An overview of composite recycling in the wind energy industry

Wind turbine blades are made up of composite materials that boost the performance of wind energy by allowing lighter and longer blades. Today 2.5 million tonnes of composite material are in use in the wind energy sector.

The wind industry is committed to sustainable waste management in line with the multi-step approach put forward by the EU. In this approach waste prevention is regarded as the most favourable option followed by repurposing, recycling and disposal.

Wind turbines already have a recyclability rate of 85% to 90%. Most components of a wind turbine – the foundation, tower, components of the gear box and generator – are recyclable and are treated as such. Wind turbine blades represent a specific challenge due to the complex nature of materials used to manufacture them.

15,000 wind turbine blades will be decommissioned in the next five years. Dealing with this significant volume requires logistical and technological solutions for the collection, transportation and waste management of the relevant material.

Today composite materials are commercially recycled through cement co-processing. Further development and industrialisation of alternative technologies like solvolysis and pyrolysis will provide the wind industry with additional solutions for end-of-life.

The EU must prioritise R&I funding to diversify and scale up recycling technologies as part of the next R&I framework programme, Horizon Europe. This is critical to Europe's technology leadership as we embark on a global sustainable energy transition.

In parallel, national governments should harmonise their implementation of EU regulations on waste treatment to help develop a pan-European market for recycled composites.

Recommendations for policymakers: research and innovation focus

Composite recycling technologies of existing blades

Provide funding for a research study comparing the economic viability of new recycling technologies, including market barriers associated with different end-uses;

Set up a large-scale demonstration facility to industrialise and scale up new recycling solutions for wind turbine blades;

Provide funding to support new manufacturing processes using recycled materials from blades in other sectors;

Establish a European cross sectorial platform (including the building, transportation and energy sectors) to share best practices in recycling composites.

Development of new materials for blades

Earmark R&I funding for the development of new high-performance materials that are more easily recyclable;

Support a demonstration facility to test and integrate newly developed sustainable materials into next generation wind turbine blades;

Fund research into "smart" materials with embedded sensors to enable material health monitoring and health forecasting capabilities;

Establish a full-scale demonstrator of a next generation wind turbine using "smart" materials that help optimise maintenance and increase lifetime.

ETIPWind®, the European Technology and Innovation Platform on Wind Energy, connects Europe's wind energy community. Key stakeholders involved in the platform include the wind energy industry, political stakeholders and research institutions.

The ETIPWind was established in 2016 to inform Research & Innovation policy at European and national level. ETIPWind provides a public platform to wind energy stakeholders to identify common Research & Innovation (R&I) priorities and to foster breakthrough innovations in the sector.

Its recommendations highlight the pivotal role of wind energy in the clean energy transition. They inform policymakers on how to maintain Europe's global leadership in wind energy technology so that wind delivers on the EU's Climate and Energy objectives. As such, the platform will be key in supporting the implementation of the Integrated SET-Plan.

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Sources: Bax & Company (2017), Cefic, ECP4 (2018), EMIRI (2019), ETIPWind (2018), EUCIA (2019), EuPC, PlasticsEurope, WindEurope (2019), Windpower engineering & development (2019).

Acronyms:
ETIPWind: European Technology & Innovation Platform on Wind Energy
FRP: Fibe Reinforced Polymer
PE: Polyethylene
PET: Polyethylene Terephthalate
PMI: Polymethacrylimide
PUR: Polyurethene
PVC: Polyvinyl Chloride
R&I: Research & Innovation
TRL: Technology Readiness Level

For more information check the ETIPWind website under https://etipwind.eu/publications/

ETIP Wind
EUROPEAN TECHNOLOGY & INNOVATION PLATFORM ON WIND ENERGY

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HOW WIND IS GOING CIRCULAR
blade recycling

