



smart dismantling, sorting and **RE**cycling of glass **F**iber **RE**inforced composite from wind power **S**ector through **H**olistic approach

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Anurag Bansal
ACCIONA Construcción S.A.
(REFRESH consortium partner)



Today's Agenda

- The growing blade end-of-life challenge
- Industry and market barriers
- The REFRESH circular solution
- 2025 achievements
- 2026 plans
- Industry engagement & next steps



Evolution of an Asset: The Repowering Challenge

The past
(An ageing wind farm at the end of its service life)

98 turbines = 78.4 MW



The present
(Repowering the wind farm)

13 turbines = 84.4 MW



The Paradox of Success: Solving the retired Wind Turbine Blade Problem



294 retired blades on ground from this Wind farm
&
many more from various Wind farms around the globe

Industry Challenges

Technical

- Blades are complex composite structures.
- Recycling technologies exist, but many are not yet deployed at industrial scale.

Economical

- Economically, logistics and transport are costly.
- Secondary raw materials markets are still developing.

Regulatory & Environmental

- Landfill is not completely banned in every country.
- Incineration is not a long-term sustainable solution.

It is not just a technical issue. It is a systematic value-chain challenge

Barriers for End-User Industries

- Performance Uncertainty
- Regulatory Compliance
- Traceability & Quality Assurance
- Integration Compatibility
- Cost-Value perception, etc.

So, the key barrier is not only recycling. It is the market confidence.

The REFRESH Consortium

11 partners from 5 countries:

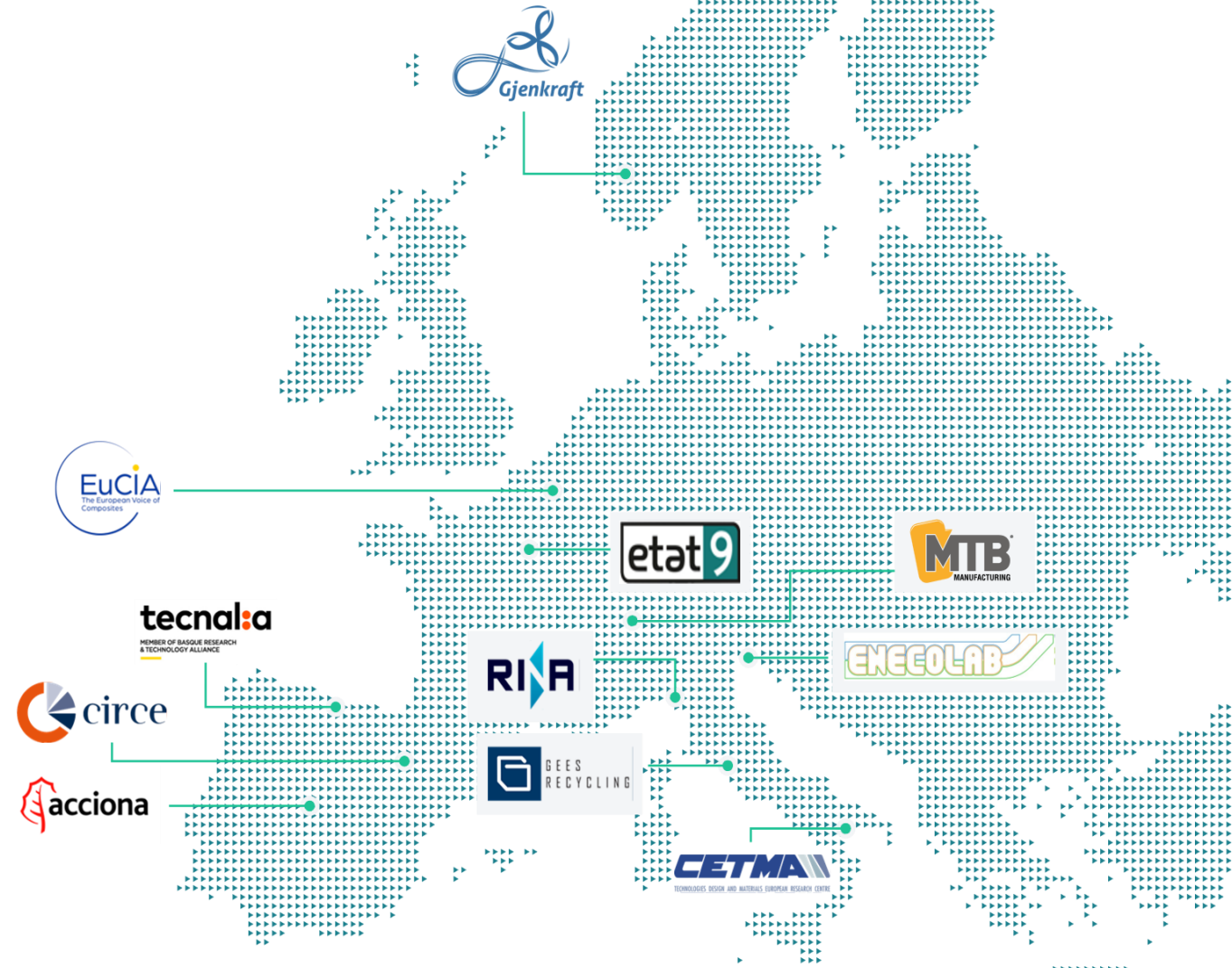
- Waste recycling and remanufacturing companies
- Engineering and consulting companies
- Research and development companies
- Access to stakeholders in the composites sector manufacturers

