ETIP Wind

EUROPEAN TECHNOLOGY & INNOVATION
PLATFORM ON **WIND ENERGY**

Webinar-Blade recycling and innovative materials for new blade designs

September 2019

etipwind.eu

Supported by:

European Commission

Disclaimer:

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Project details:

Duration:
Jan 2019 - Dec 2021 (36 Months)
Grant agreement:
No: 826042

Got a question?

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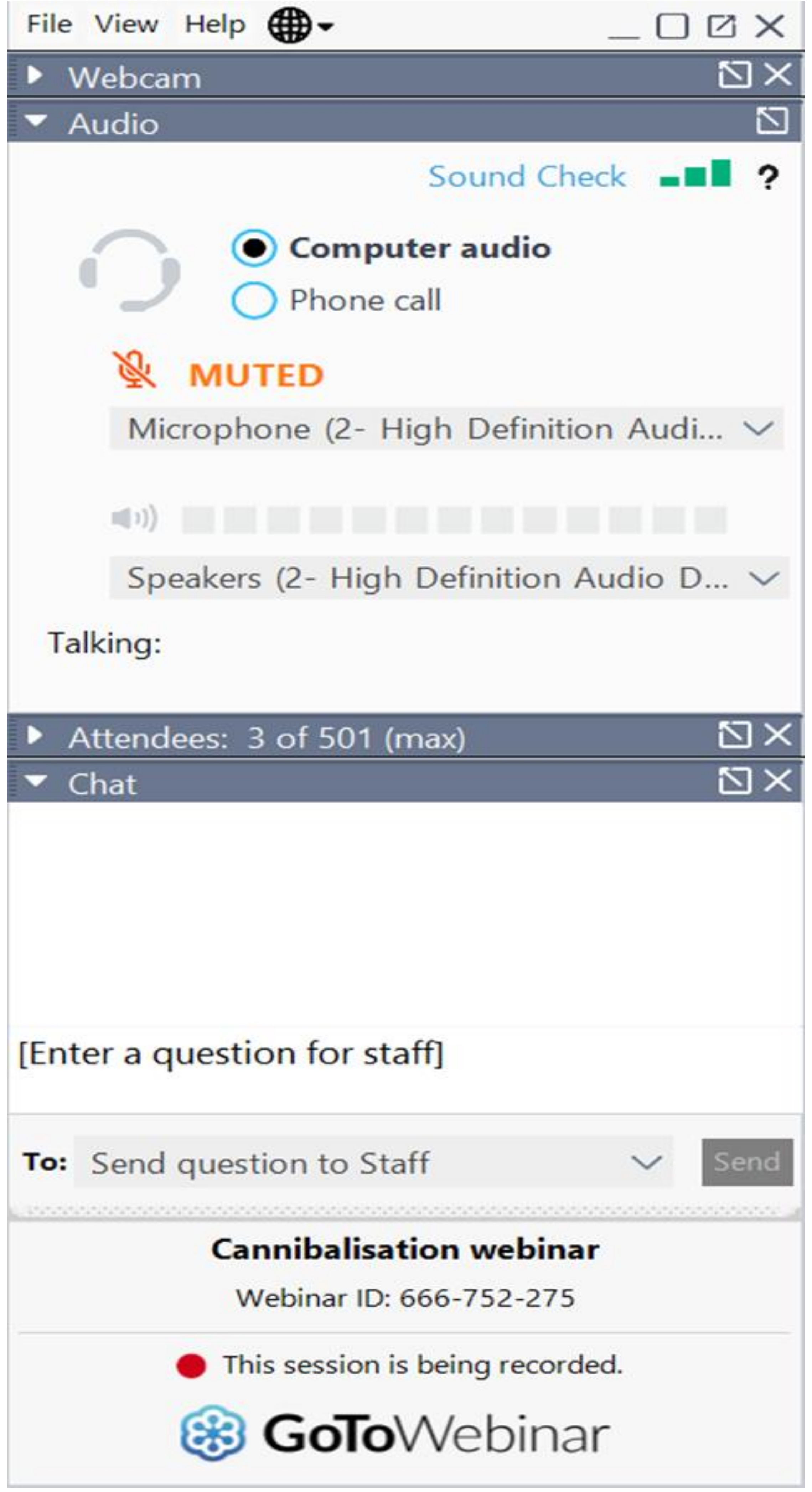

Agenda

Time	Topic
11:00 – 11:05	Introduction- Aidan Cronin, Siemens Gamesa & ETIPWind chair
11:05 – 11:15	Overview of composite material use in wind energy and other sectors- Thomas Wegman, EUCIA
11:15 – 11:30	Blades: composition, manufacturing and future design- John Korsgaard, LM Wind
11:30 – 11:45	Innovative materials for new blade design- Johanna Reiland, Bax & Company
11:45 – 12:00	How to recycle composite materials from wind turbine blades- Olga Rodriguez Largo, CSIC
12:00 – 12:10	ETIPWind factsheet When wind goes circular: blade recycling- Sabina Potestio, WindEurope
12:10 – 12:30	Questions & Answers

Recycling Composites:
Integral Part of Wind Turbine Blade Life Cycle

Thomas Wegman

Wind Europe Wind Turbine Circularity Webinar

September 19th, 2019

EuCIA
European Composites Industry Association

we know | we show | we grow
THE WORLD OF COMPOSITES

EuCIA – European Composites Industry Association

We know, we show, we grow the world of Composites

- Representing large number of national European trade associations and key sector associations in Composites
- Active at EU Commission level and supporting decision making
- Promoting solutions for Composites sustainability and recycling
- Growing Composites markets and applications across Europe

EuCIA
European Composites Industry Association

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THE WORLD OF COMPOSITES

Composites Bring Performance and Sustainability

- Enabling technology for wind turbines: freedom of shape, low weight, durability
- Key for optimizing conversion efficiency and increasing turbine power output
- Manufacturing footprint outweighed in major way by sustainable energy generated during turbine life

EuCIA
European Composites Industry Association

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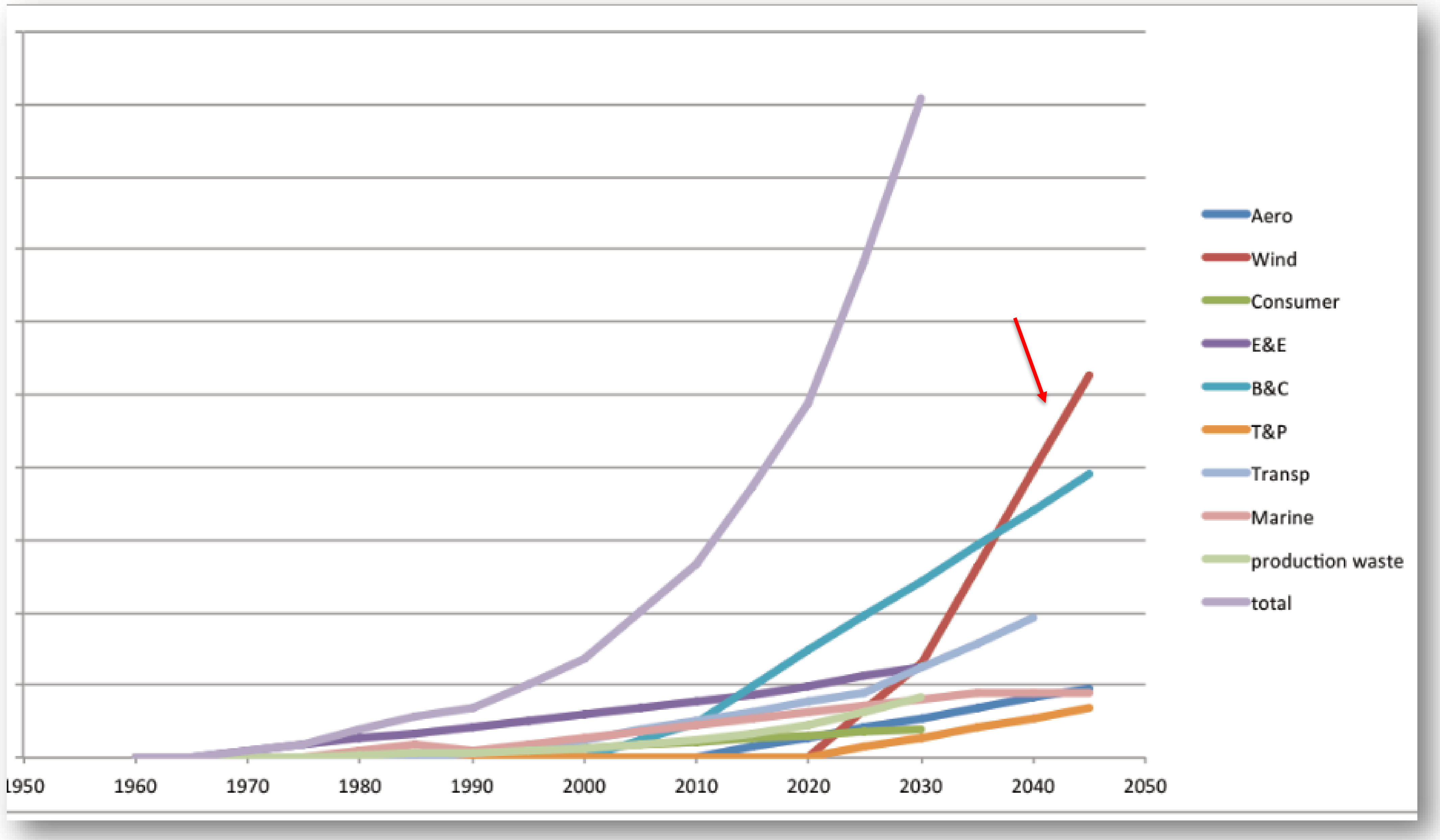
Waste from Wind Turbine Blades Predicted to Grow Significantly

- EuCIA is developing model based on GDP growth, application start, life expectation
- Different dynamics per industry and end-use market
- Still work in progress: data validation is ongoing with different stakeholders
  - Wind Europe, ICOMIA, others
- Composite waste only fraction of total waste streams



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Recycling through Cement Co-Processing is Commercial at Industrial Scale

- Re-use of valuable raw materials plus energy recovery: reduction of CO_2 footprint
- Easy to manage regrind, also in scale up
- Economically viable at present
  - Process in operation at Neowa (Bremen) and Holcim (Lägersdorf)
- So far only suitable for glass reinforced composites
- Early studies indicate positive LCA effects
- Desire to better recuperate composite waste stream
  - Combine into larger quantities

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Size Reduction On-Site vs. Size Reduction at Recycling Operation

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From Parts to Small Chunks to Cement

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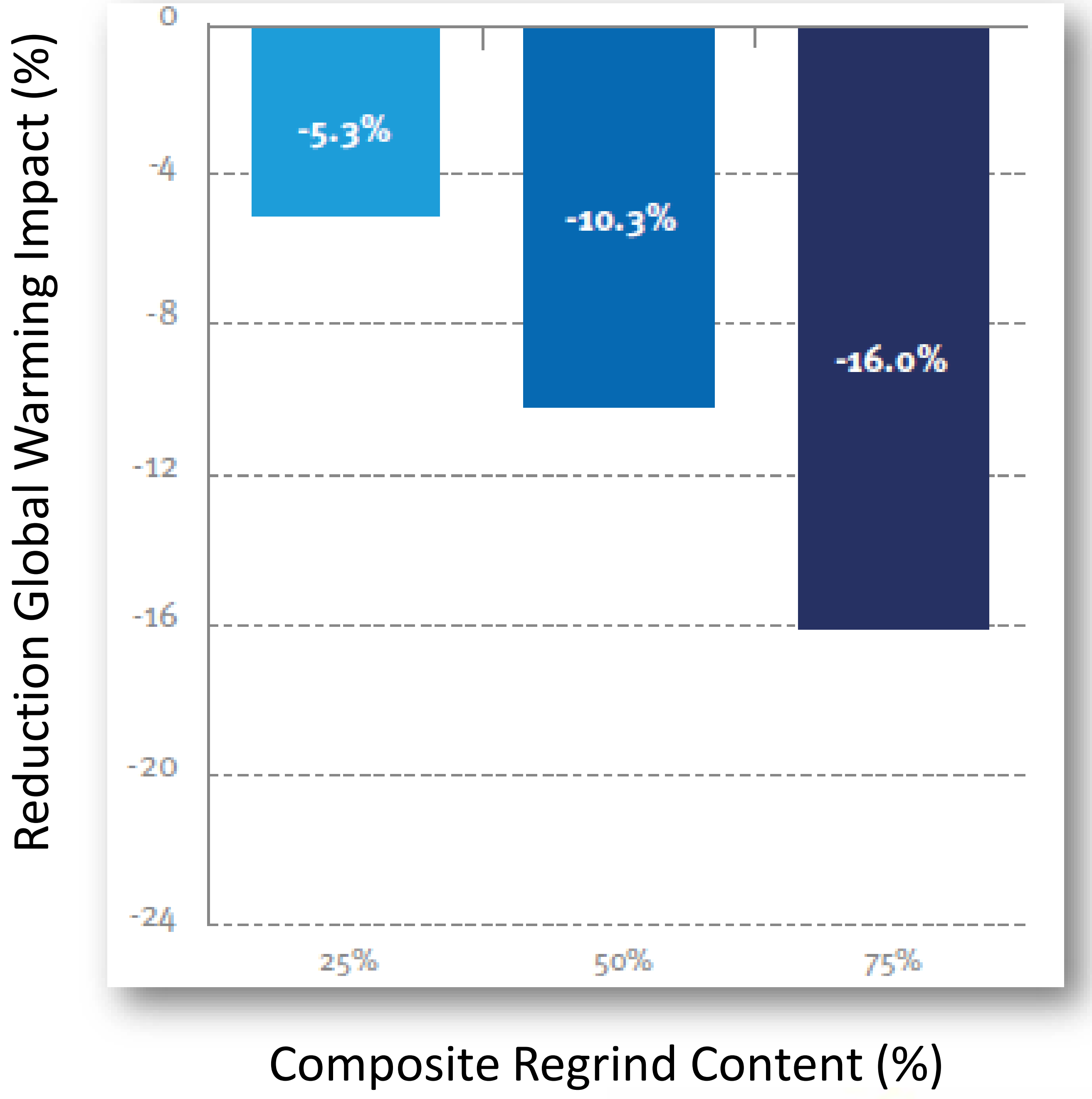
Enabling Reduction Carbon Footprint Cement Manufacturing

- Model developed with ETH in Zürich
  - Reviewed by industry experts
- Analysis carried out by Holcim and DSM LCA experts
- Composite recycling through co-processing in cement clinker manufacturing
  - Partially replacing coal and raw materials by glass-reinforced composites
- Significant emission reduction using glass reinforced composite: 0.9 kg CO_2-eq/kg composite



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Mechanical Recycling Well Established, Yet Small in Volume

- Conversion of composite parts and components into fine fibers and powders
  - Already in use for over 30 years
- Re-use as small percentage in new formulations
- Also use in non-traditional Composites applications, with positive LCA effect
- Knowledge built up through Ercom experience
  - Commercial recycling company ~25 years in operation
- Difficult to manage powders and fibers: risk of creating waste
- Not competitive (yet) with use of virgin raw materials
  - E.g. in high speed thermoplastics compounding
  - Re-use in critical applications like Wind Turbine blades not envisioned

New Recycling Solutions under Investigation: e.g. Solvolysis

- Bringing back cured resins into new raw materials
- At different stage of investigation
  - Demonstrated in small scale equipment only
- Key challenge is to handle fibers
  - Ensure fiber length and properties can be maintained
- Requires separation of liquid fractions that can be reused
- Potential recycling routes for carbon fiber
  - For glass not competitive (yet) with use of virgin raw materials
- LCA impact not yet understood (likely higher energy requirement)

Limited Composite Waste Separation from General Waste in EU

Wind Turbine Blades are Positive Exception

- Opportunity in Wind Energy sector to “do things right”
- In Automotive and Electrical, composite waste is mixed with other waste streams
  - Typically combined with plastics waste stream
- Desire to make larger waste volumes available for further processing

Team up for a Sustainable Business

- Strengthen existing collaboration Wind Europe, Cefic, EuCIA and other stakeholders
  - WindEurope, Cefic and EuCIA have created a cross-sector platform to advance novel approaches to the recycling of wind turbine blades
- Develop joint approach for Composites Recycling as integral part of the life cycle of wind turbines
- Continue to demonstrate the true sustainability of our business

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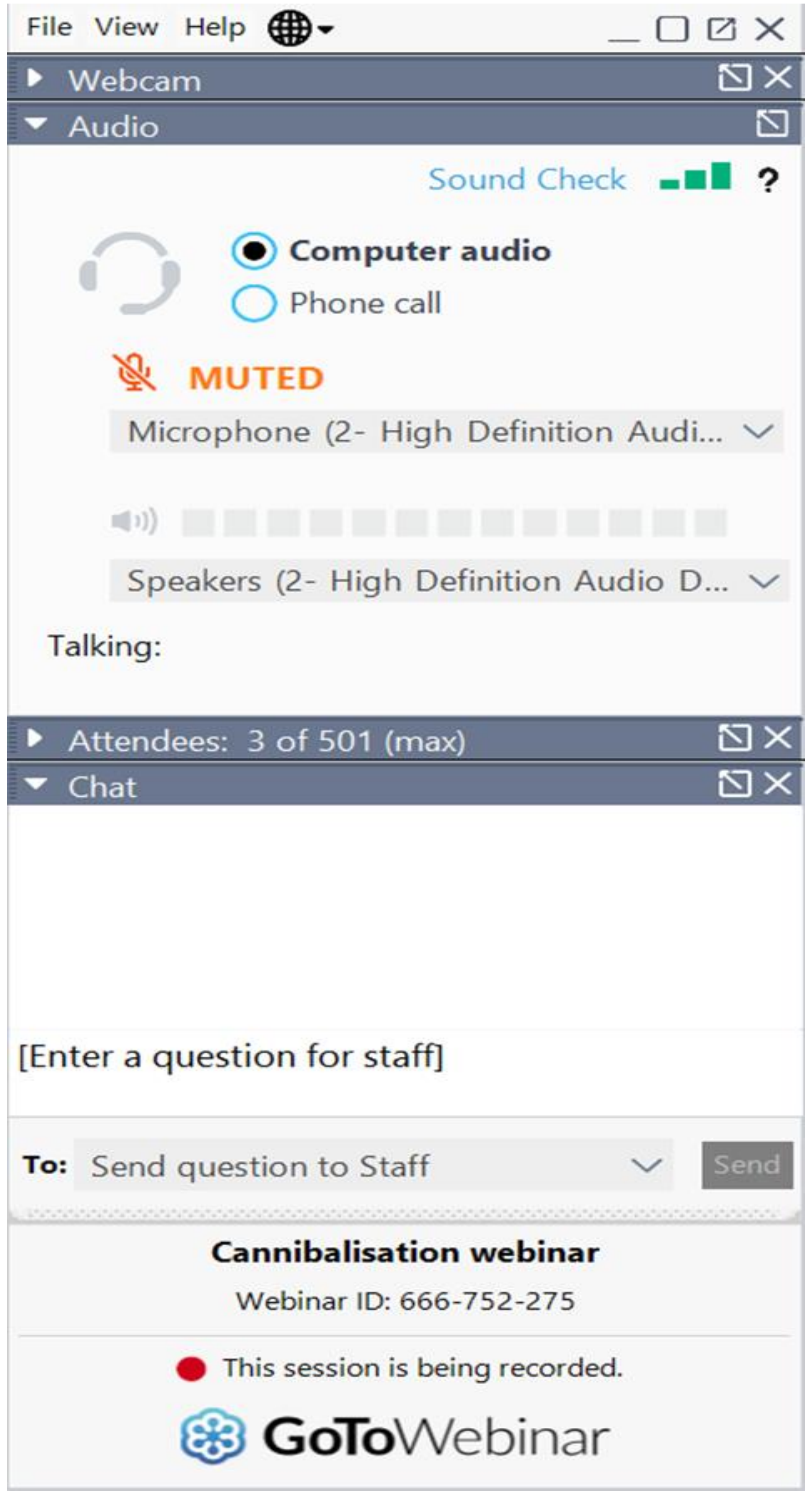


