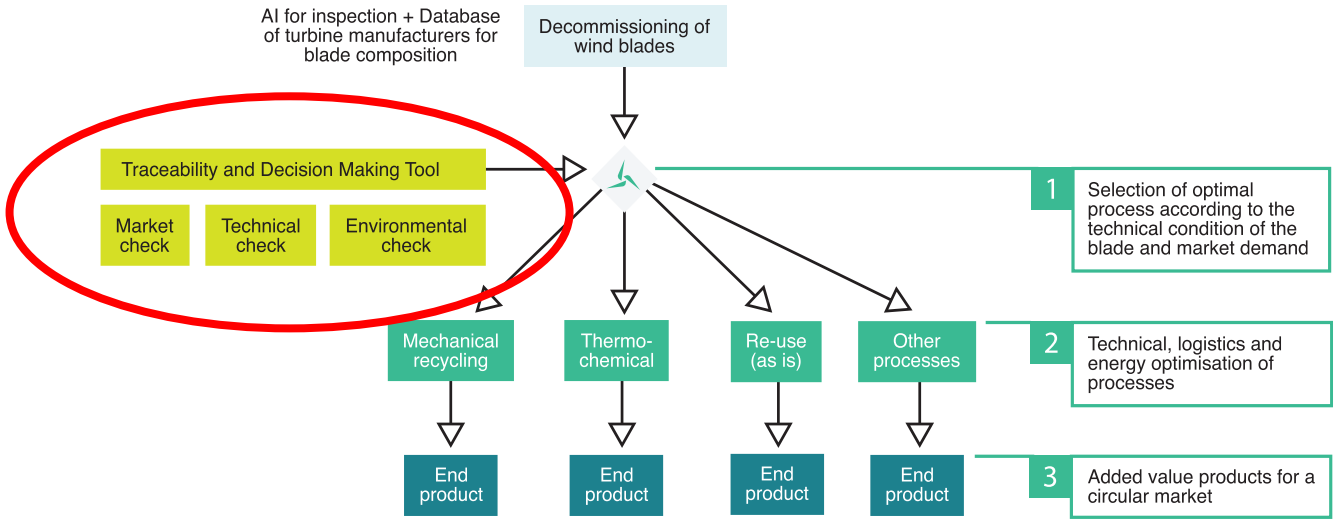
- ❖ Real-time tracking
- ❖ Transparent information sharing
- ❖ Secure data storage

Benefits:

- Enhanced quality control
- Improved efficiency
- Increased confidence and secondary materials acceptance
- Regulatory compliance

Data-driven decision-making tool



REFRESH smart tool for traceability (TECNALIA)

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Goal: to provide an **accurate and verifiable** set of information about the **products**

REFRESH smart tool for traceability (TECNALIA)

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- System integration
- Data accuracy
- Stakeholder participation
- Privacy concerns

- Cross-industry material exchange
- Fully transparent wind energy sector
- Further standardization and DPP
- Extended Producer Responsibility

REFRESH

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101096858.

acciona

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Photo by Nicholas Doherty on Unsplash

End-User Challenges in adopting Recycled materials

- Performance Uncertainty
- Regulatory Compliance
- Tracelability & Quality Assurance
- Integration Compatibility
- Cost-Value Perception

Opportunities with REFRESH Secondary Materials…..

(Unlocking Circular Potential in Construction)

DEMONSTRATION 1

From recycled fiberglass and after a crushing/micronization process, its incorporation as filler in the pultrusion process for the manufacture of structural profiles will be studied

Pultrusion

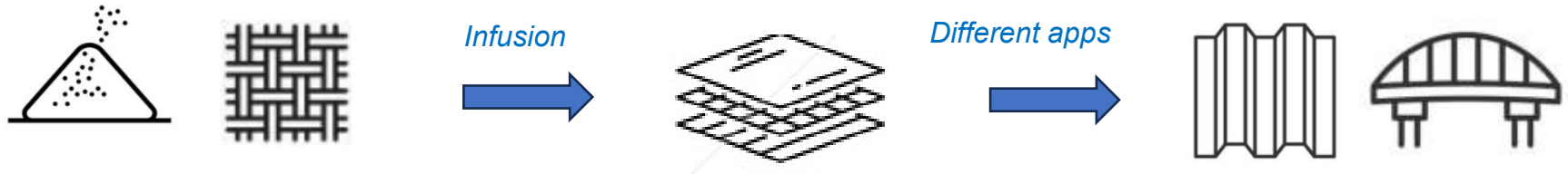
Pultruded profiles

Opportunities with REFRESH Secondary Materials…..

(Unlocking Circular Potential in Construction)

DEMONSTRATION 2

Two proposals can be considered: a) using the filler obtained in demo 1 with recycled fiberglass, its incorporation into the infusion process will be studied b) using a mat manufactured by CETMA from recycled fiberglass, incorporate it into the infusion process as a final finish

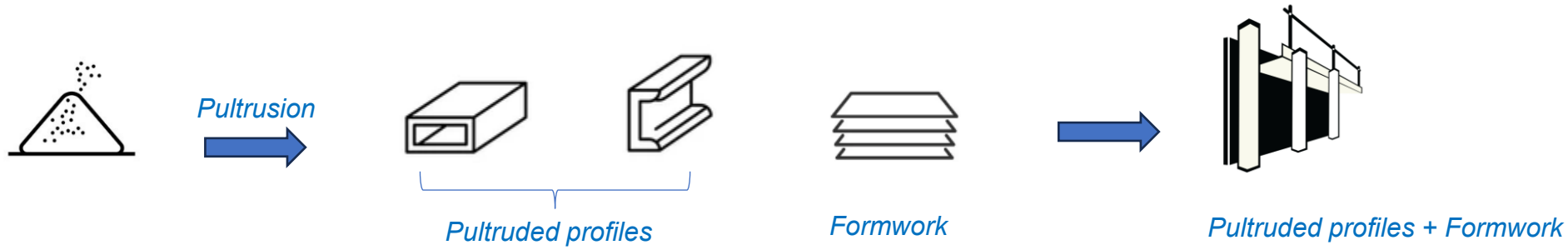


Opportunities with REFRESH Secondary Materials…..

(Unlocking Circular Potential in Construction)

DEMONSTRATION 3

Validating the GEES composite panel as a formwork application, either by considering just the panel or as a complete formwork system: panel and pultruded profile from demo 1



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REFRESH

Thank you for your attention!

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