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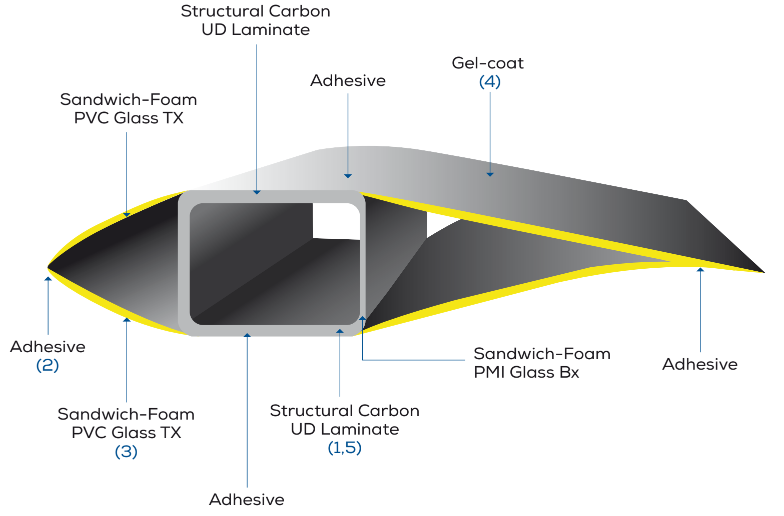
Blade composition and upcoming volumes of composite waste in the industry

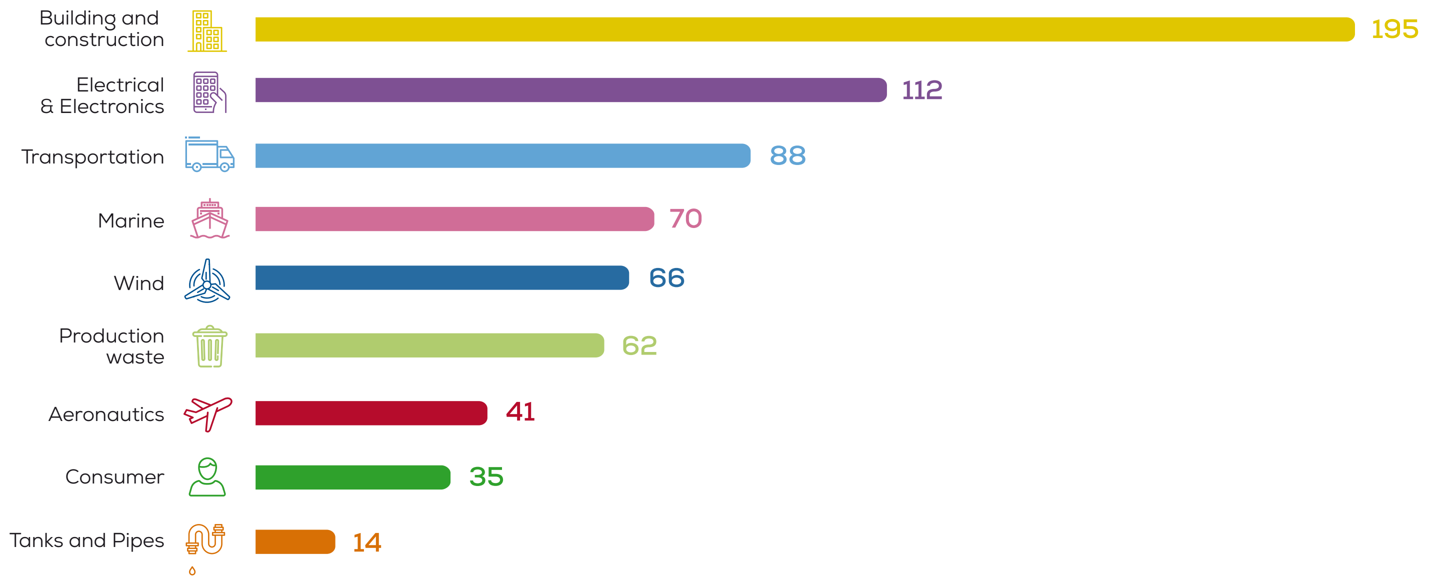
Generic composition of a wind turbine blade