BLADES: COMPOSITION, MANUFACTURING AND FUTURE DESIGN

ETIPWind Webinar | September 19, 2019

By John Korsgaard, Senior Director, Engineering Excellence

LM WIND POWER

a GE Renewable Energy business

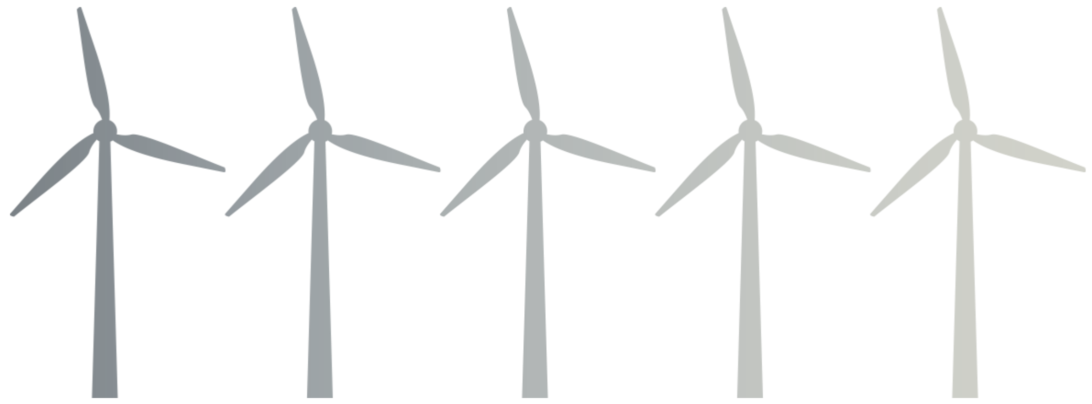
LM Wind Power

A leading blade supplier to the wind industry

LM WIND POWER
a GE Renewable Energy business

15 blade factories

13,998 people worldwide year start - 2019



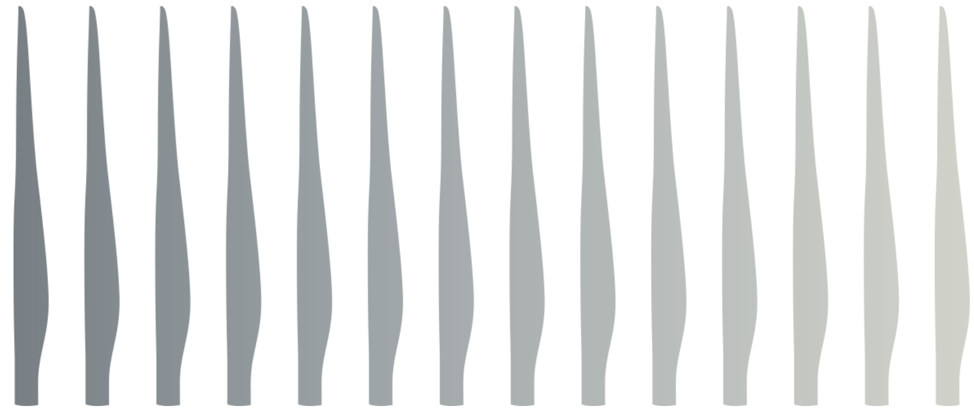
1/5 turbines in the world have LM Wind Power blades

Global capacity and supply chain

CARBON NEUTRAL FROM 2018

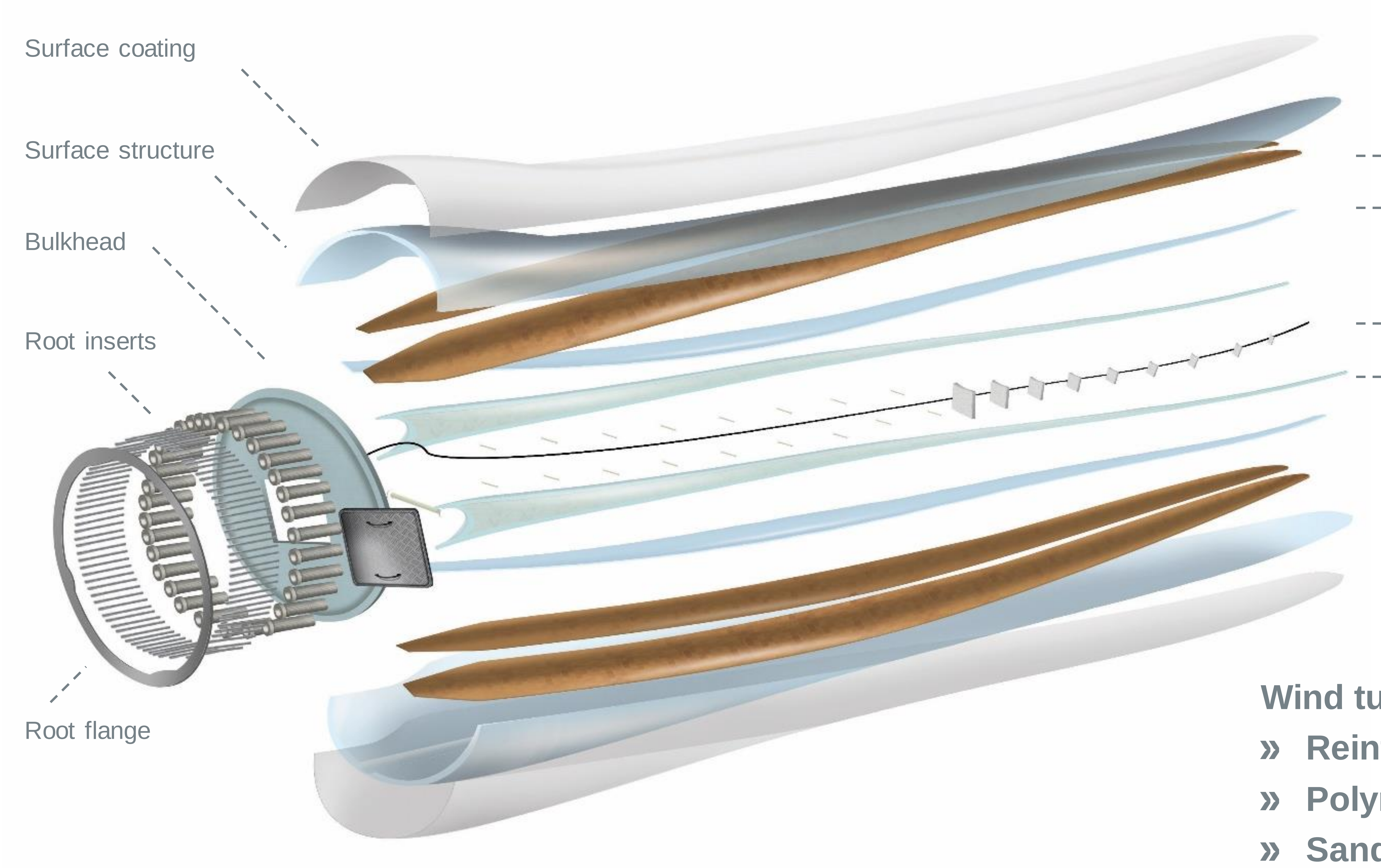
CleanLM

LEADING THE WAY FOR A CLEANER WORLD



215,000 blades produced since 1978

A wind turbine blade is a complex structure to design and manufacture



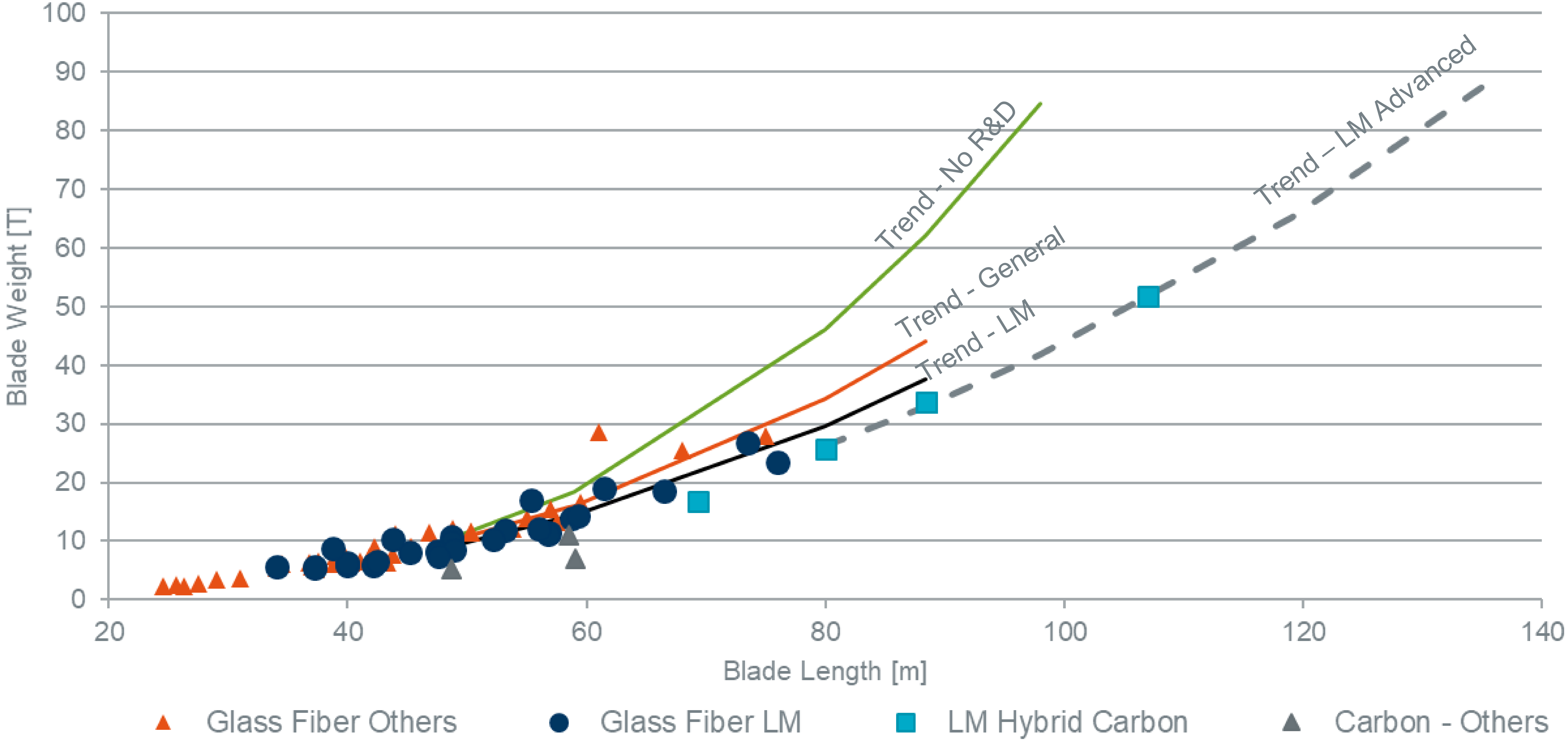
Wind turbine blade materials (typical examples)

- **Reinforcement fibres** (glass, carbon or hybrid)
- **Polymer matrix** (epoxy, vinylester, polyester)
- **Sandwich core** (balsa wood, PET, PVC)
- **Surface coating** (polyester, polyurethan)
- **Metals** (root inserts, down conductor)