RINA is the project coordinator

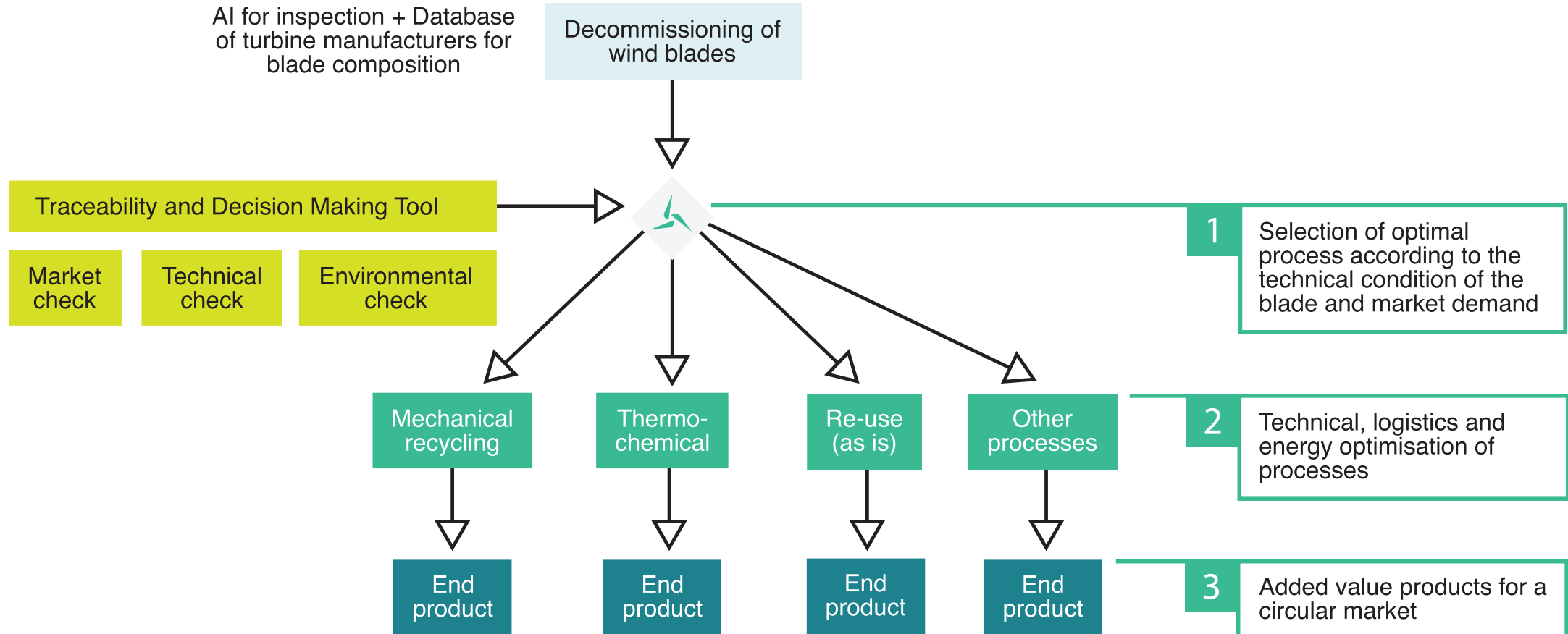
EuCIA leads communication & dissemination activities



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The REFRESH Concept



Focus of REFRESH

Keep parts for longer.

Design for easier dismantling and recycling.

Minimise number of materials in design manufacture.

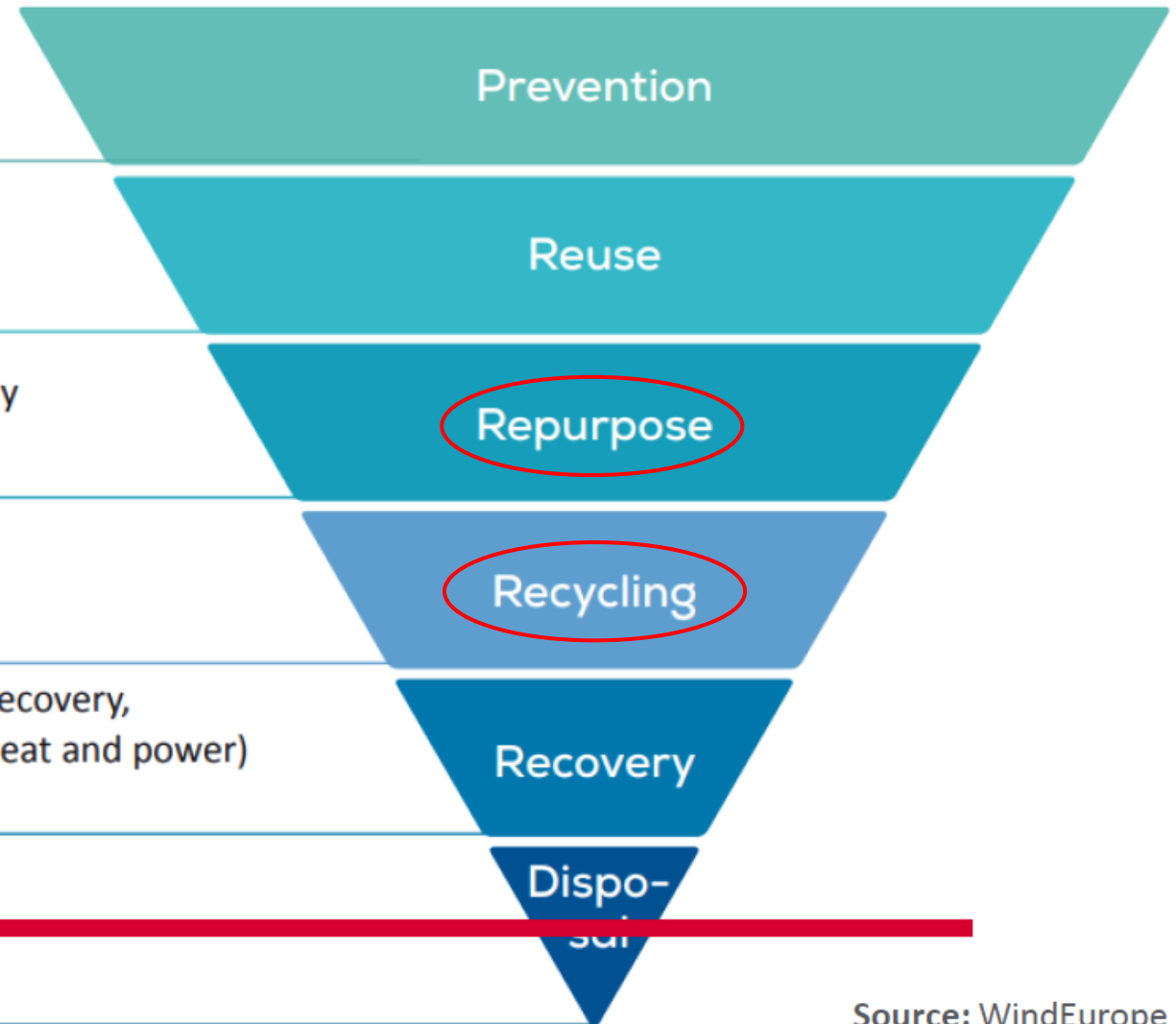
Check, clean, repair, refurbish, repair whole items or spare parts.