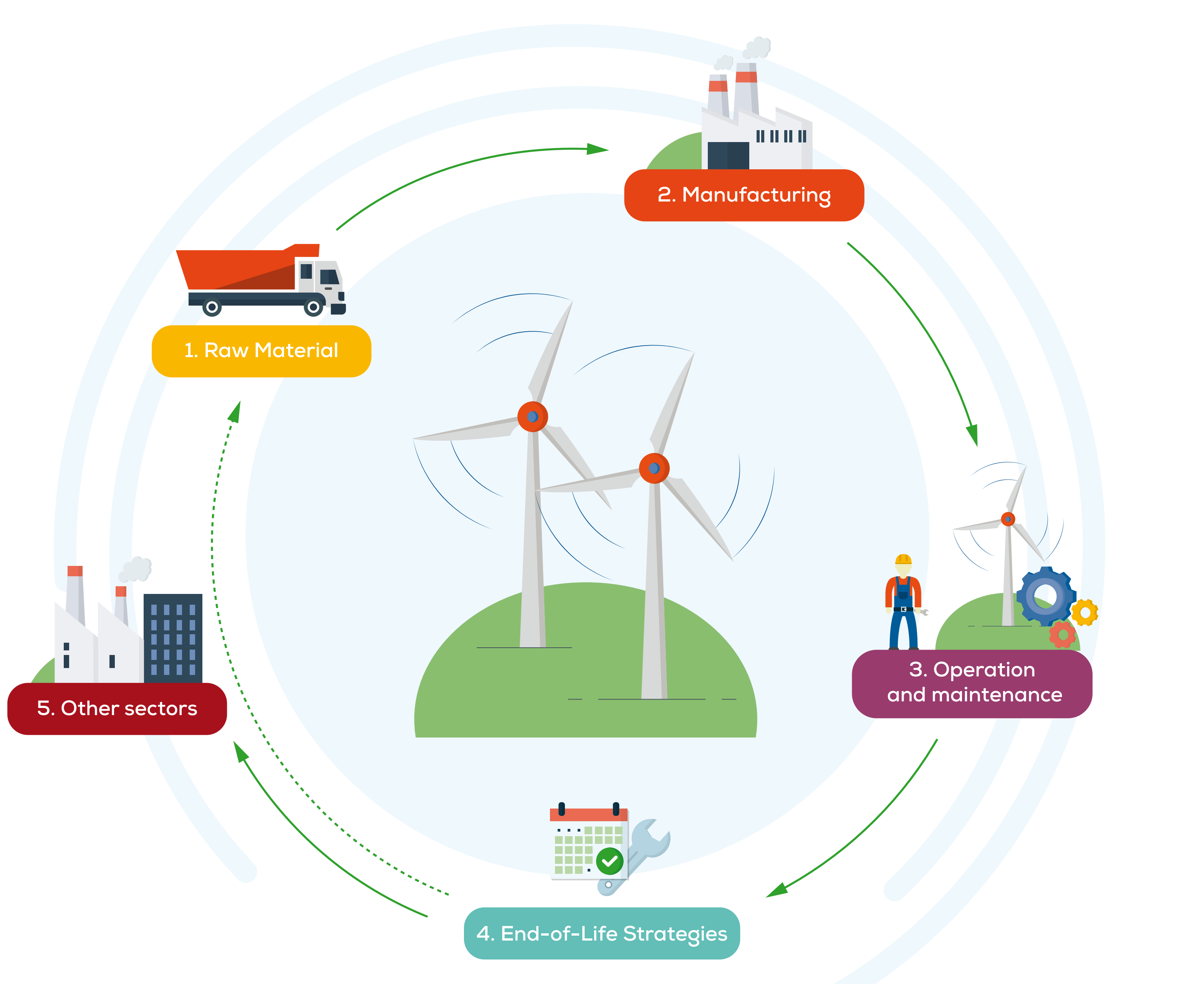
Wind turbine blades are considered a composite structure, consisting of various materials with different properties. The material compositions vary between blade types and blade manufacturers, but blades are generally made of:

1) **Reinforced fibres** (glass, carbon, aramid or basalt)
2) **A polymer matrix** (thermosets such as epoxies, polyesters, vinyl esters, polyurethane, or thermoplastics)
3) **A sandwich core** (balsa wood or foams such as polyvinyl PVC, PET)
4) **Coatings** (PE, PUR)
5) **Metals** (copper wiring, steel bolts, etc.).