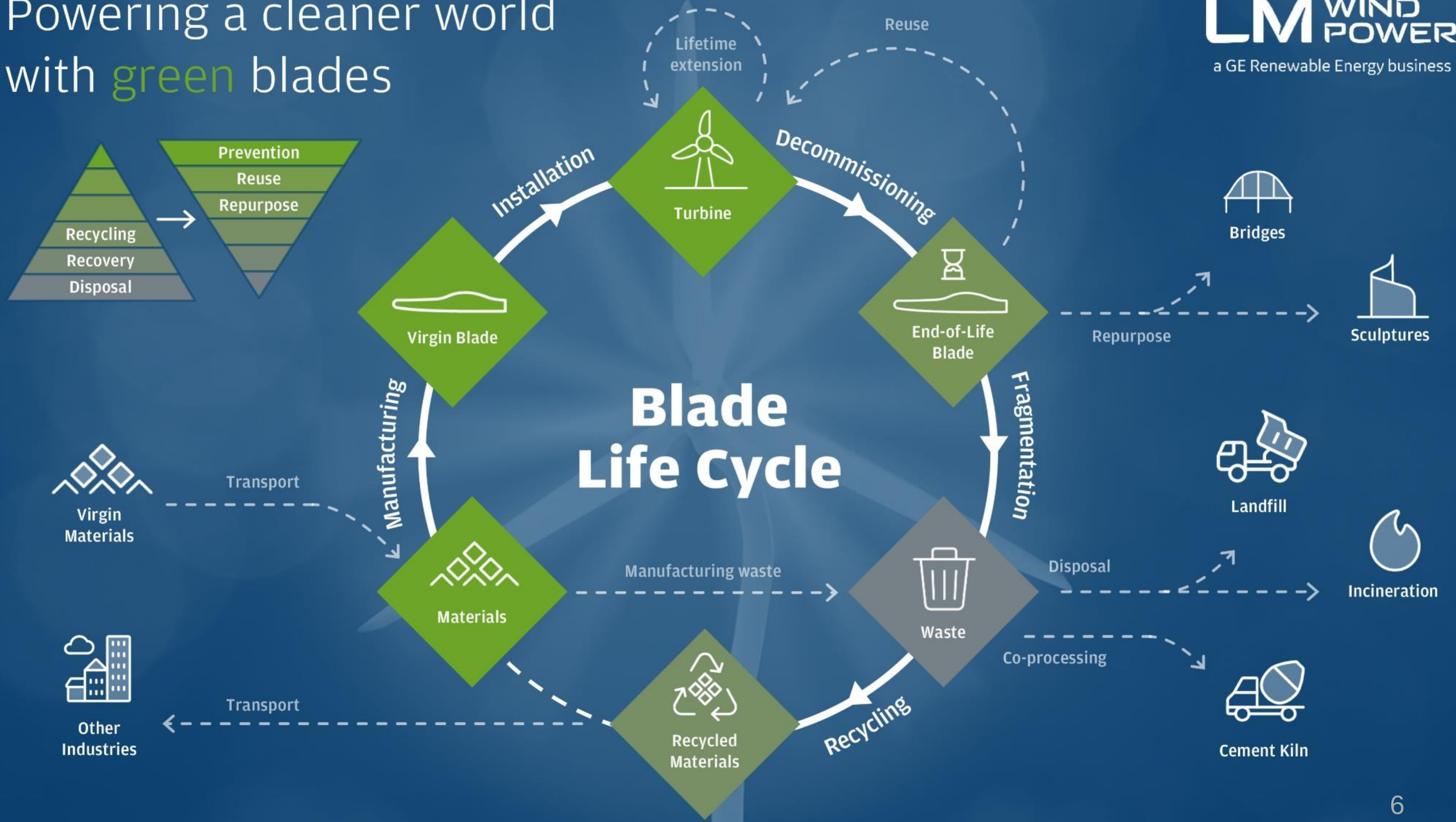
A history of breaking size records

a GE Renewable Energy business

Ultra long blades call for more advanced blade designs to keep blade mass down



Powering a cleaner world with green blades



Powering a cleaner world with green blades

LM WIND POWER
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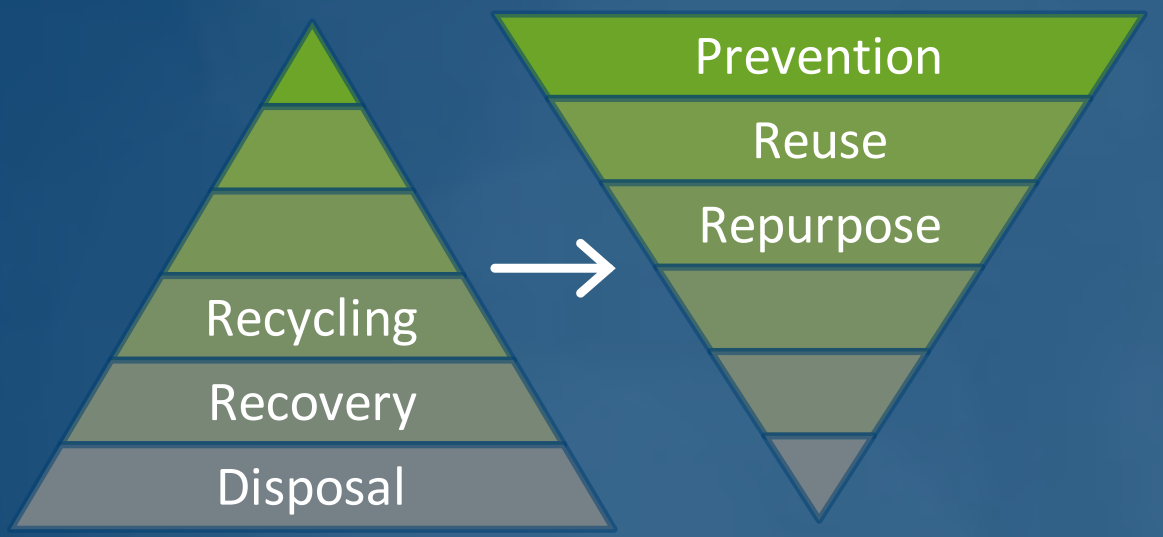
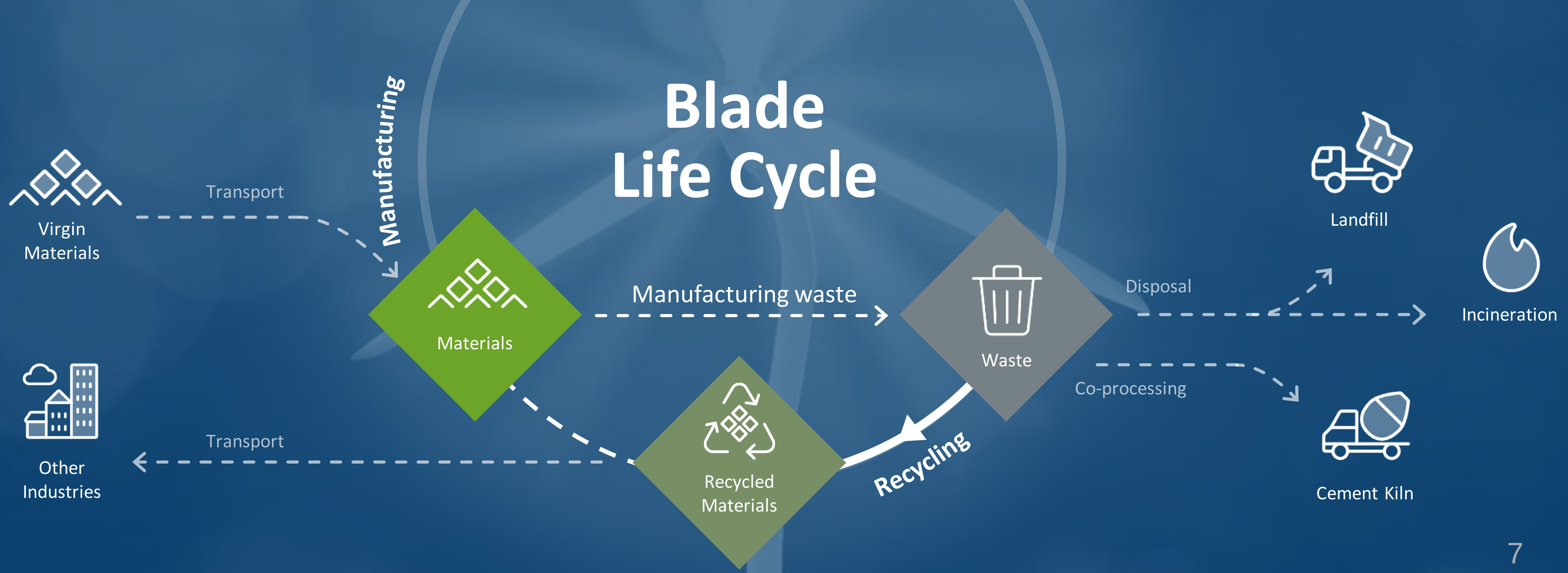
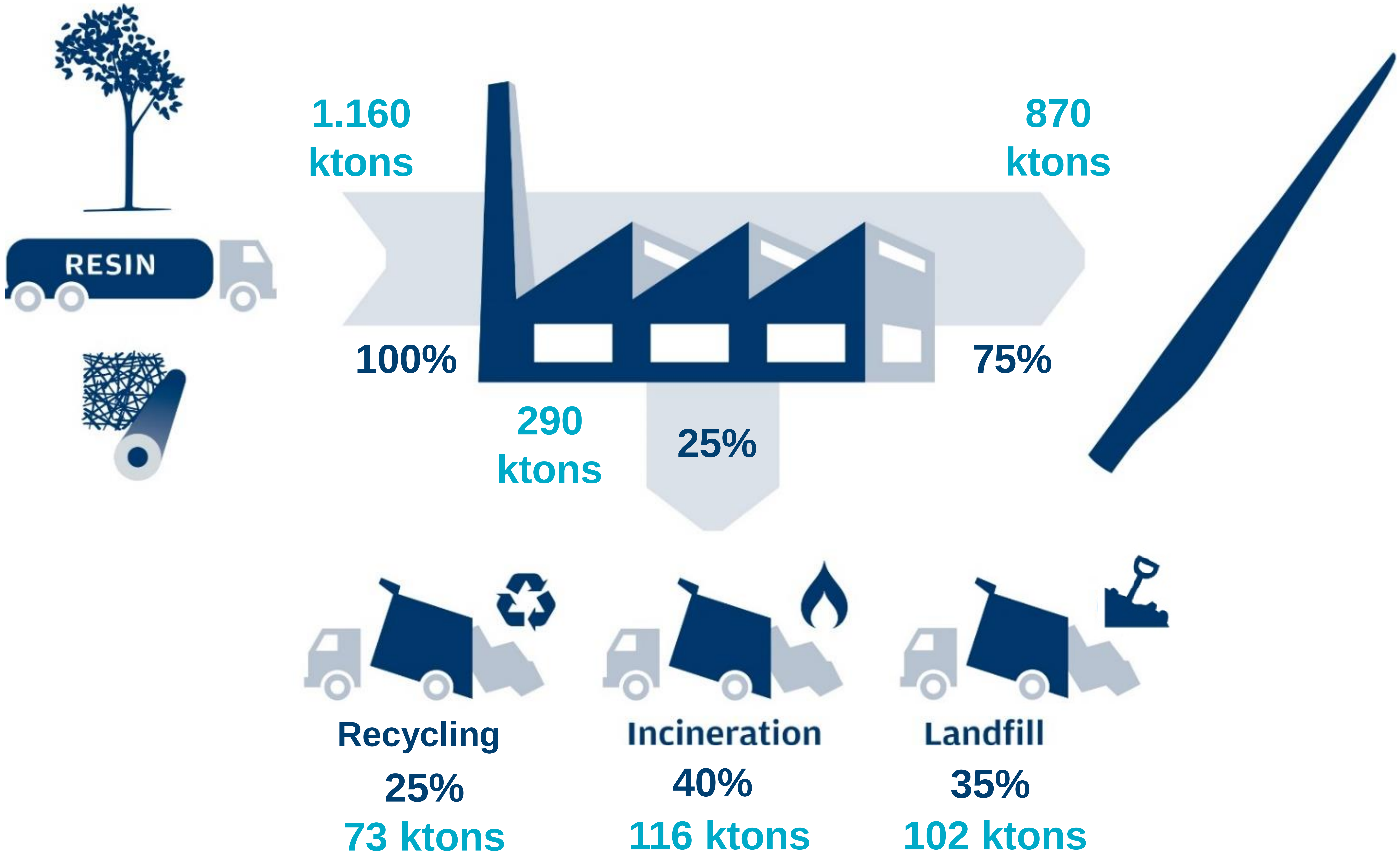




Waste reduction must occur across the full blade life cycle



Data based on:
Wind Turbine Blade Waste in 2050 by Pu Liu – 2017
LM Wind Power Sustainability Performance 2018 report

Summary

LM WIND POWER
a GE Renewable Energy business

» A wind turbine blade is a complex structure to design and manufacture

» Onshore wind turbine blades approach 80+ meters in length while Offshore blades are beyond 100+ meters

» The increasing size of wind turbine blades results in increased weight of the blades and increased challenges in the manufacturing of wind turbine blades

» Repowering and Life Extension are key enablers to achieve the EU climate and Renewable Energy objectives

» Manufacturing waste is a significant volume compared to composite waste from end-of-life blades

Thank you for your time

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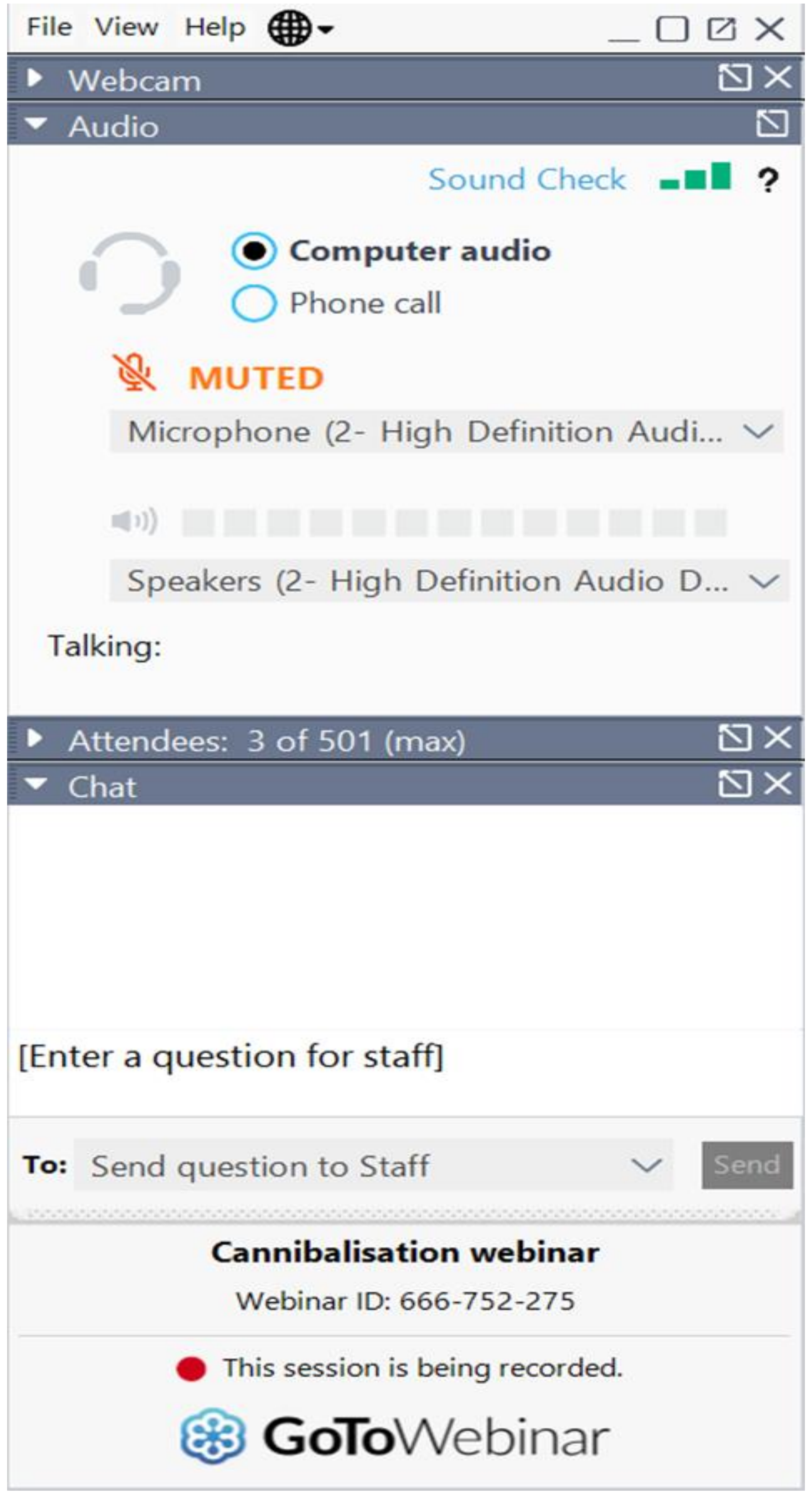

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etipwind.eu

Innovative materials for new blade design

ETIPWind Webinar; Johanna Reiland, Marcos Ierides – Bax & Company

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VALUE FROM SCIENCE AND TECHNOLOGY

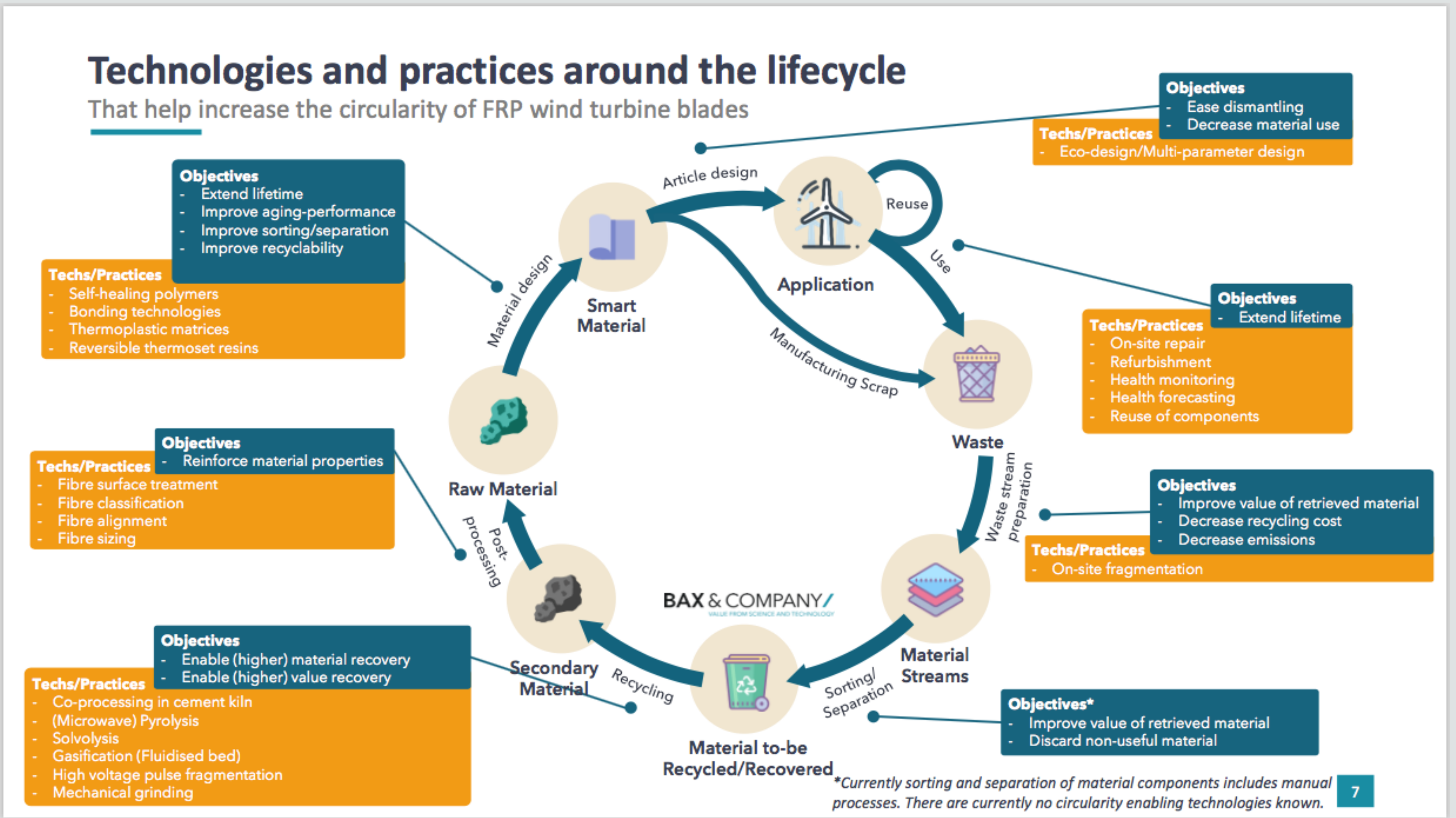
www.baxcompany.com

Content

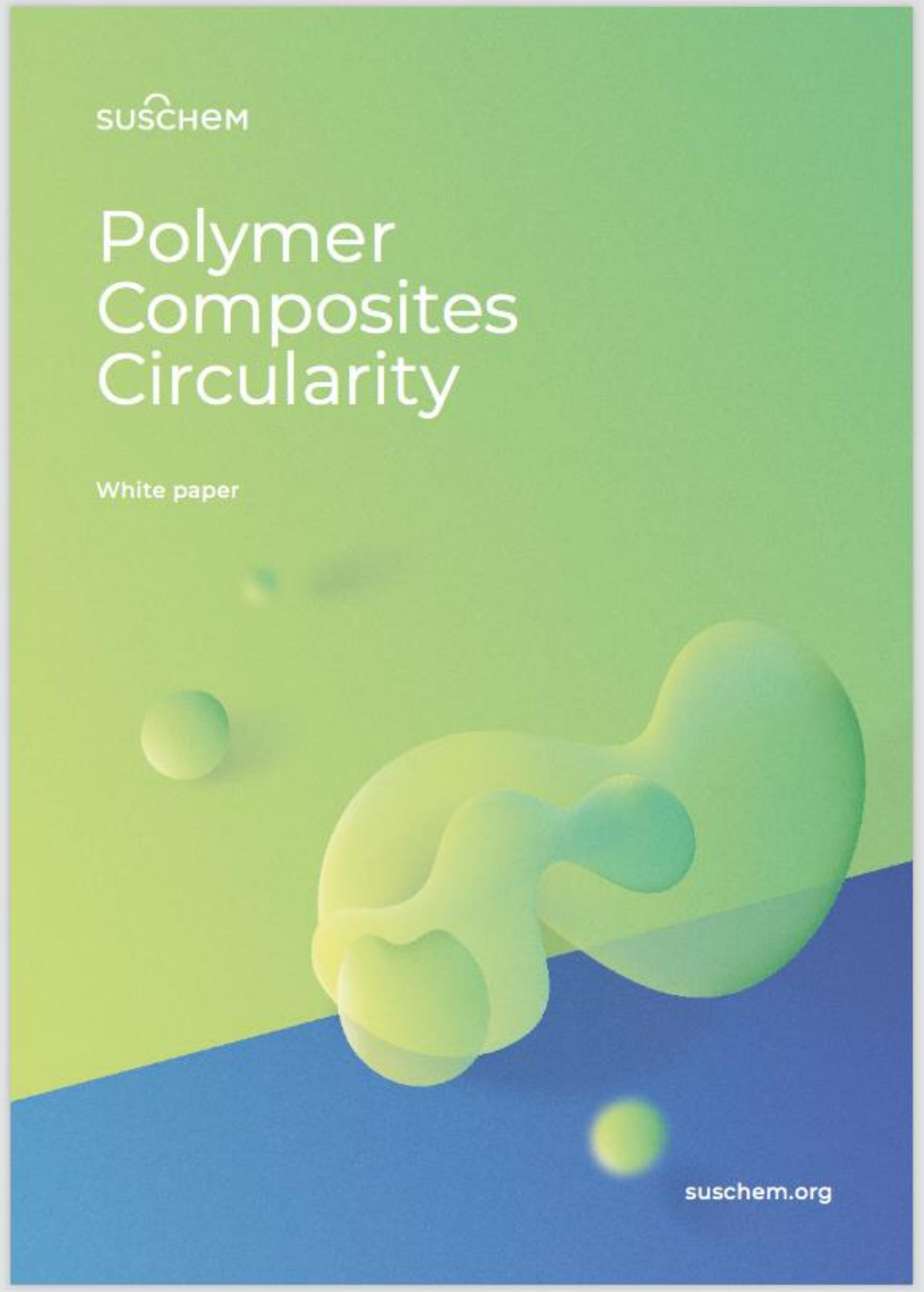
- Blades: key element and key challenge
- A wind turbine blade's lifecycle
- Innovative materials in blade design (technologies and practices overview)
    - State of the Art
    - TRLs
    - Key players
    - Benefits and points to address
- Summary and Findings

Bax & Company references

EMIRI
Key R&I Priorities for FP9



Cefic/WindEurope
Wind Turbine Blade Circularity
Presentation WindEurope E&C



SusChem
Polymer Composites
Circularity White Paper

The Blade

Key element and key challenge

- Blade materials have to withstand extreme loads and environmental conditions

⇒ Multi-material solutions (composites) are currently the optimal choice considering blade sizes and operating conditions

Conventional thermoset FRP composites cannot be recycled through re-melting due to their cross-linked three-dimensional chemical structure and their complex structure.

Are downgrading recycling processes the only “circular” solution?