Re-use an existing part for a different application, usually of lower value than the original.

Convert waste into a new substance or product.
Includes composting if it meets protocols.

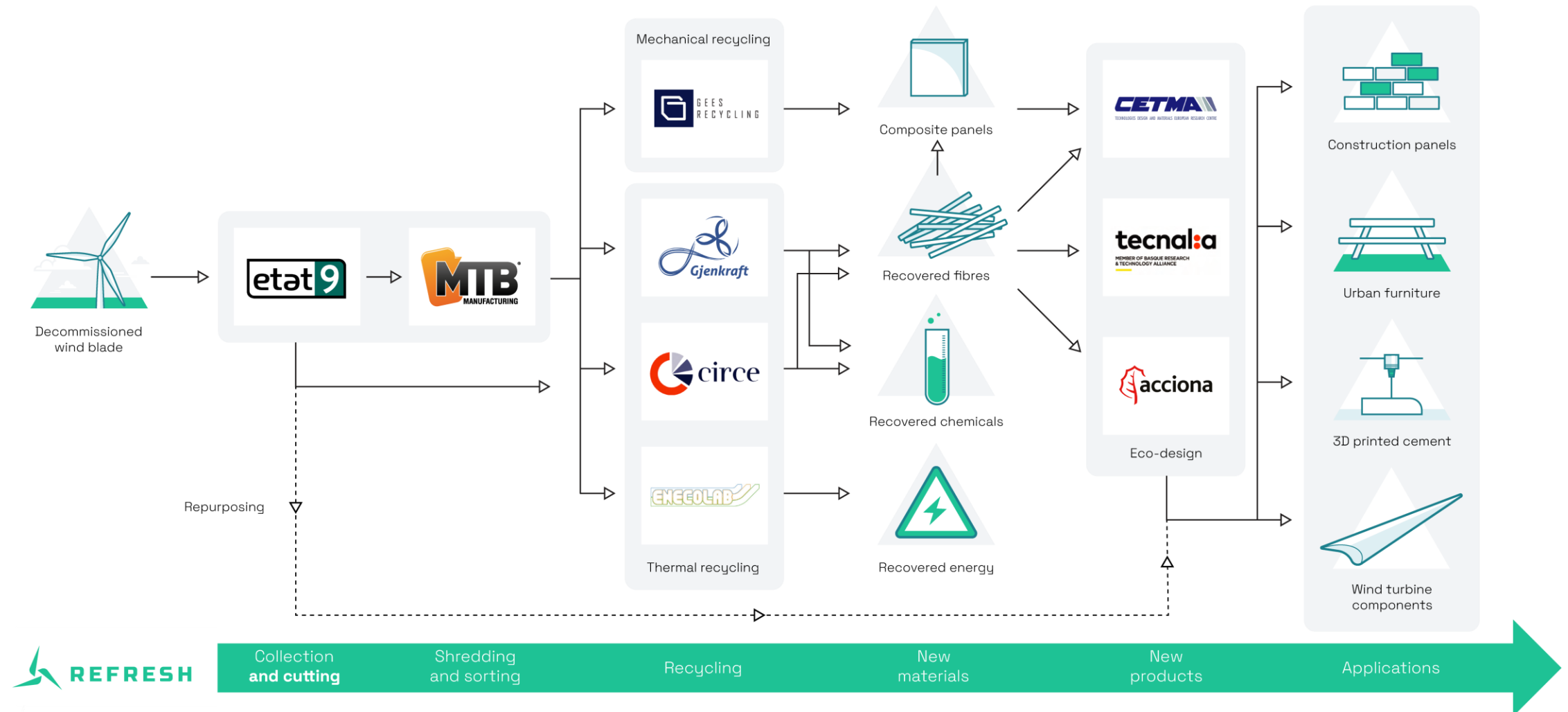
Includes anaerobic digestion, incineration with energy recovery, gasification and pyrolysis which produce energy (fuels, heat and power) and materials from waste.

~~Landfill and incineration without energy recovery.~~



Source: WindEurope

Methodology-REFRESH Value Chain



Technology for on-site Cutting and Stacking: ETAT 9



Dismantling



Circular Saw Cutting



Wire Saw Cutting



Packing



Transportation

Technology for Shredding and Sorting: MTB



Shredding



Sorting

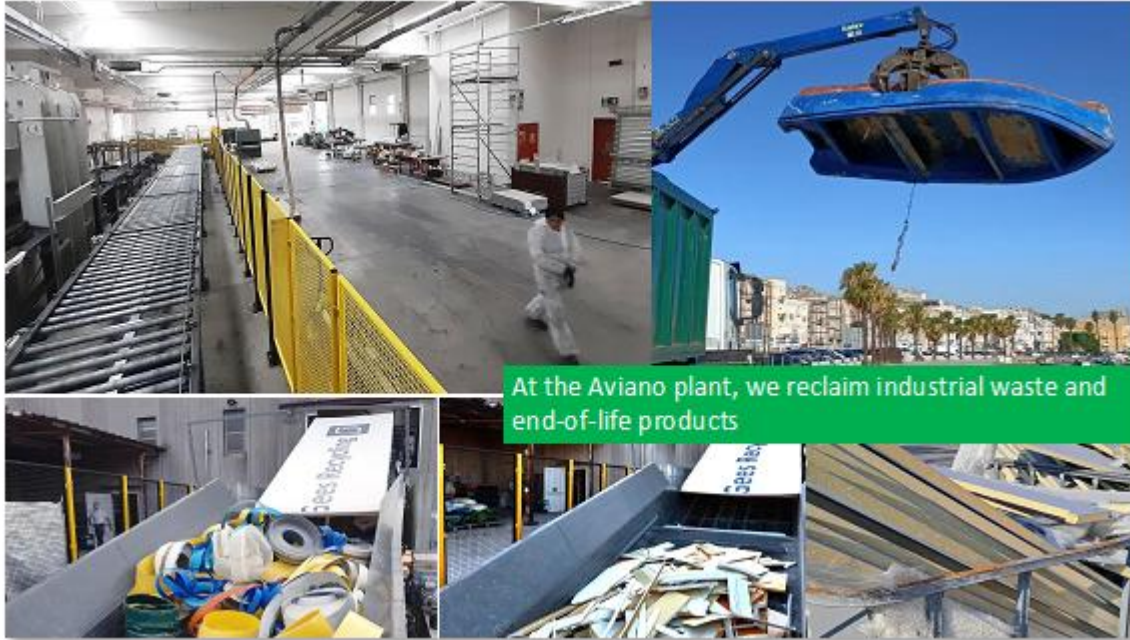


Shredded blade

Technology innovations: Mechanical Recycling facility:GEES



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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

Currently **>1800 t/y** are processed; in the REFRESH project this number will be increased to **>5500 t/y**.

