**Recommendations for policymakers:**

**Research and innovation focus**

- **Composite recycling technologies of existing blades**
  - Provide funding for research and development 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 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 foster突破 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 European 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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**Content coordinator:** Sabina Potestio

**Design by:** www.formas dopossivel.com


**Acronyms:**

- ETIPWind: European Technology & Innovation Platform on Wind Energy
- FRP: Fibre Reinforced Polymer
- PE: Polyethylene
- PET: Polyethylene Terephthalate
- PMI: Polymethylacrylimide
- PUR: Polyurethane
- PVC: Polyvinyl Chloride
- R&I: Research & Innovation
- TRL: Technology Readiness Level

**For more information check the ETIPWind website under [https://etipwind.eu/publications/](https://etipwind.eu/publications/)**

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**How wind is going circular**

Blade recycling

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 reusing, recycling and disposal.

Wind turbines already have a recycling rate of 85% to 90%. Most components of a wind turbine—the foundation, tower, gear box and generator—are recyclable and are treated as such. Wind turbine blades represent a new 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 materials.

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 as waste treatment to help develop a pan-European market for recycled composites.
### Blade composition and upcoming volumes of composite waste in the industry

**Generic composition of a wind turbine blade**

- **Most turbine blades are an ordered composite structure, consisting of various materials with different properties. The external structure consists of either glass or carbon fibres, and these are consolidated into a laminate by applying resins such as epoxies or vinyl esters.**

<table>
<thead>
<tr>
<th>Material</th>
<th>Composition</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibres</td>
<td>UD Laminate</td>
<td>Wind turbine blades</td>
</tr>
<tr>
<td>Fillers</td>
<td>PMI Glass</td>
<td>Wind turbine blades</td>
</tr>
<tr>
<td>Adhesives</td>
<td>PE, PUR</td>
<td>Wind turbine blades</td>
</tr>
<tr>
<td>Core materials</td>
<td>Thermoplastic</td>
<td>Wind turbine blades</td>
</tr>
<tr>
<td>Structural carbon</td>
<td>UD Laminate</td>
<td>Wind turbine blades</td>
</tr>
<tr>
<td>Glass TX</td>
<td>UD Laminate</td>
<td>Wind turbine blades</td>
</tr>
<tr>
<td>Adhesives</td>
<td>PMI Glass</td>
<td>Wind turbine blades</td>
</tr>
</tbody>
</table>

**Estimated composite waste per sector in thousands of tonnes in 2025**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Waste (thousand tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building and Construction</td>
<td>62</td>
</tr>
<tr>
<td>Black &amp; Electricals</td>
<td>60</td>
</tr>
<tr>
<td>Transportation</td>
<td>66</td>
</tr>
<tr>
<td>Wind</td>
<td>41</td>
</tr>
<tr>
<td>Production</td>
<td>35</td>
</tr>
<tr>
<td>Consumer</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>252</td>
</tr>
</tbody>
</table>

### The life cycle of a wind turbine blade

1. **New Production**
   - Manufacturing
   - Transportation
   - Operation

2. **Operation and maintenance**
   - Gasification (Fluidised Bed)
   - Mechanical Grinding

3. **End-of-Life Strategies**
   - Pulverization
   - Pyrolysis
   - Mechanical Grinding
   - Co-processing

### Waste treatment hierarchy

- **Prevention**
- **Reduce**
- **Reuse**
- **Recover**
- **Disposal**

### Composite recycling technologies and technology readiness level (TRL)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Current TRL</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasification (Fluidised Bed)</td>
<td>9</td>
<td>Current TRL: 9/10. Requires dedicated facilities with closed protective area.</td>
</tr>
</tbody>
</table>

### Estimated relative costs and values of composite recycling technologies

- **Costs:**
- **Material value:**
- **Energy recovery:**

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**Point of attention:**

- Not yet economically viable.
- Additional energy needed to reach high processing temperatures.
- Fibre product may retain oxidation residue or char.
- Recovery of low-quality material.
- Fluidised bed can locally collapse.
- High efficiency of heat transfer.
- Recovery of energy and potential precursor chemicals.
- Highly flexible and simple process.
- Large amounts of solvents required.
- High energy consumption due to the high-temperature process.
- Loss of original material form.
- No ash left over.
- Low quality of recyclate. High content of other materials.

**Strengths:**

- Highly efficient and fast, scalable.
- Large quantities can be processed.
- No ash left over.
- Additional energy needed to reach high processing temperatures.
- Potential of the technology.
- Hot air, microwave, and high-voltage technologies.

**Limitations:**

- Requires dedicated facilities with closed protective area.
- High investment required to reach the next TRL.
- Low efficiency; low energy consumption due to the high-temperature process.
- Low energy consumption due to the low-temperature process.
- High efficiency of heat transfer.
- Recovery of energy and potential precursor chemicals.
- Highly flexible and simple process.
- Large amounts of solvents required.
- High energy consumption due to the high-temperature process.
- Loss of original material form.
- No ash left over.
- Low quality of recyclate. High content of other materials.

**Potential leaks of gases from waste treatment chambers.**

**Preparation:**

- High efficiency of heat transfer.
- Recovery of energy and potential precursor chemicals.
- Highly flexible and simple process.
- Large amounts of solvents required.
- High energy consumption due to the high-temperature process.
- Loss of original material form.
- No ash left over.
- Low quality of recyclate. High content of other materials.

**Potential of the technology:**

- Hot air, microwave, and high-voltage technologies.