Estimated composite waste per sector in thousands of tonnes in 2025

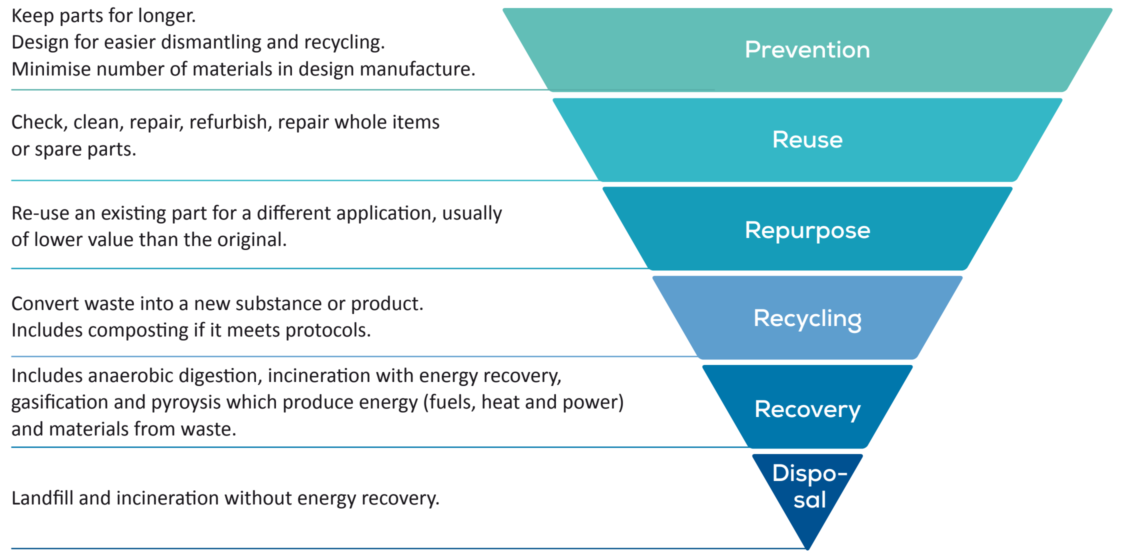


The life cycle of a wind turbine blade

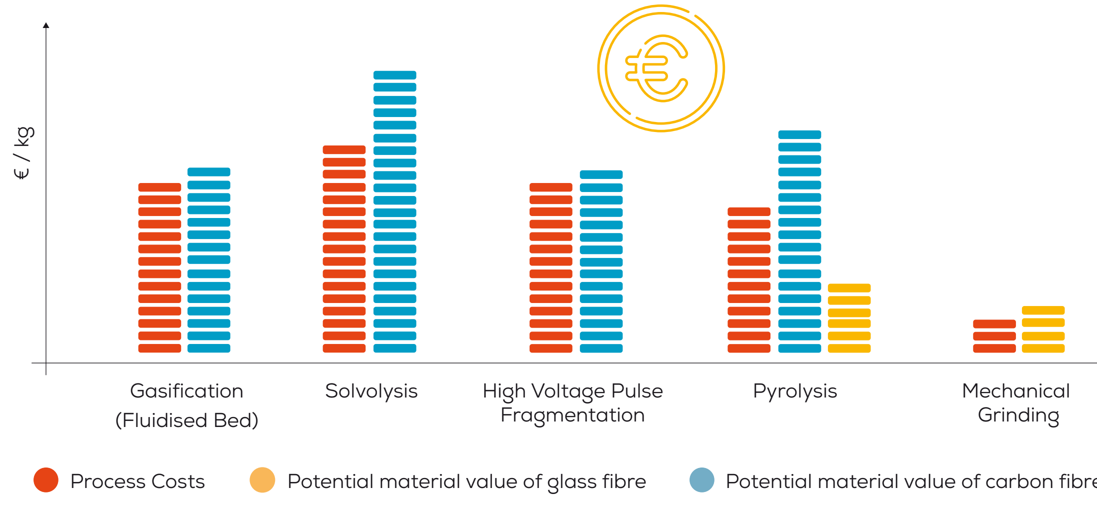


End-of-Life strategies for composite materials

Waste treatment hierarchy



Estimated relative costs and values of composite recycling technologies

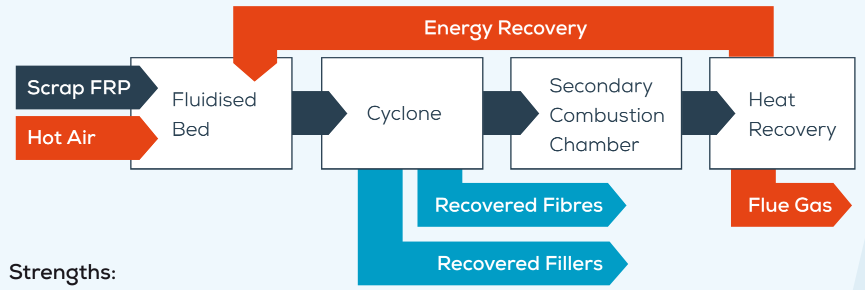


The size of the bars is indicative and varies among EU recyclers using the same process due to varying process parameters such as throughput rates/capacity, temperature/pressure and retention time in the reactor.

Composite recycling technologies and technology readiness level (TRL)

Gasification (Fluidised Bed)

Current TRL 5/6



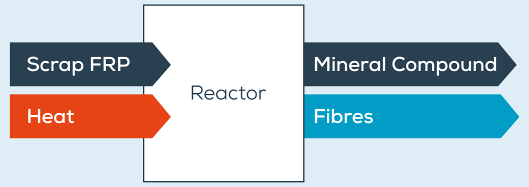
Strengths:
- Highly flexible and simple process;
- Recovery of energy and potential precursor chemicals;
- High efficiency of heat transfer.

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



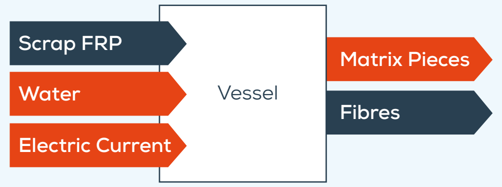
Strengths:
- Recovery of clean fibres in their full length;
- Recovery of resin which can be re-used.

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



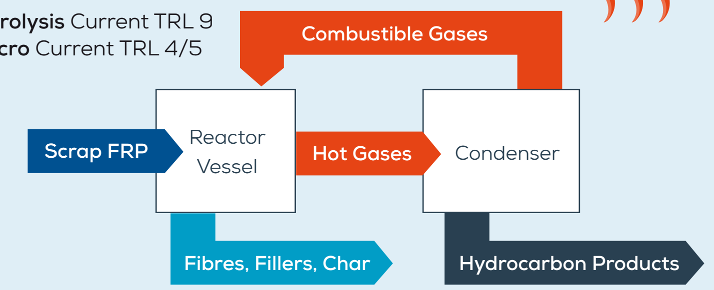