Picnic table- Repurposed Balsa panel (Etat 9) and Mechanical recycled (GEES) designed & assembly (CETMA)



Technology innovations: Pyrolysis for Fiber recovery (Gjenkraft)



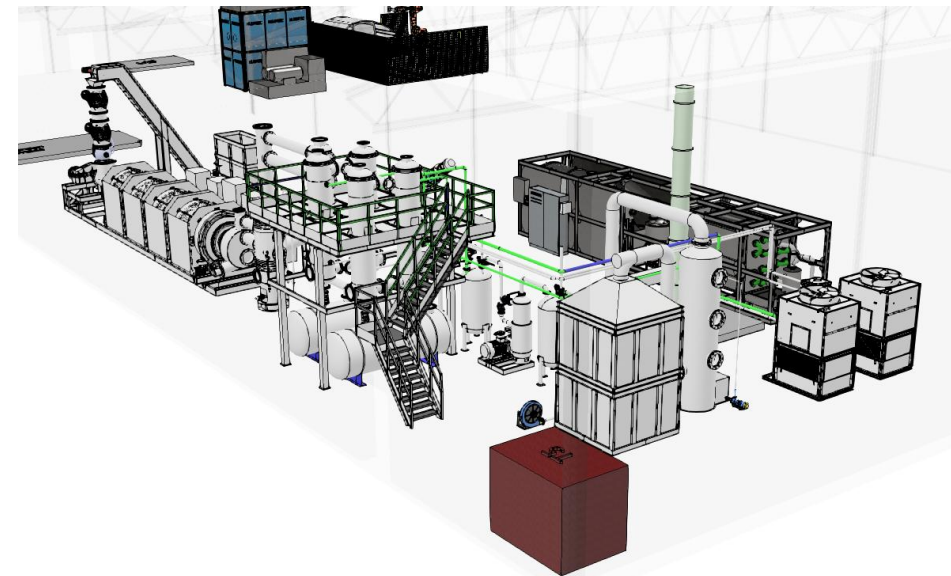
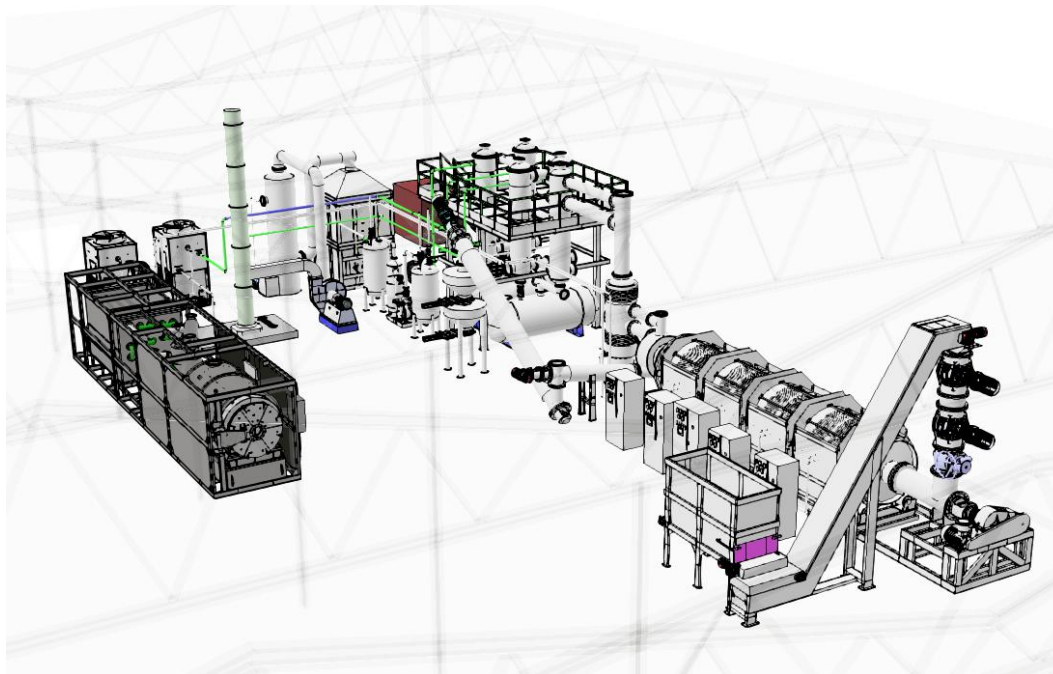
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Packages:

- Feeding system for reactor
- Pyrolysis system with electric induction heating system
- Cooling condenser system for reactor
- Syn gas collection system for reactor
- Discharging system from pyrolysis reactor
- Syn gas flare burner and exhaust cleaning system
- N₂ generator
- Control system (PLC, sensors, etc.)

Specification:

- Specification:
- Work form: Automatic continuous
- Type : horizontal rotation
- Capacity: 400kg/h
- Power: 4*100 kW
- Heating type: induction
- Operational temperature: up to 600 °C
- Particle size: up to 100-150mm



Technology innovations: MW Pyrolysis and Solvolysis (CIRCE)