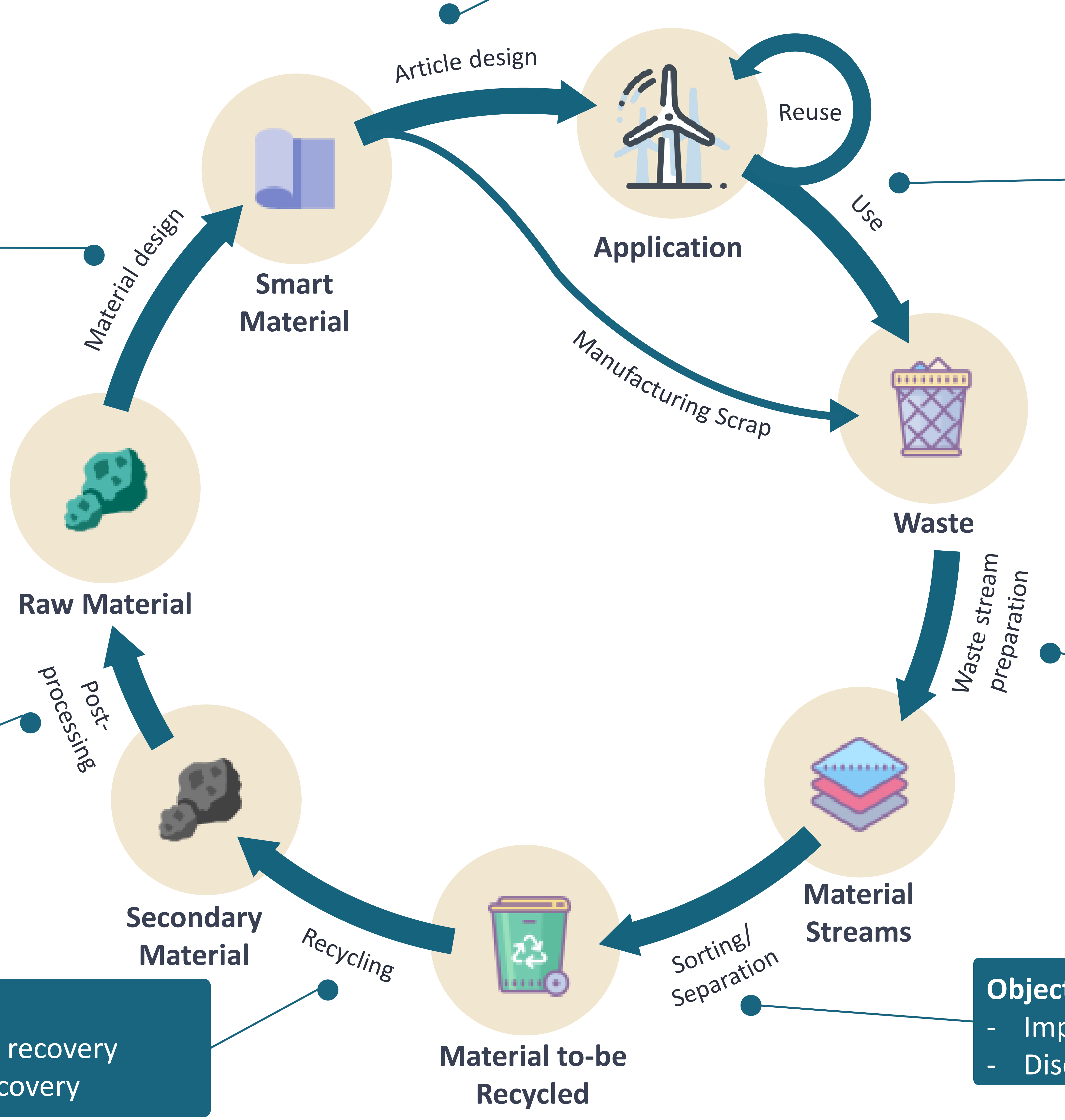
A wind turbine blade's lifecycle

Objectives to increase the circularity of wind turbine blades

Objectives
- Ease dismantling
- Decrease material use

Objectives
- Improve durability
- Improve circularity

Objectives
- Extend lifetime



Objectives
- Improve value of retrieved material
- Decrease recycling cost
- Decrease emissions

Objectives
- Reinforce material properties

Objectives
- Enable (higher) material recovery
- Enable (higher) value recovery

Objectives
- Improve value of retrieved material
- Discard non-useful material

Innovative materials in blade design

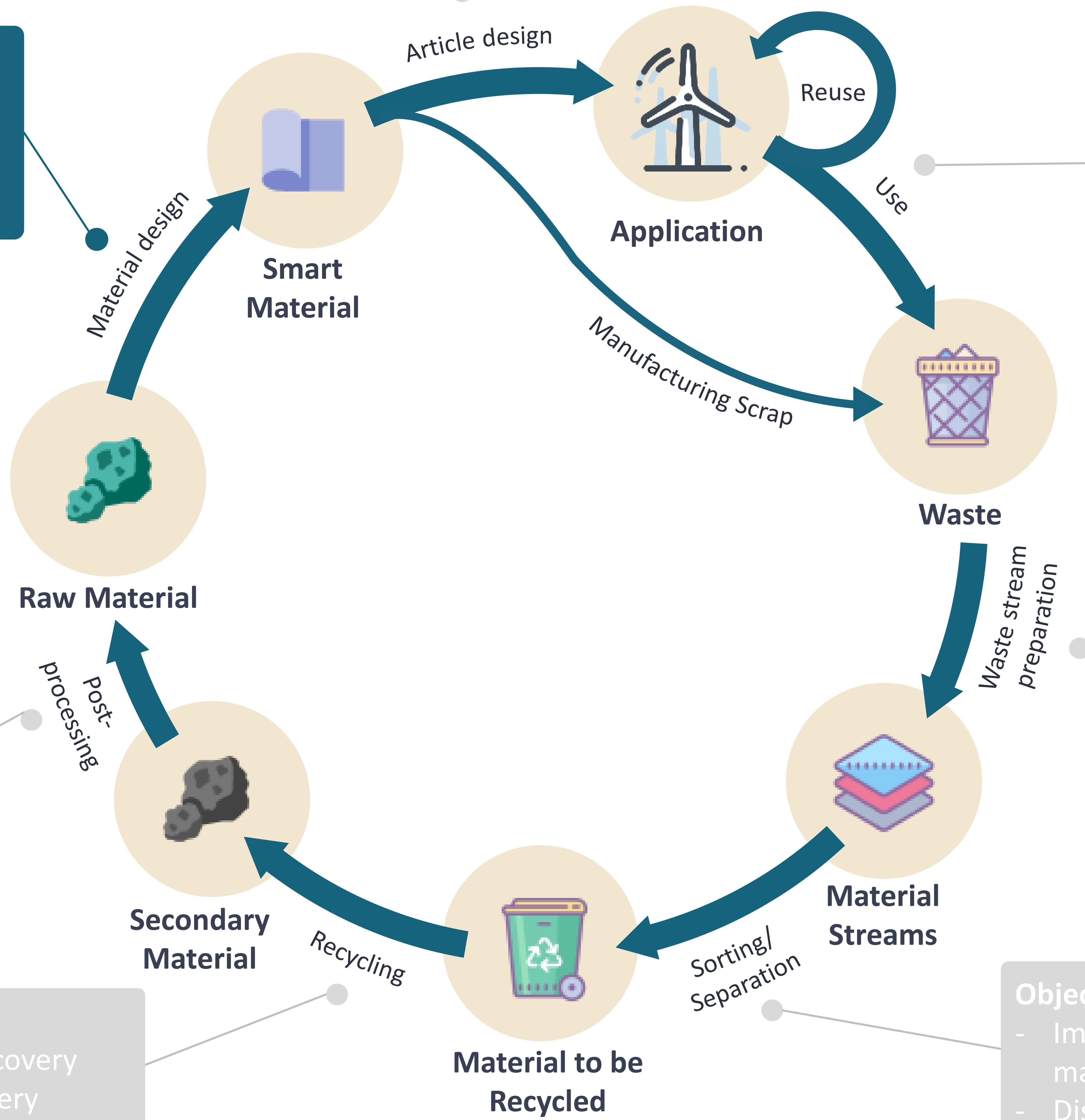
Overview of challenges, and technologies/practices

Objectives/ Challenges

- **Improve durability**
- **Improve circularity**

Technologies

- Nano-reinforcements
- Self-healing polymers
- Hybrid polymers
- Reversible crosslinking (thermoset resins)
- Innovative bonding technologies
- Thermoplastic matrices
- Bio-based composites



Objectives
- Ease dismantling
- Decrease material use

Objectives
- Extend lifetime

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- Improve value of retrieved material
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- Decrease emissions

Objectives
- Improve value of retrieved material
- Discard non-useful material

Objectives
- Enable (higher) material recovery
- Enable (higher) value recovery

Objectives
- Reinforce material properties

Resin nano-reinforcements

Improve durability

TRL 7

- Humectant and dispersant additives as resin nano-reinforcement in order to improve composites properties (e.g. addition of **carbon nanotubes** (CNTs)

University of Manchester
Cardiff University
Washington State University
Xinjiang Institute

Detect blade's internal structure defects

Improve aging performance

Improve composites properties, such as fatigue resistance, shear strength, fracture toughness and modulus.

Improve interfacial interaction between the fibers and the FRP matrix

Costs

Decrease material recyclability

Byproducts are harmful to human health and the environment

Self-sensing and self-healing polymers

Improve durability

TRL 3

- Different defects are initiated during manufacturing and in-service. The addition of **carbon nanotubes** (CNTs) and graphene nanoplatelets (GNPs) allows for detection of such defects.
- Self-healing polymers with **embedded microencapsulated healing agents** can repair these damages (disulphide-thiol exchange or thermally reversible Diels-Alder reactions). The process is triggered through detection signals (e.g. **UV, pH, temperature**).

Fraunhofer IFAM
National Technical University of Athens
TECNALIA
Arkema Group
citeve

SMARTFAN
HIPOCRATES
MASTRO

- ✓ **Extend the lifetime of the blade**
- ✓ **Reduce (costly) maintenance**
- ✓ **Improve in-operation safety**

- ✗ **Some additives can weaken the structure**
- ✗ **Complex manufacturing process**

Hybrid polymers and reversible crosslinking of thermoset resins

Enable circularity

TRL 6

- **Combination** of the mechanical performance of thermosets with the fast processing of thermoplastics **with a thermal switch** (special type of Diels-Alder chemical reaction) to remelt and reshape the material.
- **Dynamic chemical crosslinks** (combining nucleation and low crosslinking degrees) in thermoset FRP enable the separation of the matrix and the fibres.

Evonik
Karlsruhe Institute of Technology (KIT)
Cidetec
Arkema Group
University of Groningen

Cooperation between Evonik and KIT
MASTRO

- ✓ **Improve separation of components and materials at end-of-use**
- ✓ **Heated and cooled many times without loss of properties**
- ✓ **Comparable chemical resistance to highly-crosslinked epoxy**

- ✗ **Complex and sensitive processes**
- ✗ **Costs**

Novel bonding technologies (e.g. thermoplastic adhesives)

Enable circularity

TRL 3

- Thermoplastic materials have a **reversible chemical structure**. By applying heat the material can be re-melted and therefore enables other recycling options.
- The concept has been proven for **semi-structural products** and is applied on large scale for non-structural products.

Soudal
Katholieke Universiteit Leuven
Flanders Make
TPRC

Improve separation of components and materials at end-of-use

Easy-to-apply process (existent equipment)

Lacking performance for structural components

Thermoplastic matrices

Enable circularity

TRL 6

- Thermoplastic materials have a **reversible chemical structure**. By applying heat the material can be re-melted and therefore enables other recycling options.

Arkema Group
Delft University of Technology
DTU Wind

WALiD (Wind Blade Using Cost-Effective Advanced Lightweight Design)

- ✓ **Increase recyclability at end-of-use**
- ✓ **Enable alternative joining methods such as resistance welding**
- ✓ **Enable repair during manufacturing and use-phase**

- ✗ **Currently lower interface properties between fibres and thermoplastic polymers in comparison**
- ✗ **Processing for large blades is challenging**
- ✗ **Challenging static and fatigue properties, moisture uptake**
- ✗ **High costs**

Bio-based composites

Enable Circularity

TRL 7

- Bio-based composite materials, including **flax, hemp, and wood** composites and laminates are increasingly utilized in high-performance, structurally demanding applications.

Centexbel
DTU Wind Energy
inholland Composites
University of Camerino
Wageningen University
University of Massachusetts

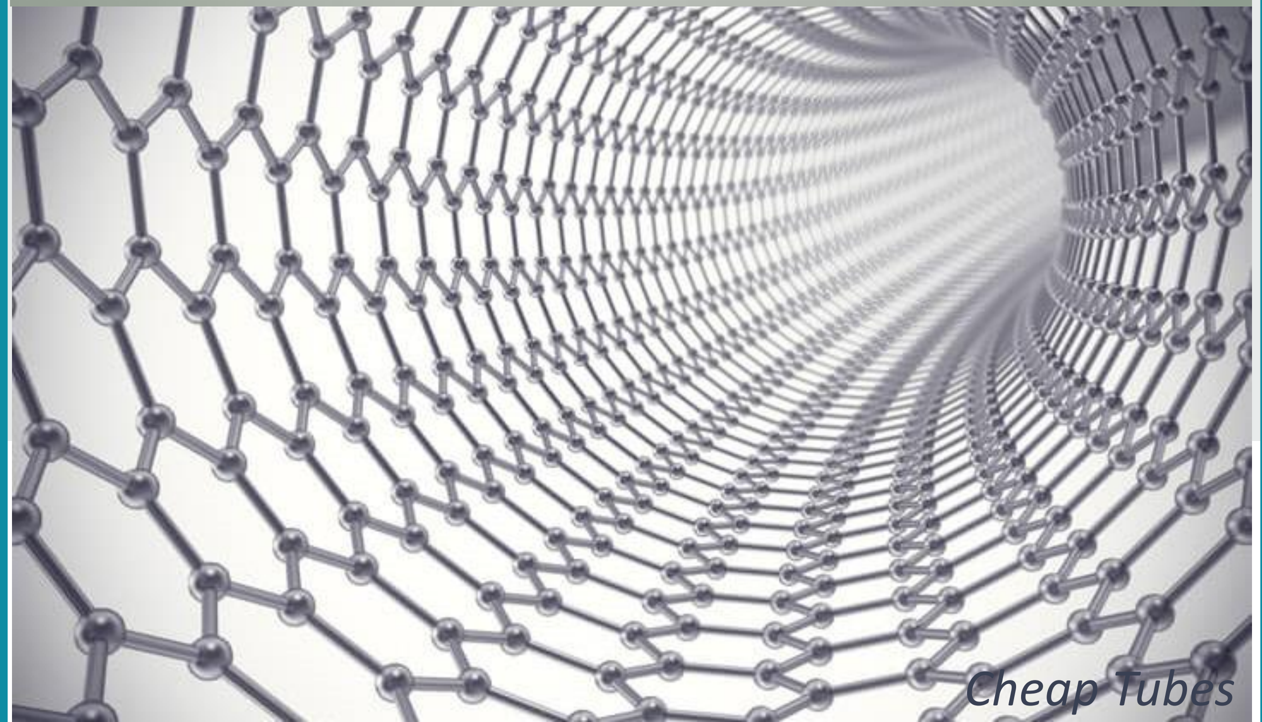
BIO4SELF

- Renewable (unlimited resource)
- Biodegradable when triggered (if matrix is also biodegradable)
- Low emissions manufacturing
- Low cost raw materials

- Limited availability of experimental data for complex loading conditions
- High sensitivity to moisture
- Variable mechanical properties
- Not fully developed manufacturing processes

Findings

- Each **circularity practice** in the design stage might **lead to other challenges** that will reduce circularity in another stage to a certain extent
  - Additives and some novel bonding technologies can decrease material recyclability or make it more difficult to obtain clean material streams at the end-of-life
- The trend for **moving from onshore to offshore**, as well as for **bigger turbine blades** puts ever-increasing expectations on material performance
- Thermoplastic based FRP although usually faster to process for smaller sizes, require **significant effort for bigger sizes** such as turbine blades
- The integration of novel materials in the manufacturing process of blades requires quite **high capital investments (machinery, tooling)**
- Increasing requirements for turbine blades will inevitably increase the length and **complexity of the supply chain** (i.e. adding CNT suppliers, coating, etc.)



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GET IN TOUCH

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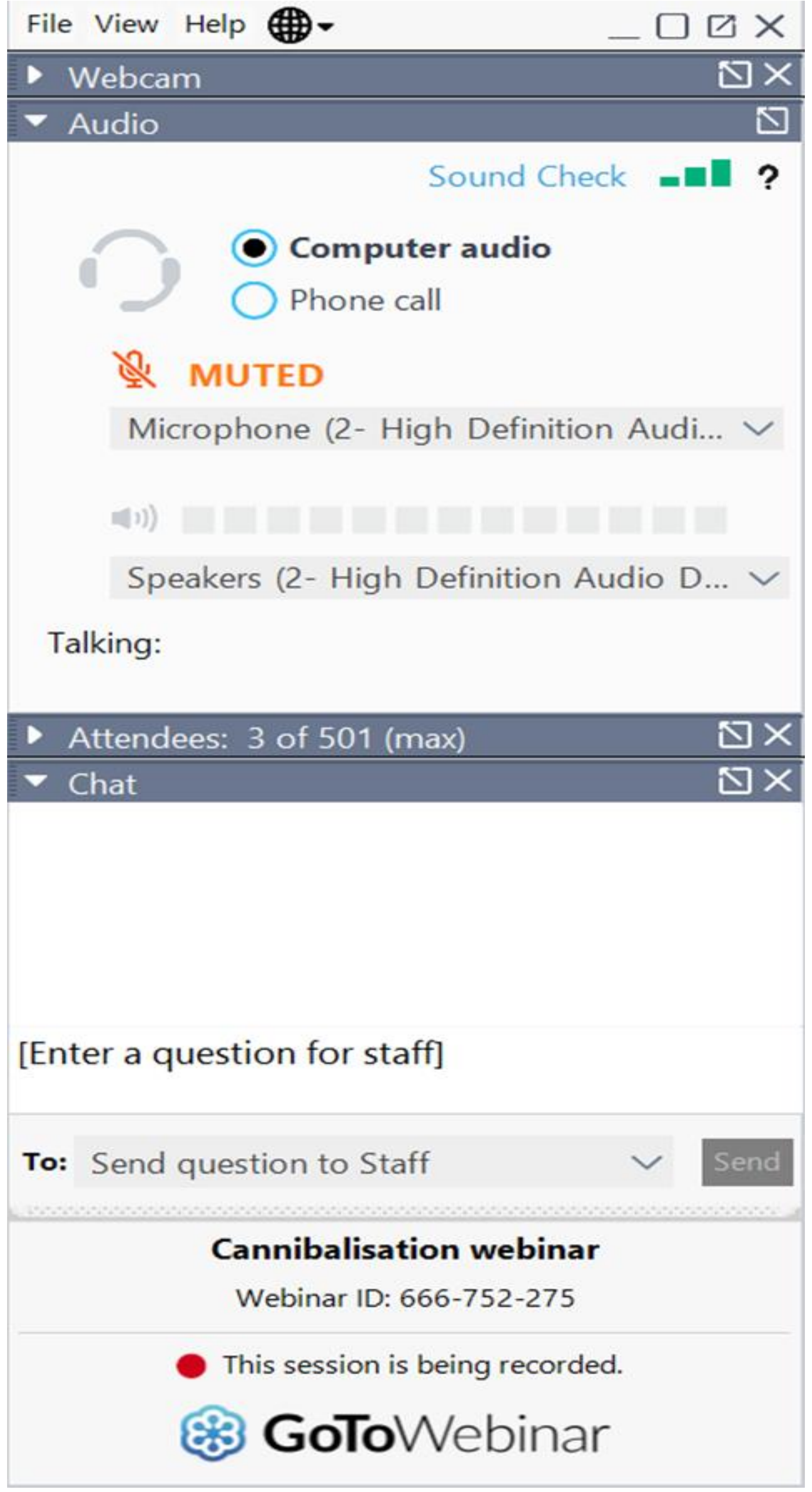


CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

CENIM
Centro Nacional de Investigaciones Metalúrgicas

TRC
THERMAL RECYCLING OF COMPOSITES

OLGA RODRÍGUEZ · CCO / Co-founder

eit Climate-KIC

EDP STARTER

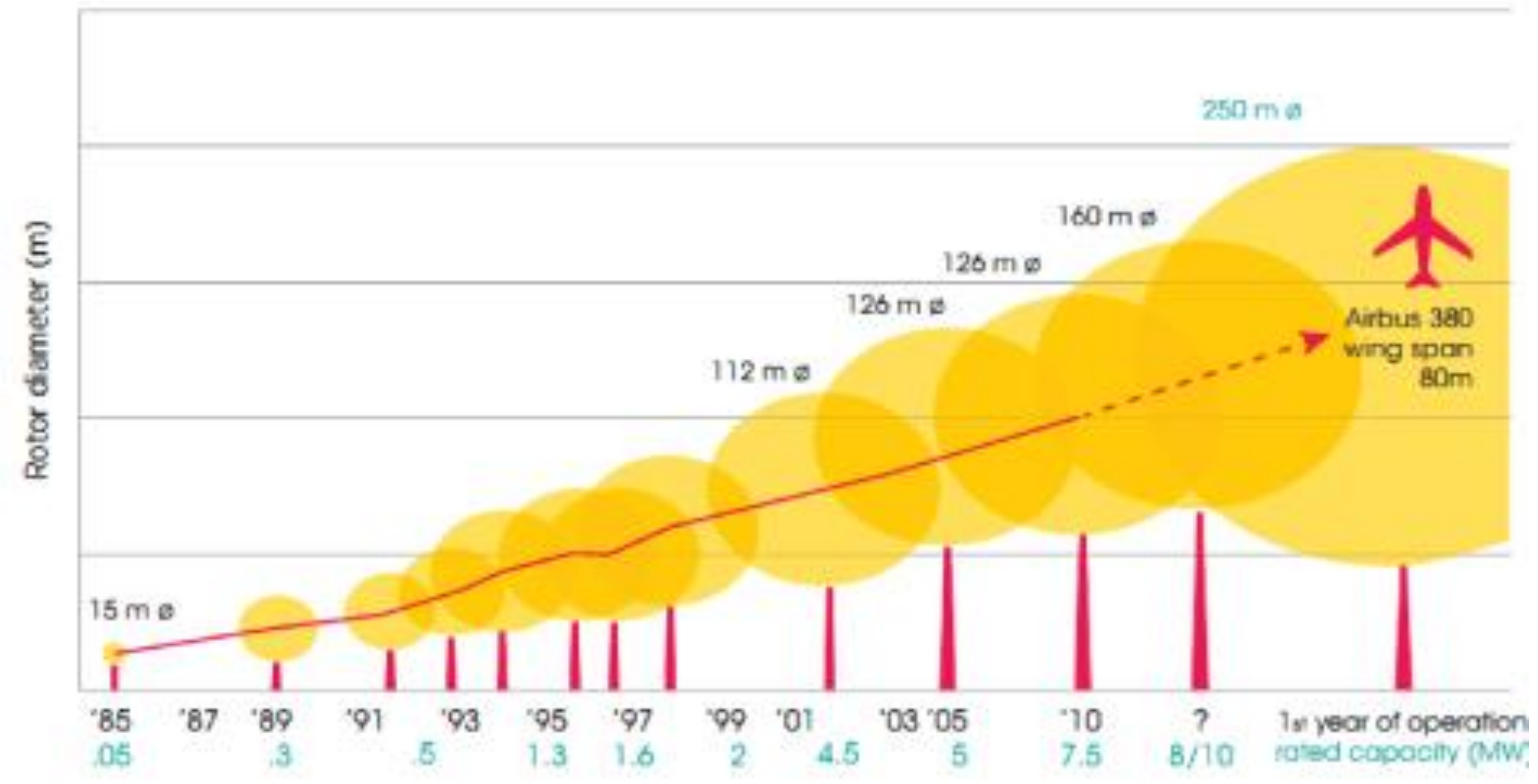
Wind Blade Structure

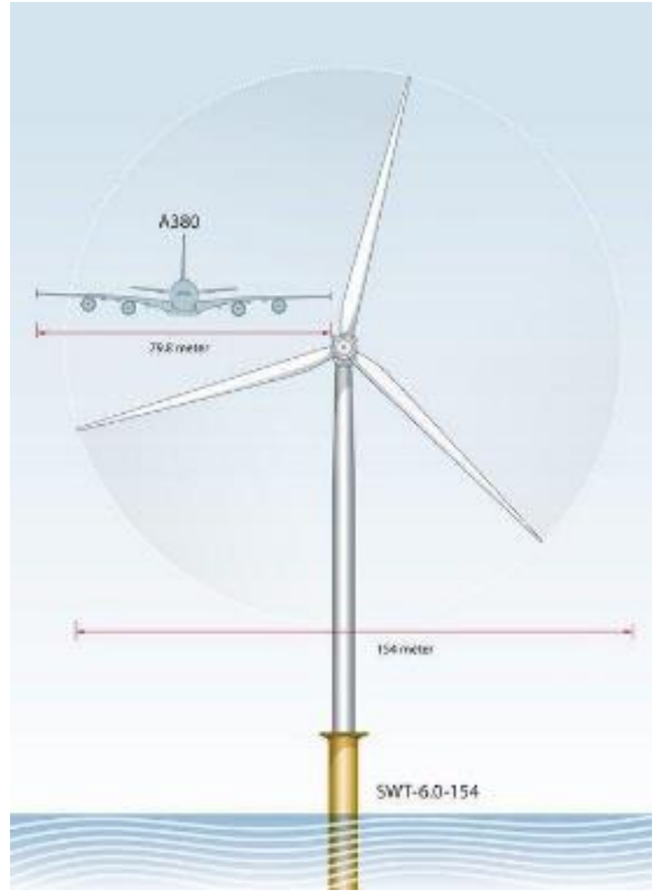
①: Adhesive joints
②: External coating (PE, PUR)
③: Glass or carbon fiber reinforced composites
④: Copper (lightning protection system)
⑤ : Foam

Material characteristics to take into account to recycle

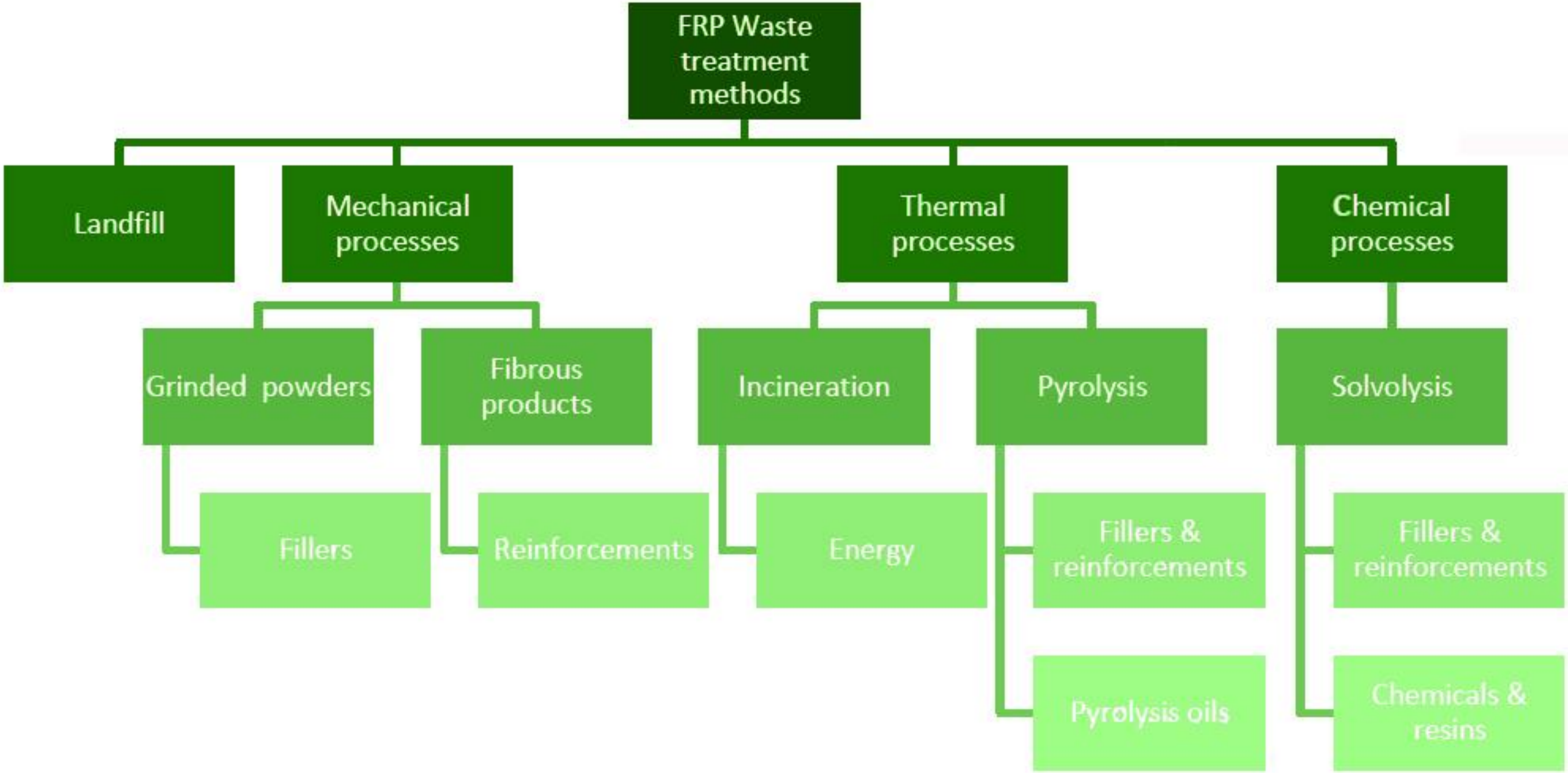
- High strength
- Thickness
- Same material in different ways (unidirectional fibers, multi-axial knitted, pre-preg…)

Material characteristics to take into account to recycle

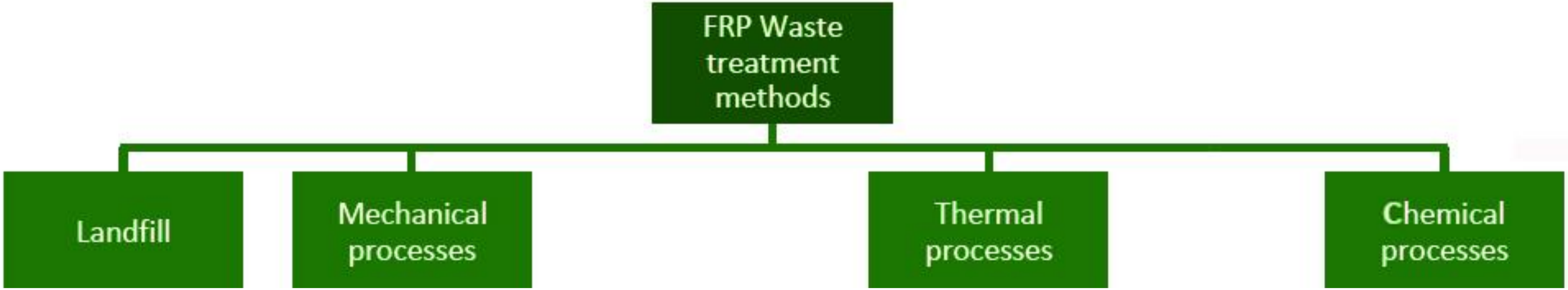




Recycling Technologies



Disadvantages



Storage/Buried
- High environmental impact
- High cost
- Waste of valuable materials)

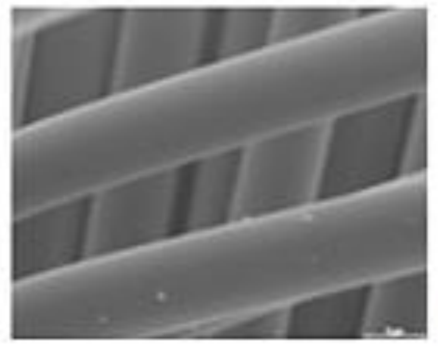
Crushing
- High energy cost
- High cost due to depreciation of cutting blades
- Resins and fibers are mixed

High temperatures
- High energy cost
- High emissions
- Mass waste (low calorific power)
- Decreasing fibers properties

Chemical compounds use
- High cost
- Environmental issues (hazardous liquid waste)

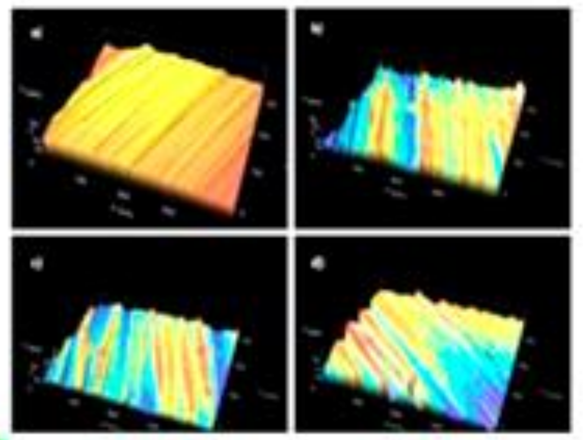
R3FIBER: New Recycling Concept (maximum material use)

Background



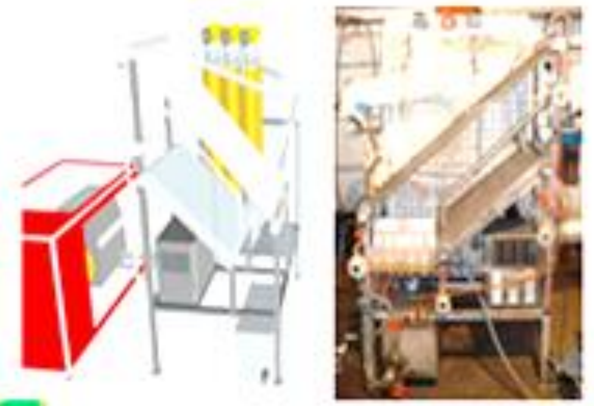
2008

- idea/concept



2010

- First results



2012

- Prototype construction

2014

- Pilot plant

2015

- Pilot plant improvemen
- Application new compos waste

TRC
THERMAL RECYCLING OF COMPOSITES

2016

- TRC Constitution
- industrial secret
- ipre-industrial plant design

2017

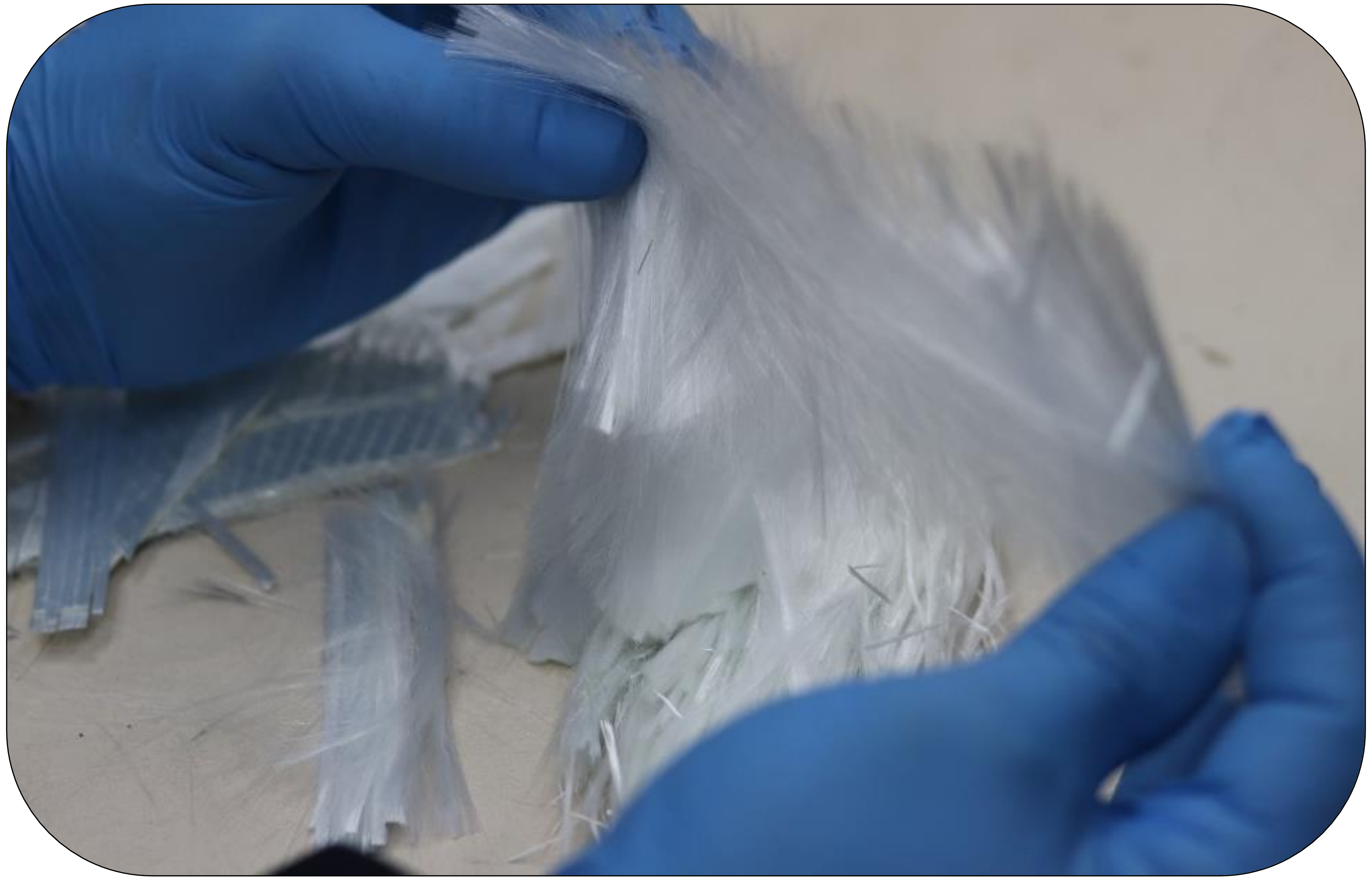
- Start construction preindustrial plant
- First sales management
- Contract EDP
- management First wind blade
- Several recognition