Strengths:
- Scalable to treat large amounts of waste;
- Low investments required to reach the next TRL.

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



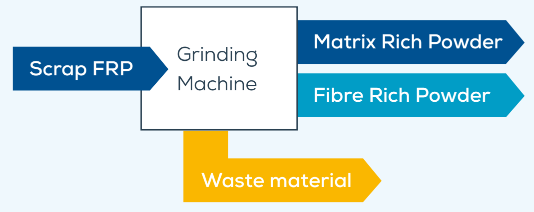
Strengths:
- Pyrolysis gas and oil can be used as energy source in the same process or in chemicals production;
- Easily scaled up;
- Microwave Pyrolysis: easier control. Lower damage to the fibre.

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.

Mechanical Grinding

GFRP Current TRL 9
CFRP Current TRL 6/7



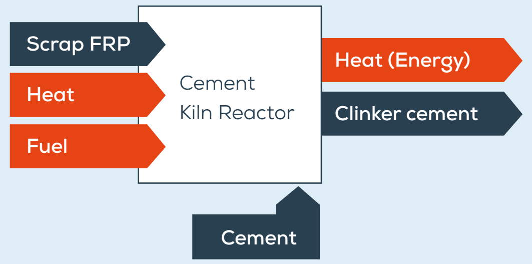
Strengths:
- Efficient and high throughput rates.

Limitations:
- Cost efficiency;
- Low quality of recyclate. High content of other materials;
- Up to 40% material waste.

Point of attention:
- Requires dedicated facilities with closed protective area to limit environmental impacts.

Co-Processing

Current TRL 9



Strengths:
- Highly efficient, fast and scalable;
- Large quantities can be processed;
- No ash left over.

Limitations:
- Loss of original material form;
- Additional energy needed to reach high processing temperatures.

Point of attention:
- Pollutants and particulate matter emissions.