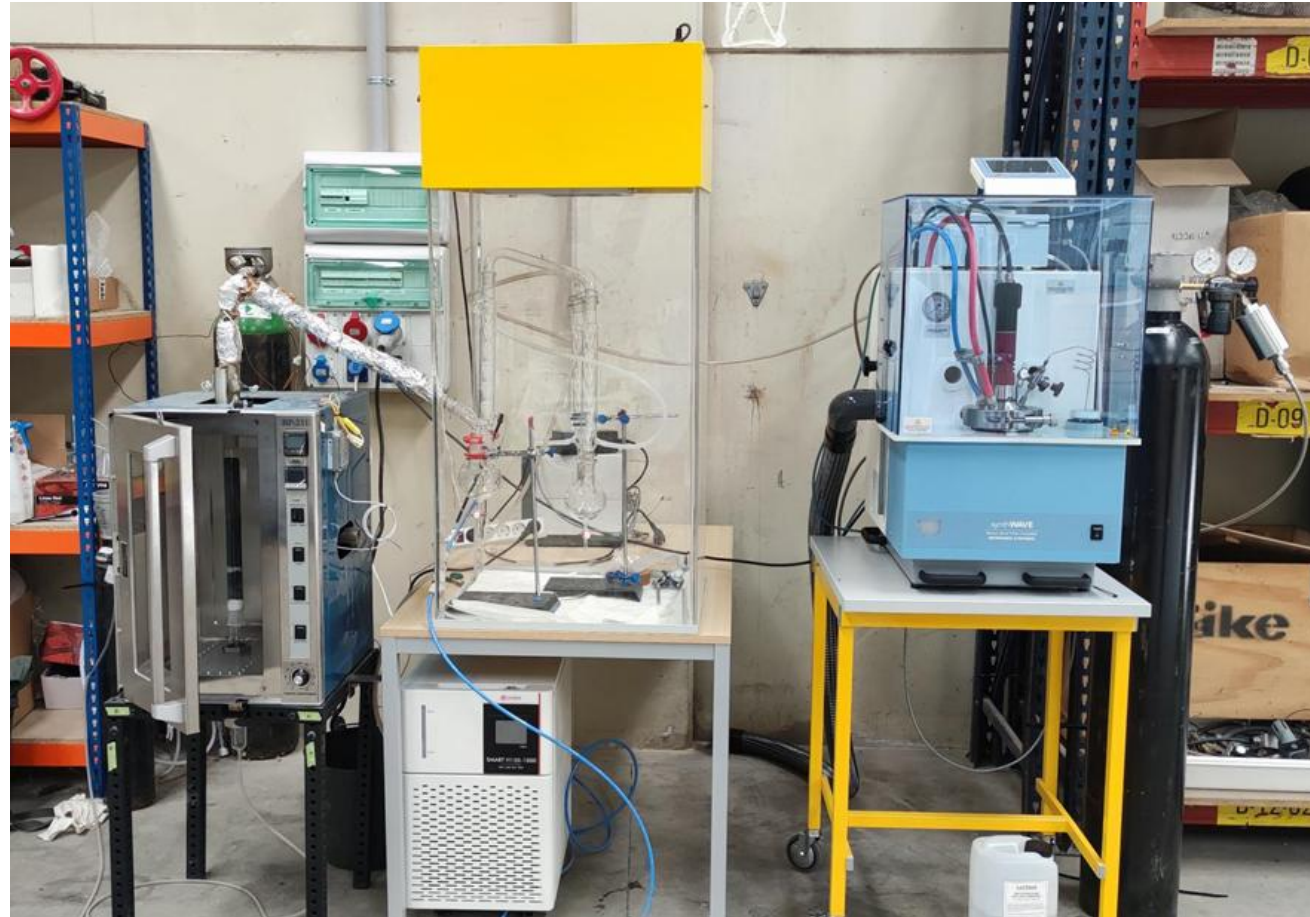
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Recovered Pyrolyzed
fibers



Isolated pyrolysis oil &
waxes



MW-Pyrolysis

MW-Solvolysis



Washed and dried
glass fibers



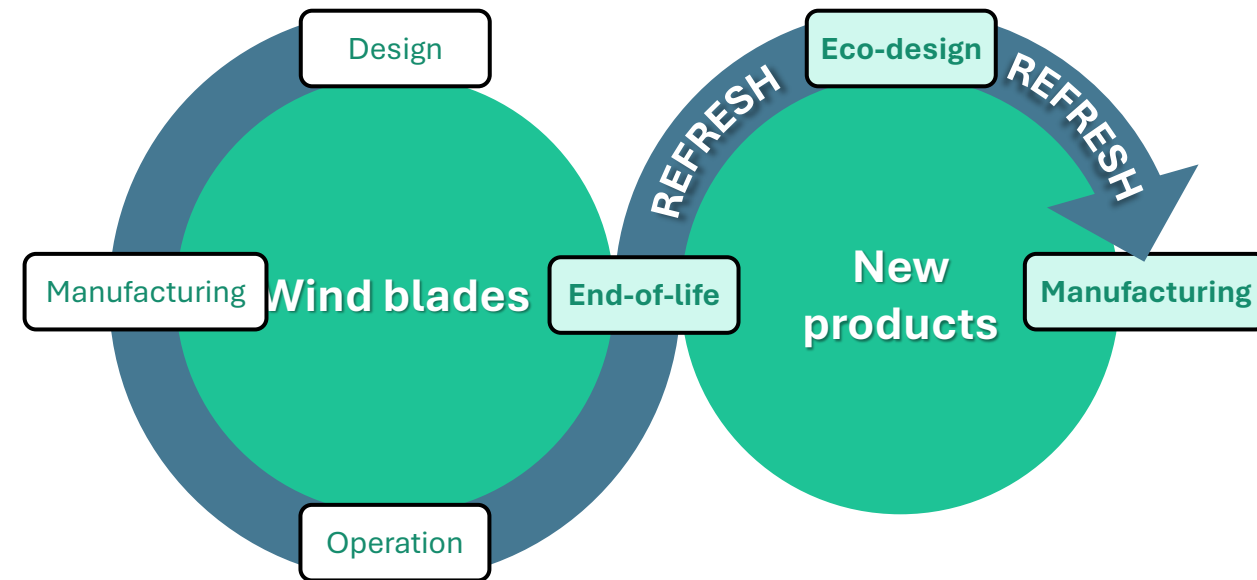
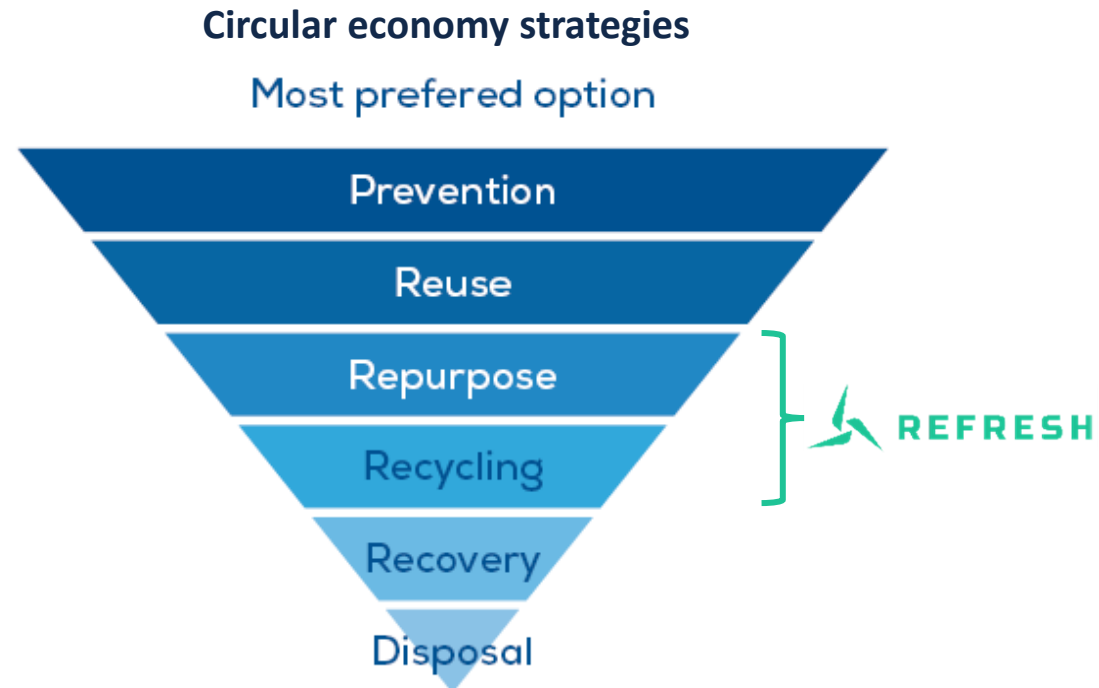
Oil phase