REFIBER
Green Composites for Circular economy

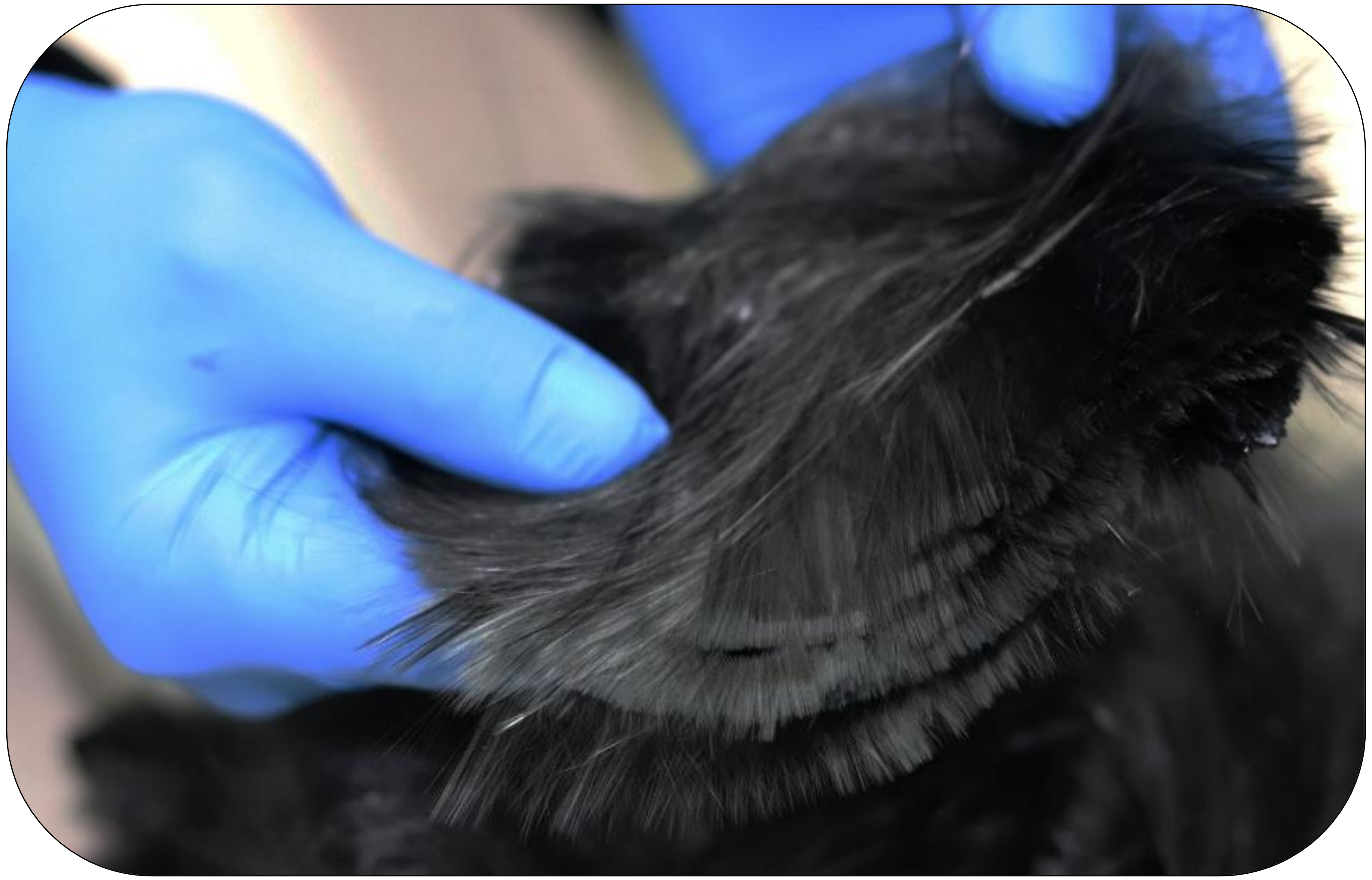
Disruptive · Efficient · Clean · Protected · Scalable · Versatile


VI-19

Versatility of the technology



Glass Fiber



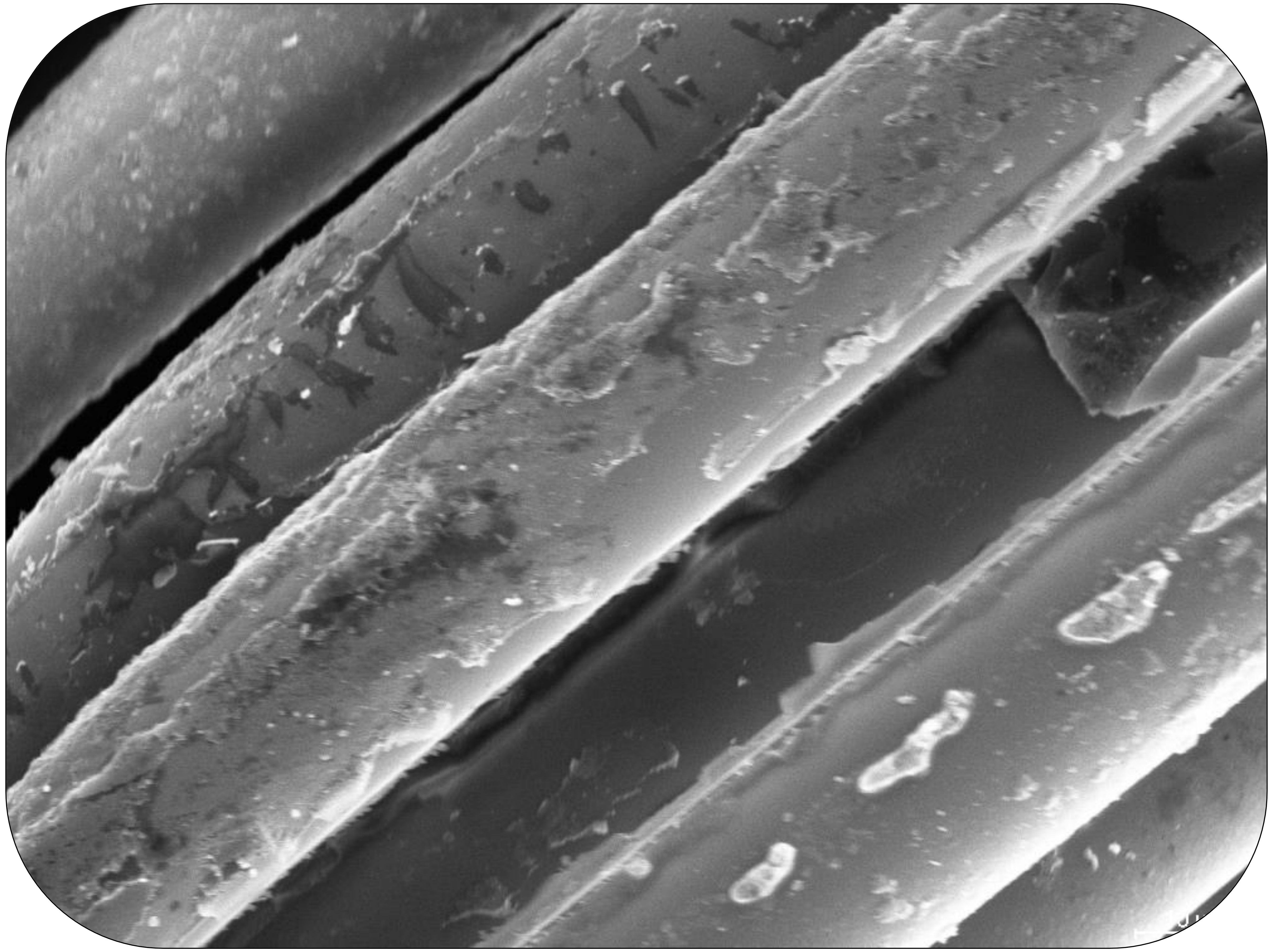
Carbon Fiber

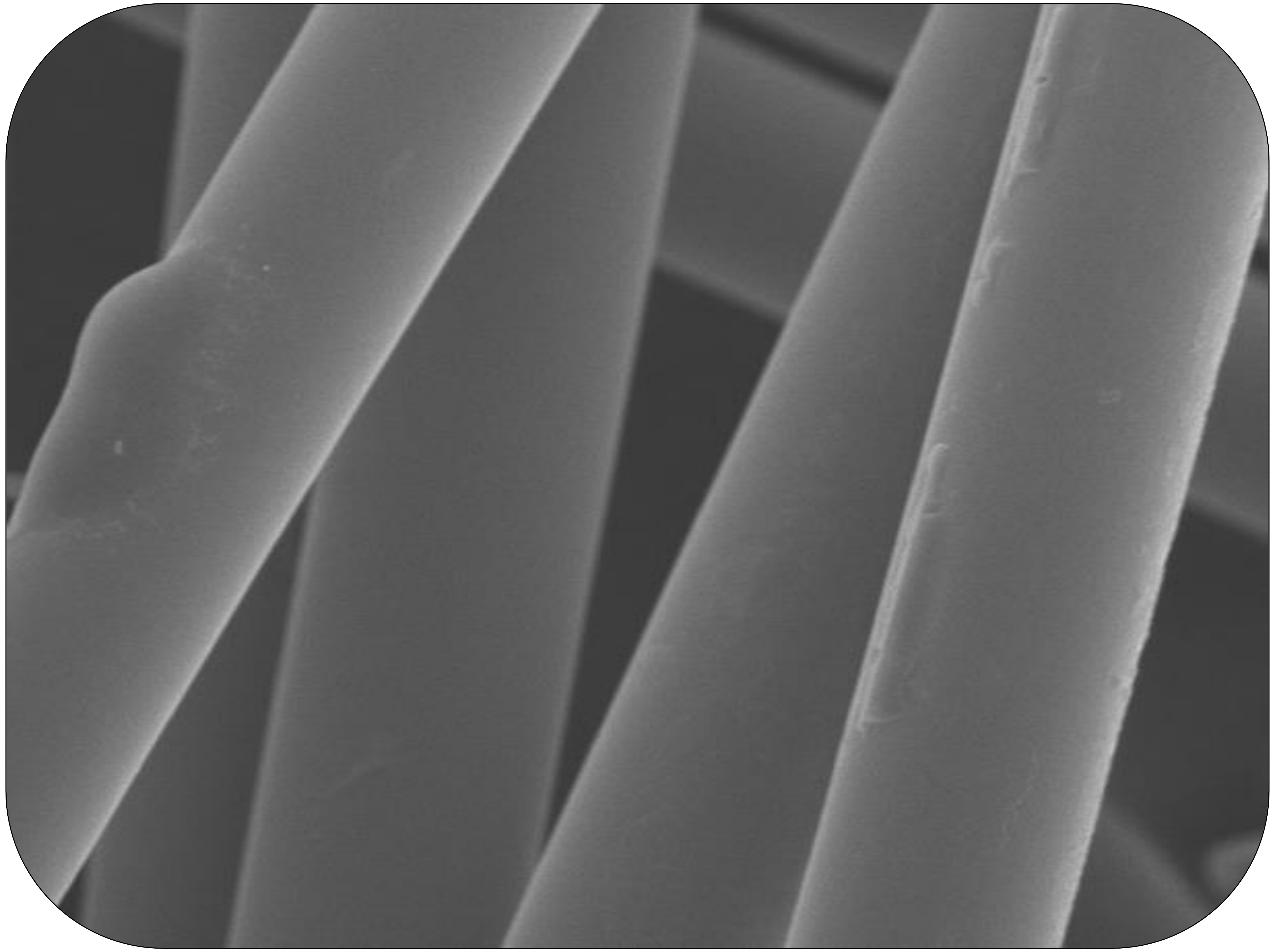
Technical properties

Commercial success

REINFORCED PLASTICS WITH CARBON FIBER

· 12% annual growth
· Excellent mechanical properties





R3FIBER

Properties

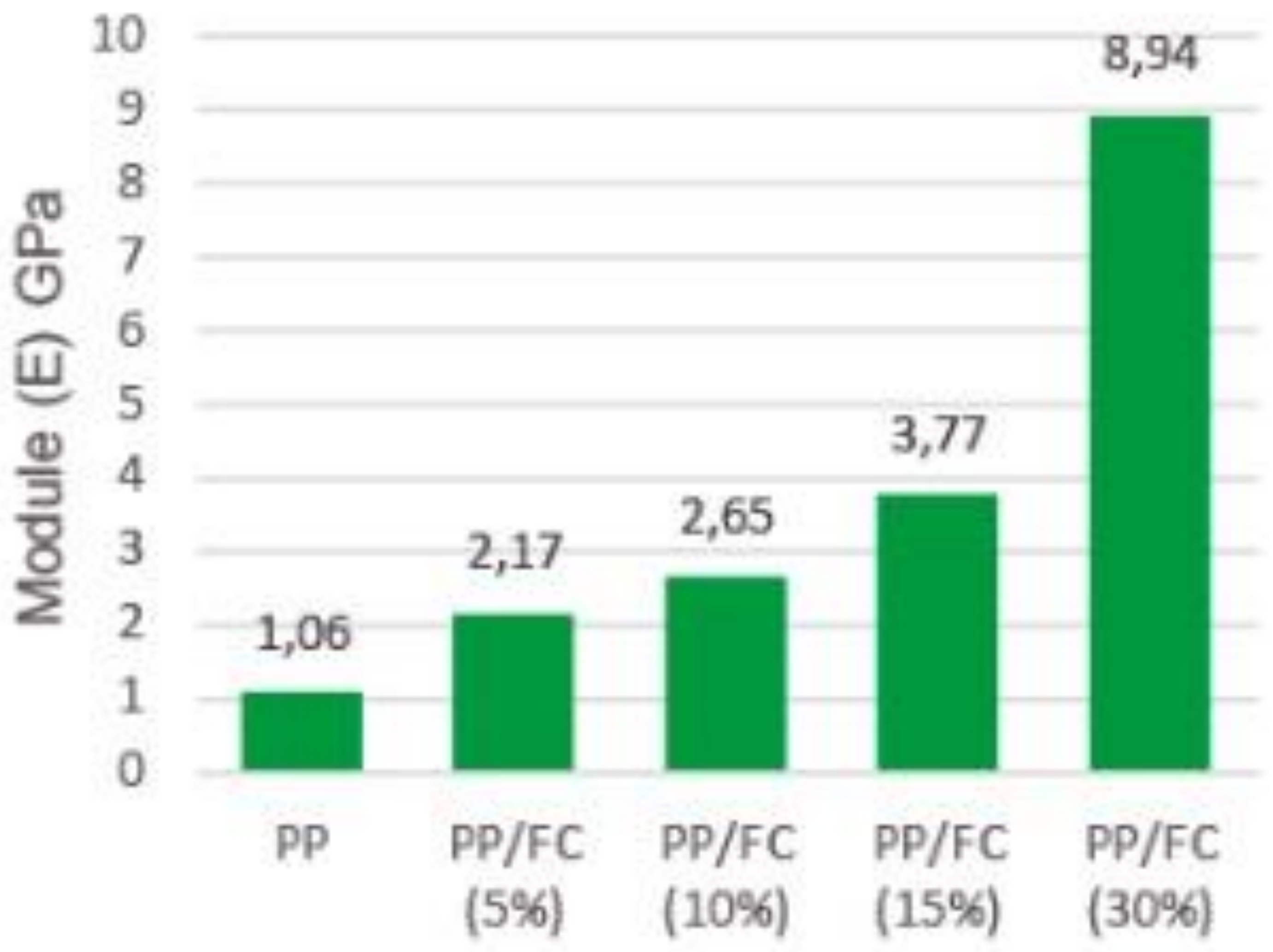
Medium diameter	0,009 mm
Density	0,02 g/cc
Length	According to customer needs
Max. Length	800mm
Traction resistance	328 Mpa (speed 5mm minute)

Properties recycled fiber vs the original fiber

Nominal diameter	100%
Tensile strength	88-93%
young module	85%

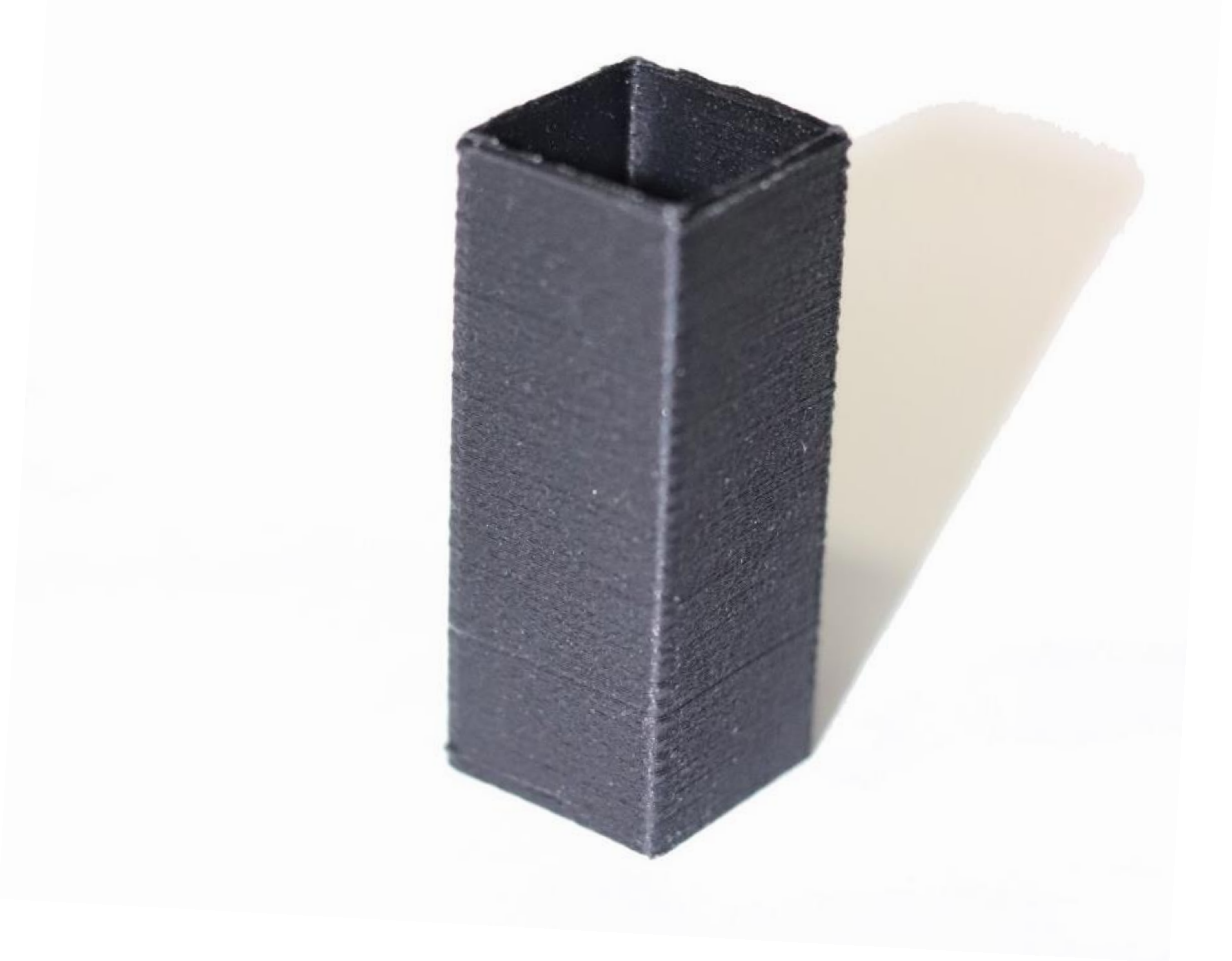
REINFORCED PLASTIC (PP)