Wind Turbine Blade section-Non-Woven from recovered Glass Fibers (CETMA)





REFRESH eco-design strategy (CETMA)



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

REFRESH preliminary LCA results (RINA-C)

The LCA methodology follows internationally standardized procedures ISO 14040/14044

Innovative REFRESH recycling processes
Recycling processes vs. linear disposal technology
Environmental benefits arise from secondary raw materials
Functional unit (FU): **1 ton of wind turbine blades to be recycled (WTBR)**



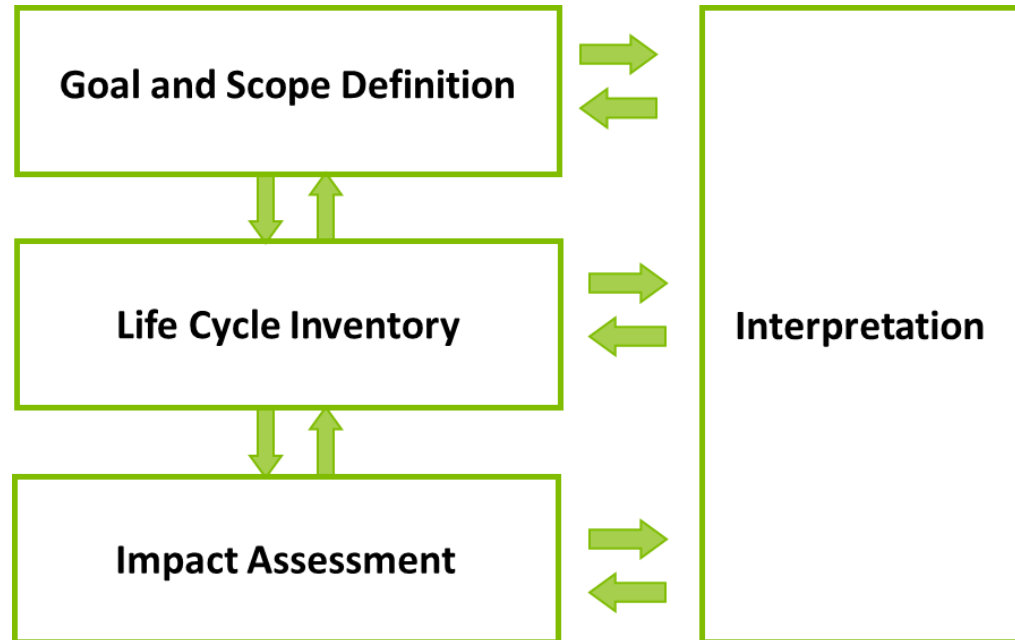
The inventory data are based on high-quality **experimental measurements** obtained through on-site testing.
Ecoinvent and Sphera LCA databases



Resource Consumption
Global Warming Potential
Waste production



Environmental Life Cycle Assessment (E-LCA)



Hotspot analysis
Comparison with linear disposal
Preliminary environmental benefits