- Multiply by 9 original stiffness
- Triple the tensile strength

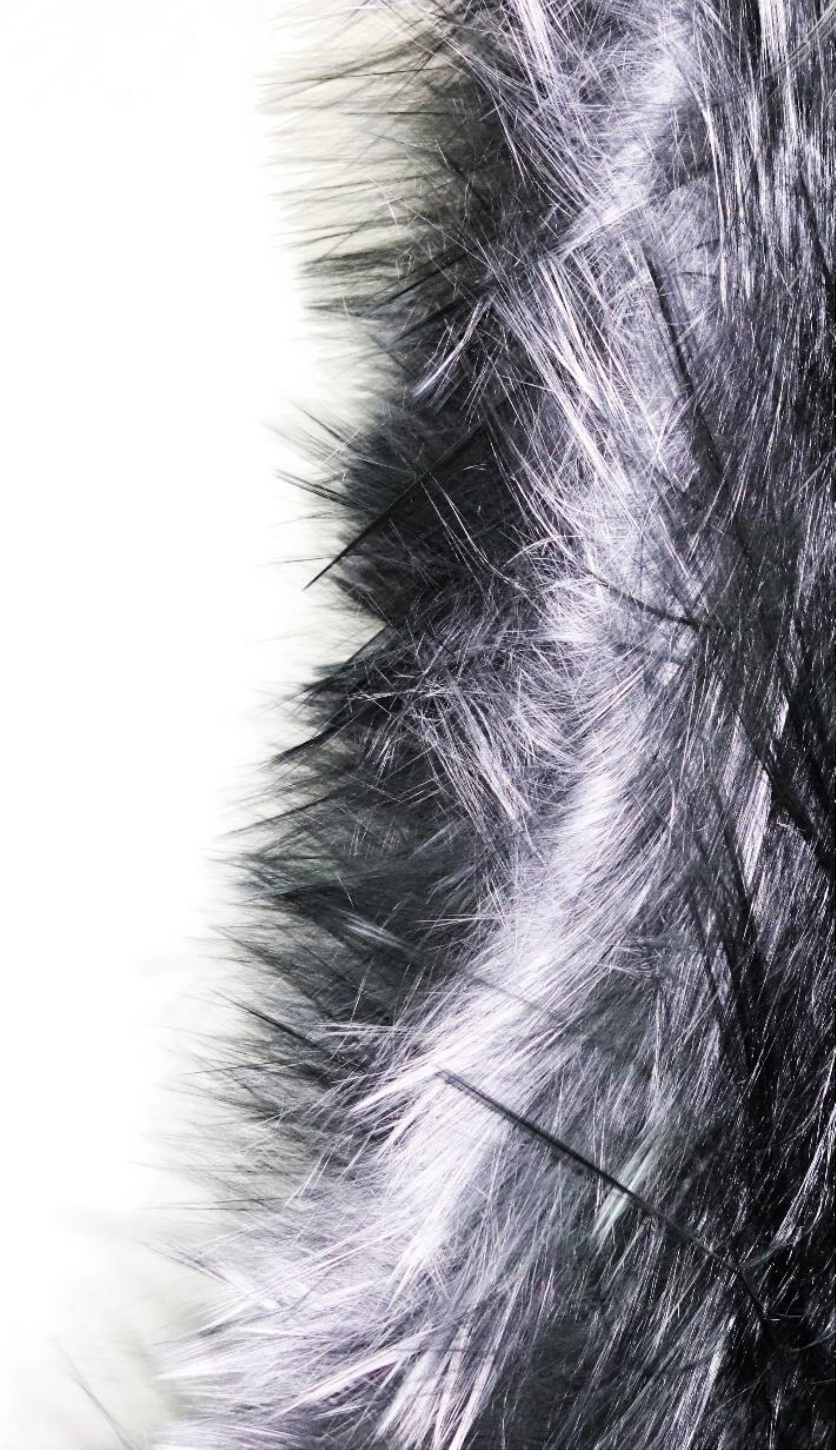


Material	Module (E)	Resistance
	GPa	MPa
PP	1,06	28,77
PP/FC (5%)	2,17	31,74
PP/FC (10%)	2,65	39,9
PP/FC (15%)	3,77	46,14
PP/FC (30%)	8,94	75,66

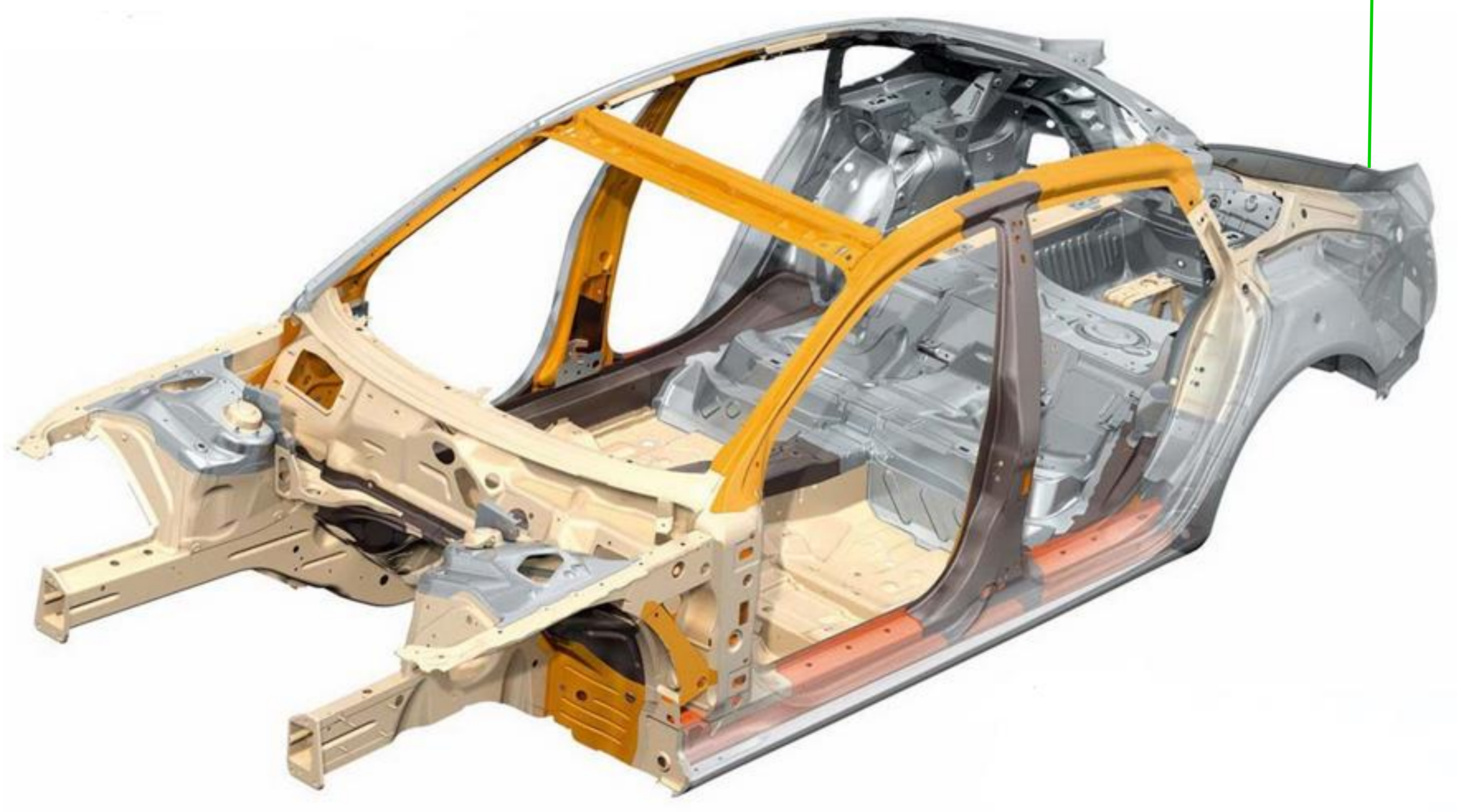
3D TECH

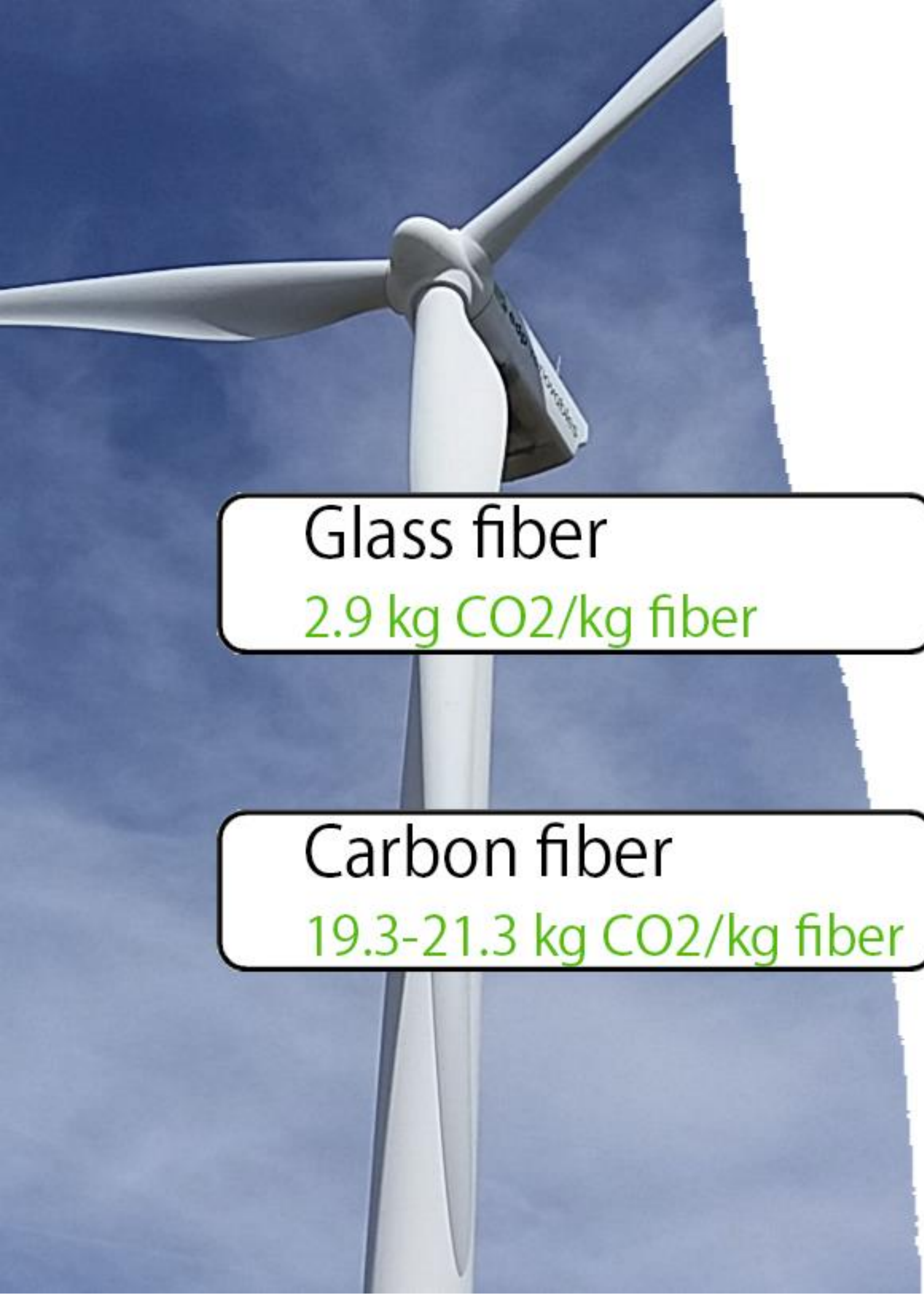


NON - WOVEN



⇩ Management cost
⇩ Production cost
⇩ Carbon Footprint
Circular Economy





26 MTn CO_2

save/5 year

Glass fiber
2.9 kg CO2/kg fiber

10.2 KTn CO_2 save/blade

Carbon fiber
19.3-21.3 kg CO2/kg fiber

74.5 KTn CO_2 save/blade

TRC
THERMAL RECYCLING OF COMPOSITES

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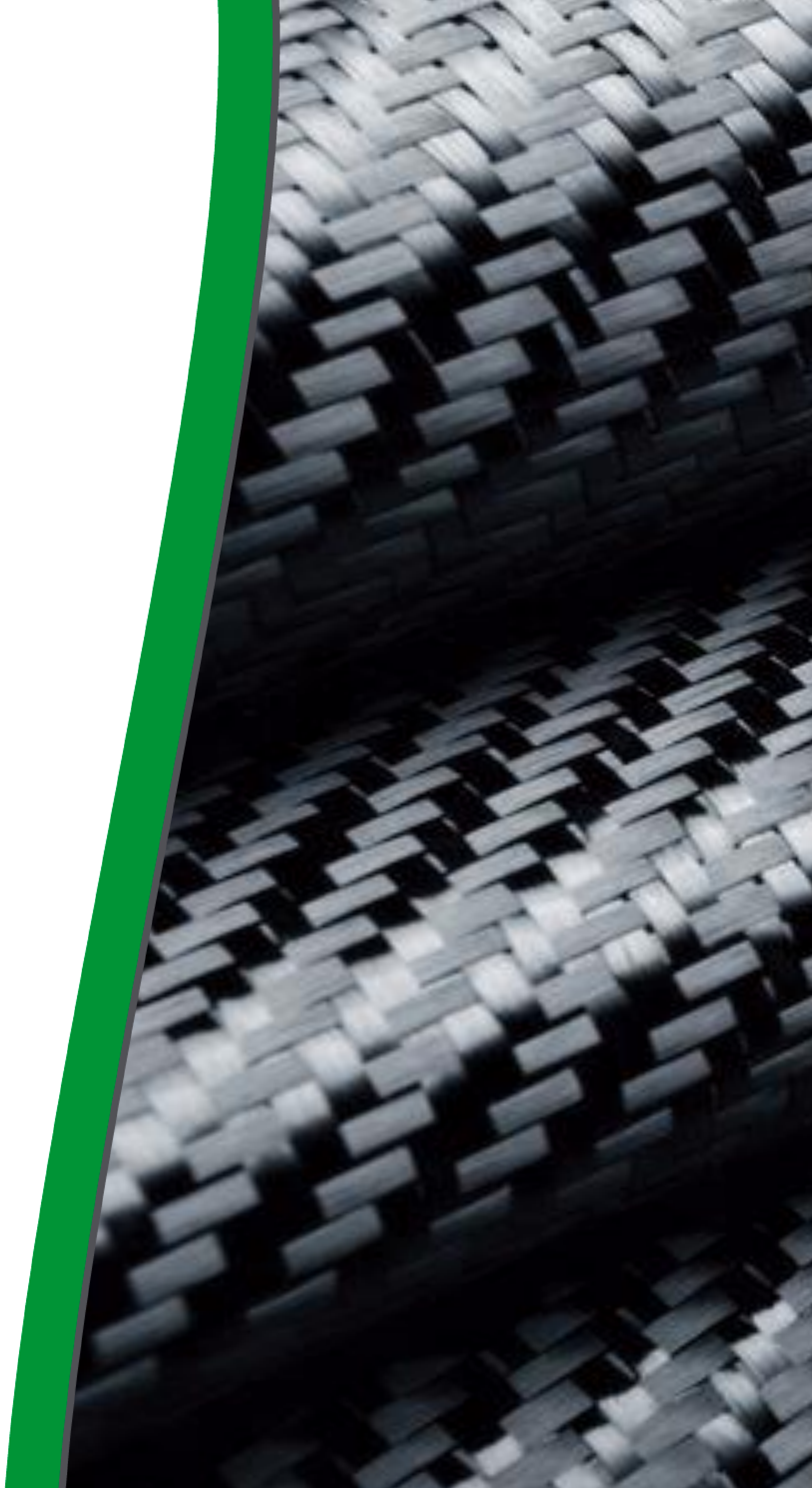

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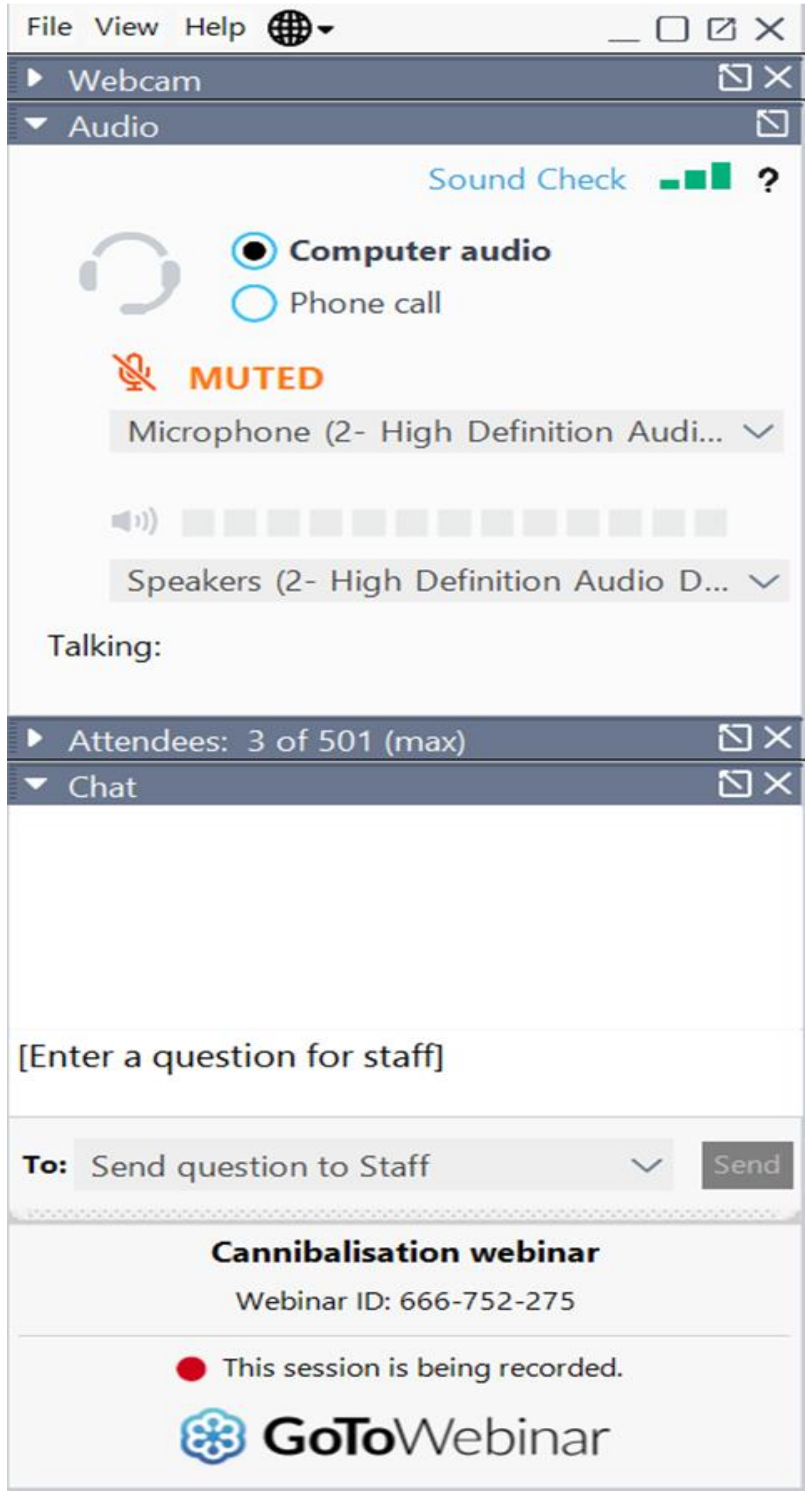
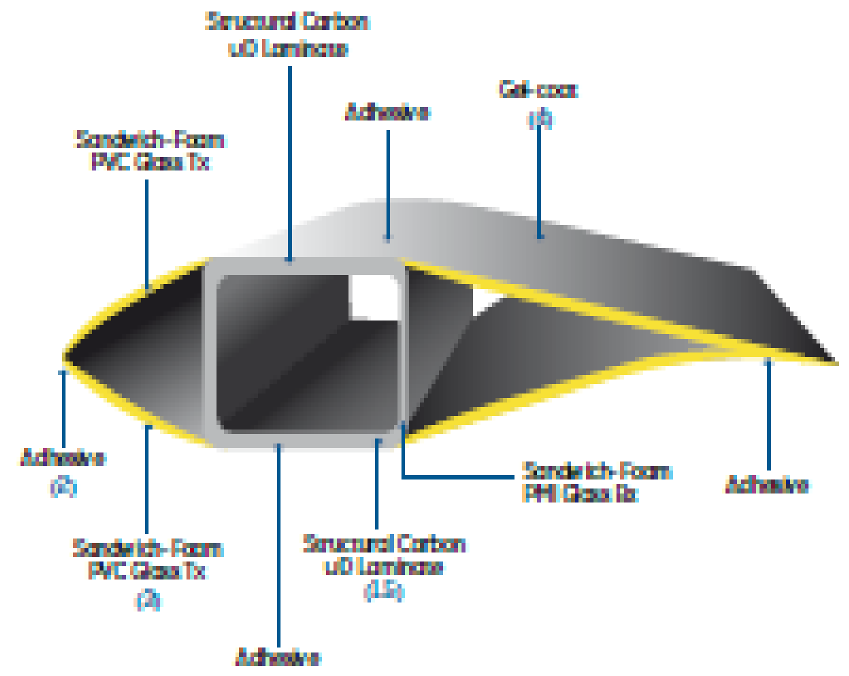