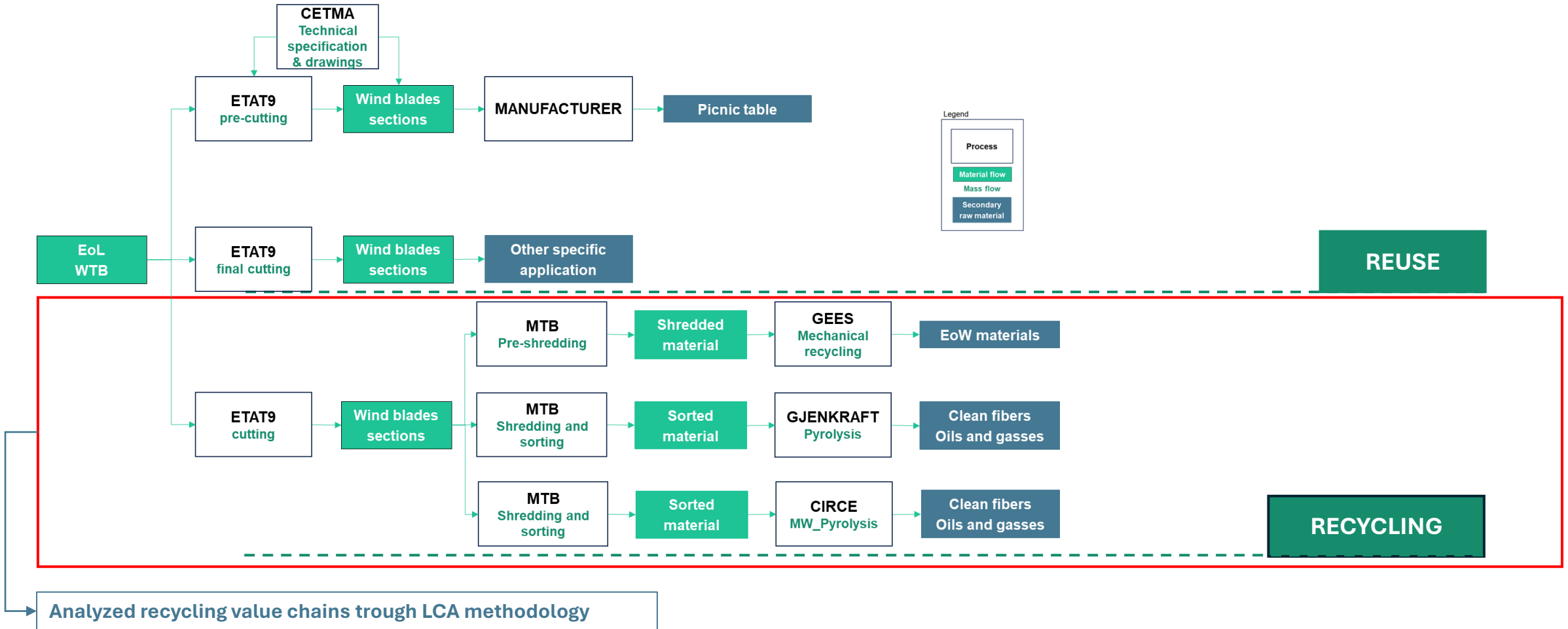


REFRESH preliminary LCA results (RINA-C)



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System boundaries applied in LCA study and REFRESH recycling value chains



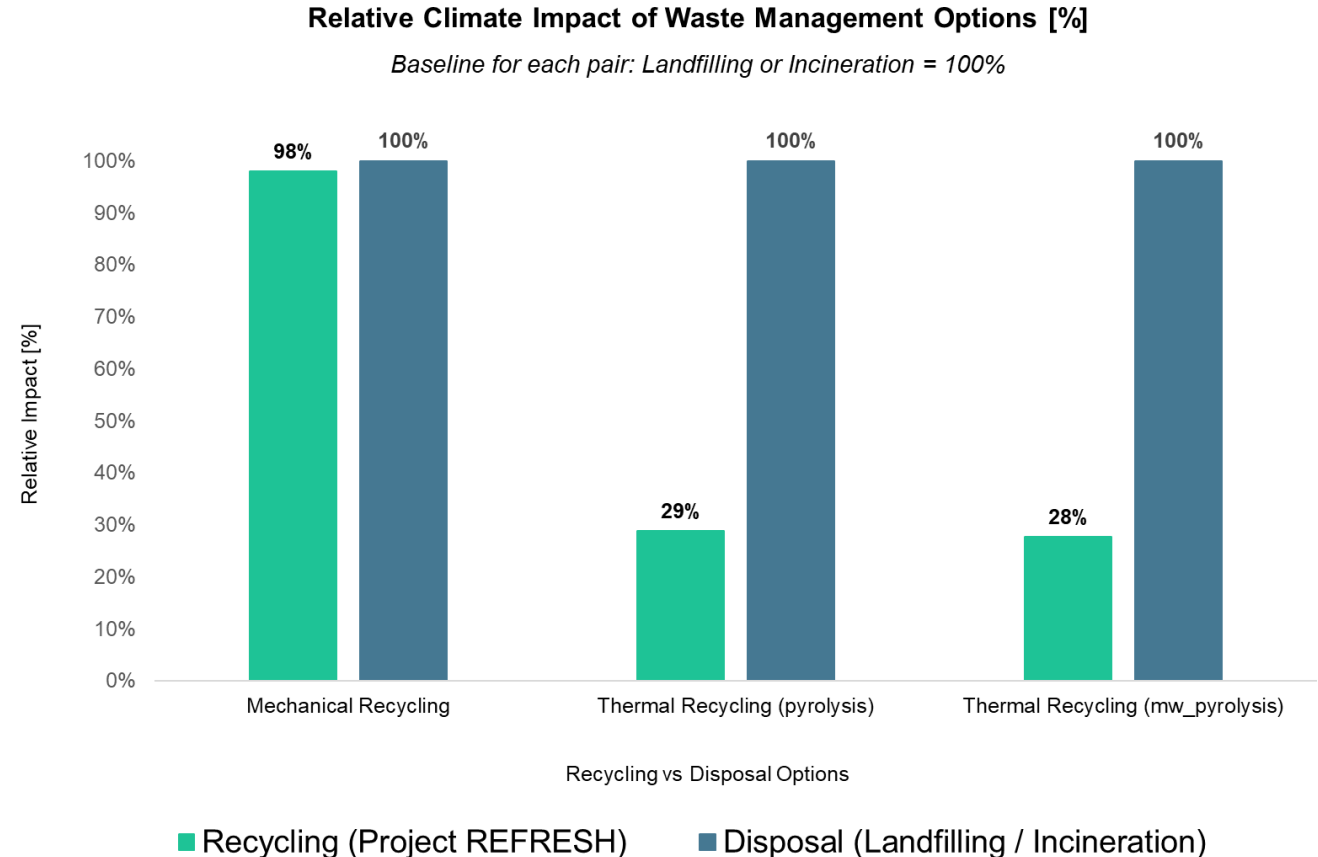
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Recycling vs. traditional disposal methods

- In the Climate Change impact category, all REFRESH recycling process show **lower environmental impacts** than landfilling or incineration.
- Recycling produces **secondary raw materials** capable of substituting virgin production.
- This substitution effect leads to further avoided greenhouse gas emissions upstream, **amplifying the climate benefits** beyond those shown by the direct process impacts.



Values normalized to disposal (100%). Lower % indicates reduced climate impact compared to baseline.

REFRESH preliminary LCA results (RINA-C)



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Recycling processes produce secondary raw materials. All recycling routes deliver large climate benefits, because we avoid virgin production.

Mechanical recycling delivers **the largest net reduction**

- 2939 kg CO₂eq

End-of-Waste (EoW) materials application in the lightweight industry replacing **virgin epoxy resin**.

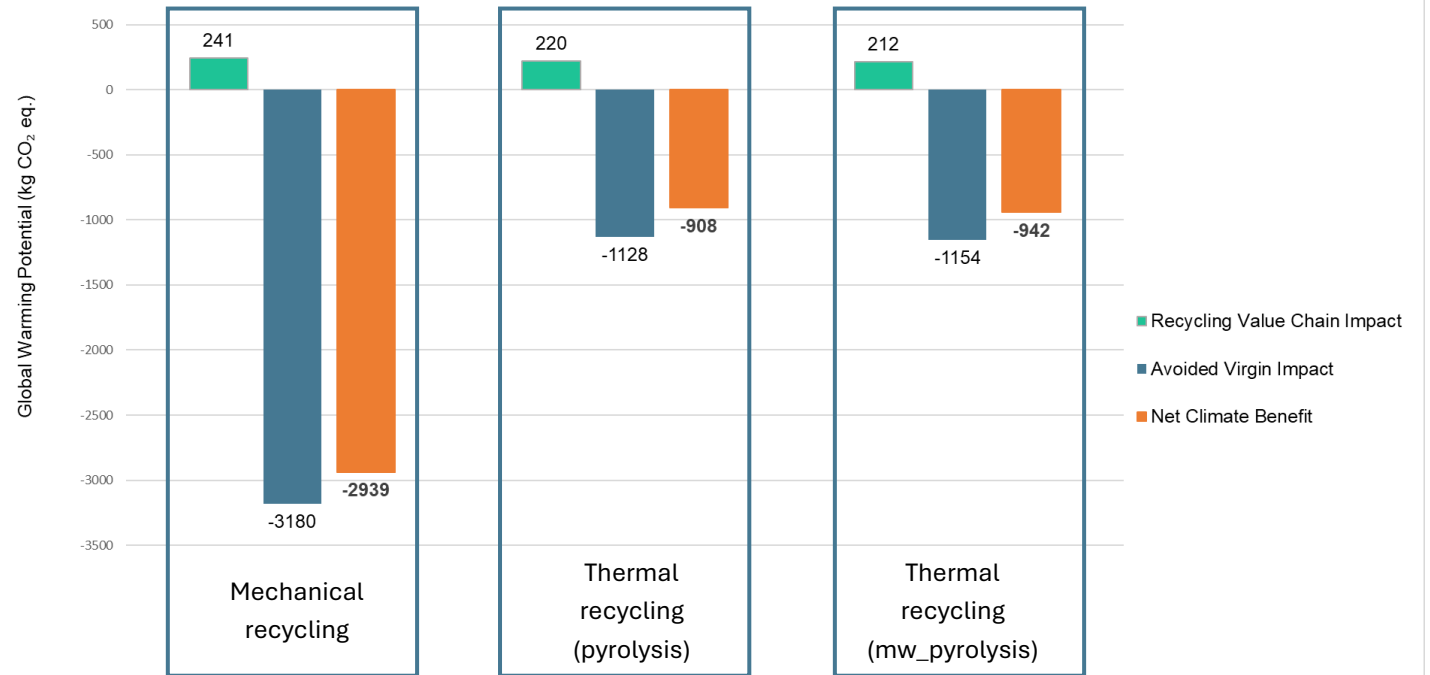
Thermal routes also deliver substantial net reductions

- 908 kg CO₂eq - pyrolysis

- 942 kg CO₂eq – mw_pyrolysis

Recycled materials substitute **virgin glass and carbon fibers**.

Environmental Performance of REFRESH Recycling Value Chains



Refresh Recycling Value Chains

Benefits calculated assuming equivalent output across all value chains. Net Climate Benefit = Avoided Virgin Impact + Process Impact.

By-product environmental credits are not included. Actual benefits would be even higher when accounting for by-product substitution effects.

Construction Use Case-to be done in 2026



Pultruded Profiles



Recycled wind blade panels

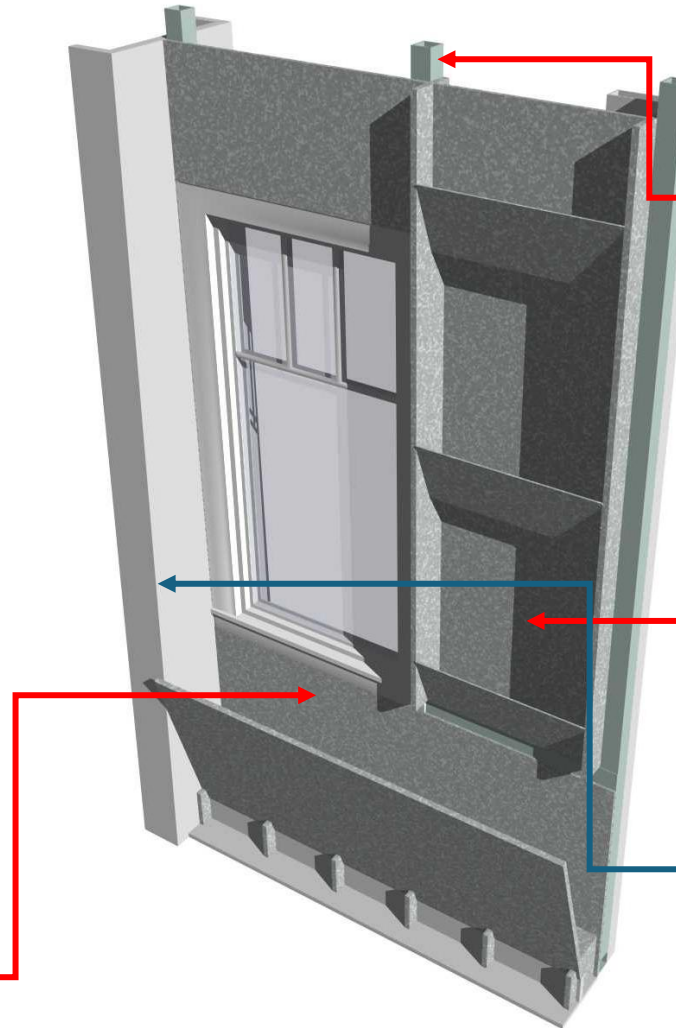


Structural profiles cut
from wind blades



Recycled GF from pyrolysis

Glass fiber insulation



EuCIA and REFRESH

EuCIA leads Work Package 7: Dissemination, Communication & Exploitation

In the final year of the project our primary goals are:

- **Communication & dissemination of the project's results, the technologies developed and their industrialisation potential**
- **Engagement of key stakeholders throughout Europe**
- **Raising awareness of REFRESH as a demonstrator of composites circularity**

How to help?

- **Follow our social channels – like, share, comment!**
- **Help connect the project partners with potential business opportunities**
- **Let us know if you need further information about the project and its results**





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