Blade composition and upcoming volumes of composite waste in the industry

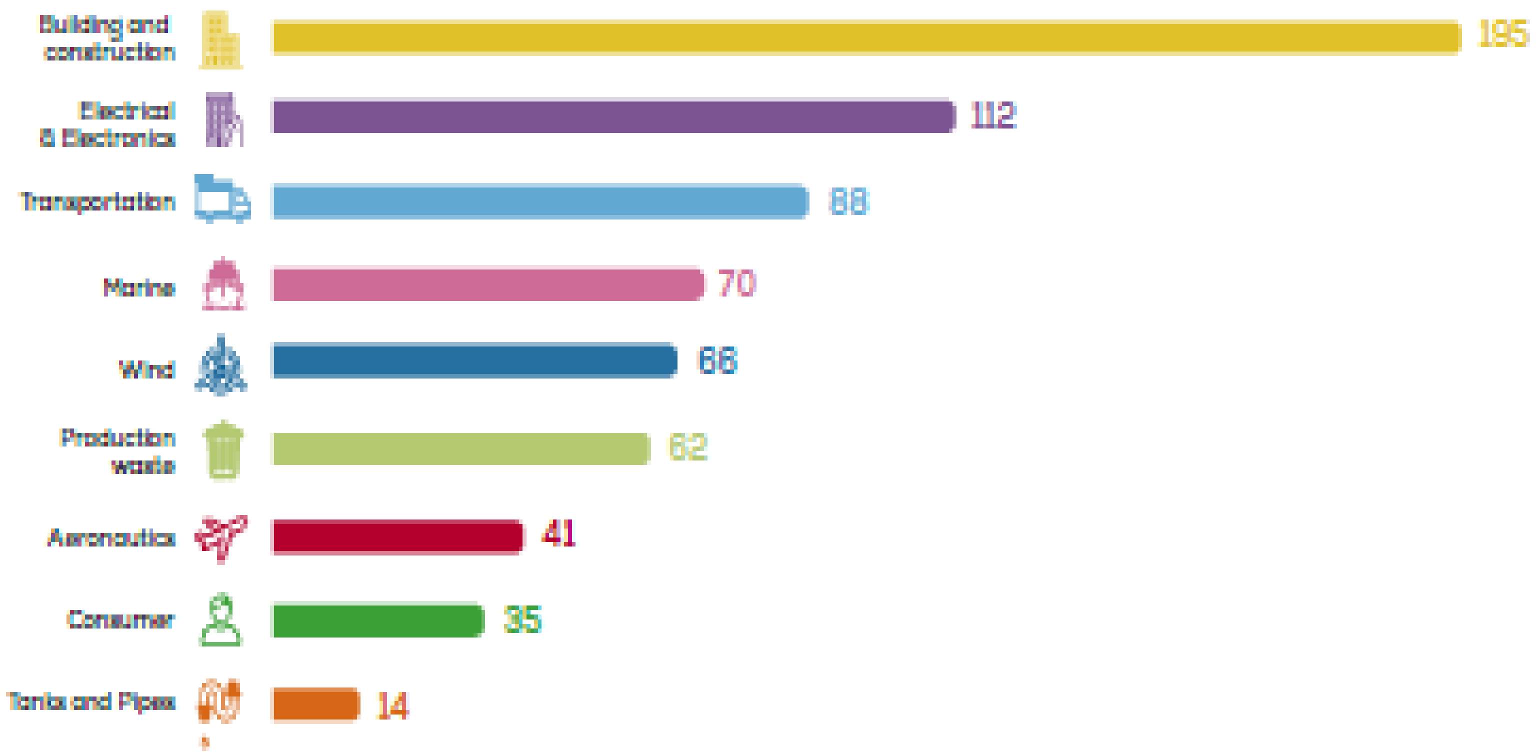
Generic composition of a wind turbine blade



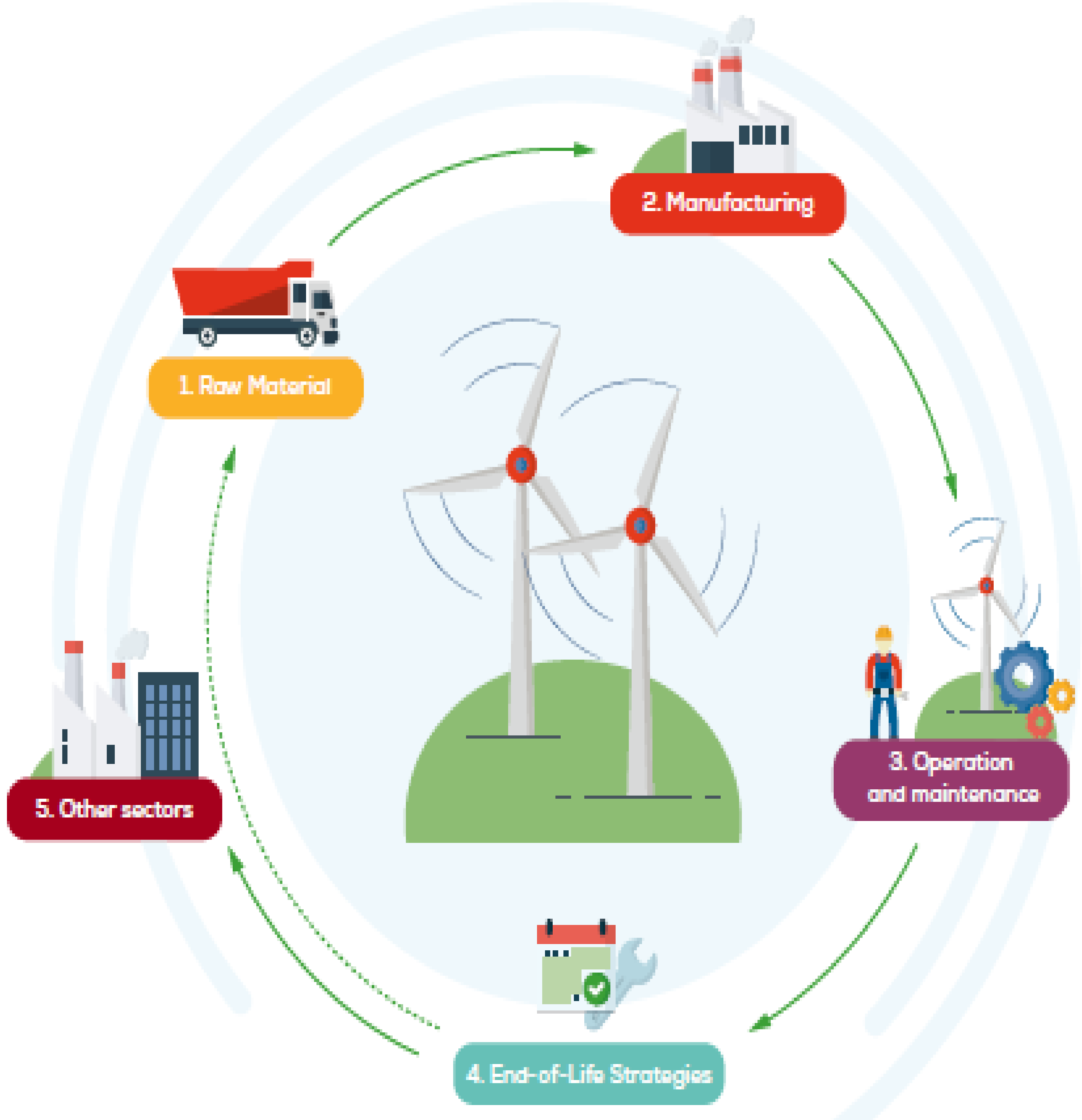
Wind turbine blades are considered a composite structure, consisting of various materials with different properties. The material compositions vary between blade types and blade manufacturers, but blades are generally made of:

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

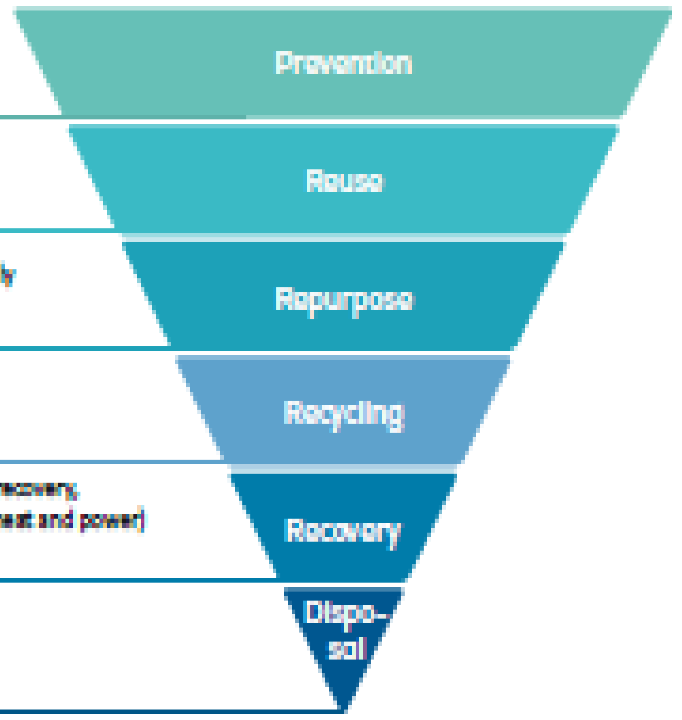


The life cycle of a wind turbine blade



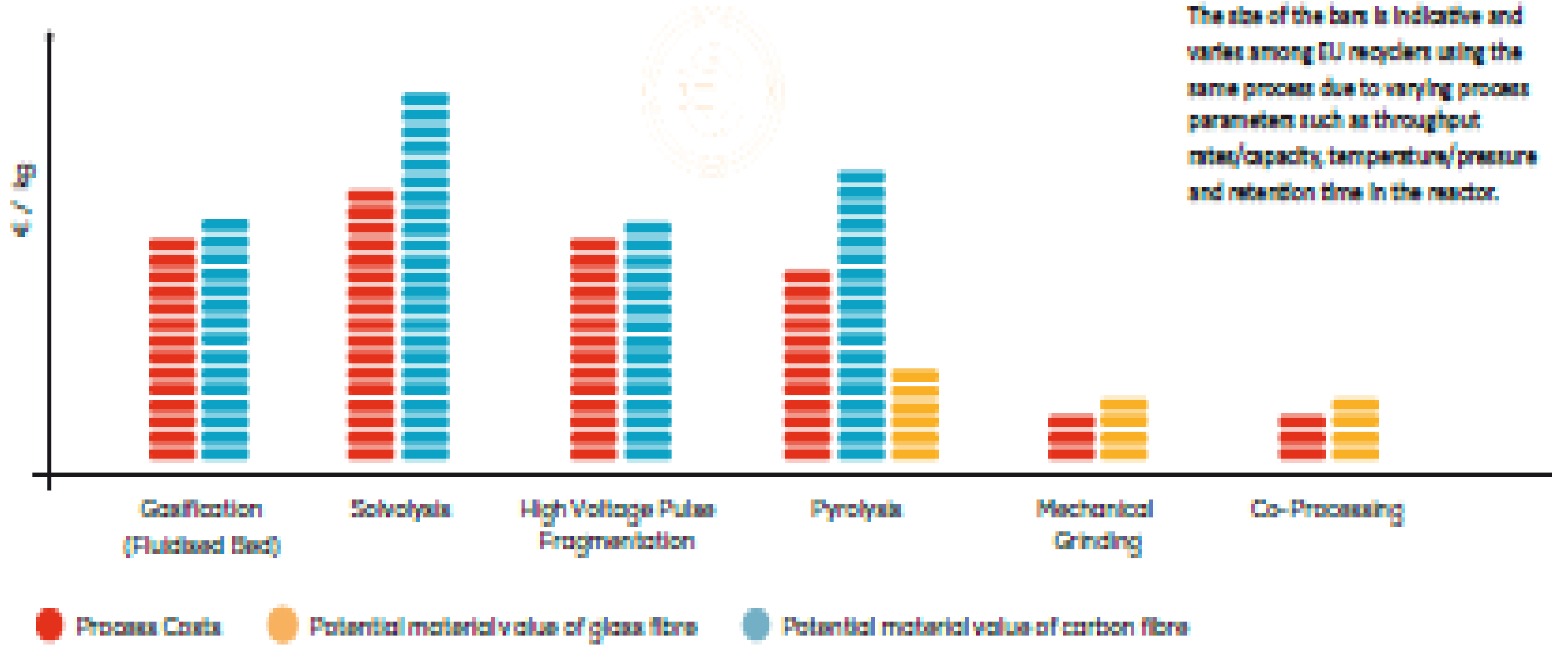
End-of-Life strategies for composite materials

Waste treatment hierarchy



- Prevention: Keep parts for longer. Design for easier dismantling and recycling. Minimise number of materials in design manufacture.
- Reuse: Check, clean, repair, refurbish, repair whole items or spare parts.
- Repurpose: Re-use an existing part for a different application, usually of lower value than the original.
- Recycling: Convert waste into a new substance or product. Includes composting if it meets protocols.
- Recovery: Includes anaerobic digestion, incineration with energy recovery, gasification and pyrolysis which produce energy (fuels, heat and power) and materials from waste.
- Disposal: Landfill and incineration without energy recovery.

Estimated relative costs and values of composite recycling technologies

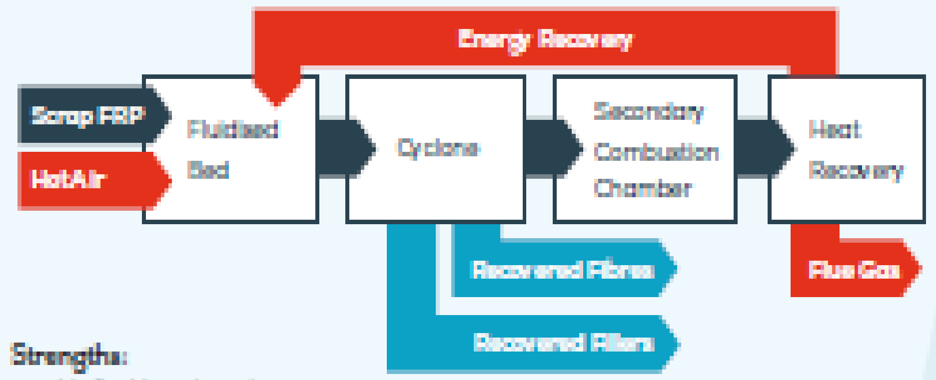


The size of the bars is indicative and varies among EU recyclers using the same process due to varying process parameters such as throughput rates/capacity, temperature/pressure and retention time in the reactor.

Composite recycling technologies and technology readiness level (TRL)

Gasification (Fluidised Bed)

Current TRL 5/6



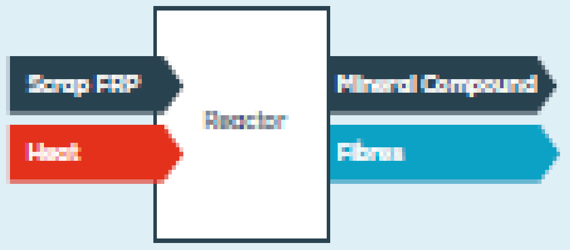
Strengths:
- Highly flexible and simple process;
- Recovery of energy and potential precursor chemicals;
- High efficiency of heat transfer.

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



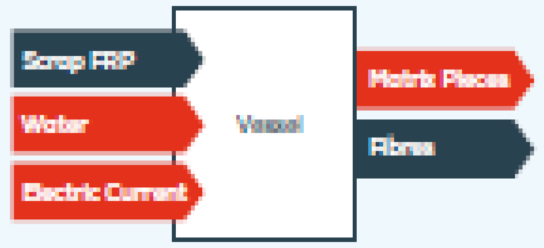
Strengths:
- Recovery of clean fibres in their full length;
- Recovery of resin which can be re-used.

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



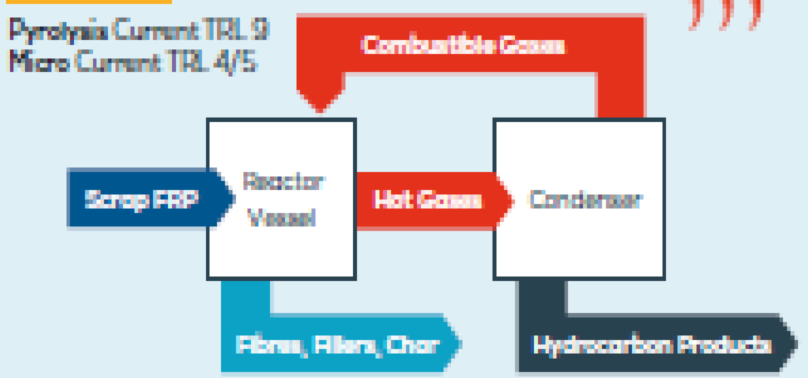
Strengths:
- Scalable to treat large amounts of waste;
- Low investments required to reach the next TRL.

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



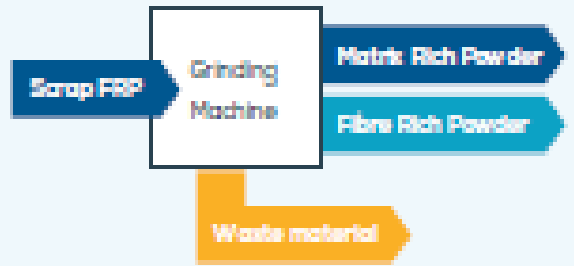
Strengths:
- Pyrolysis gas and oil can be used as energy source in the same process or in chemicals production;
- Easily scaled up;
- Microwave Pyrolysis: easier control. Lower damage to the fibre.

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



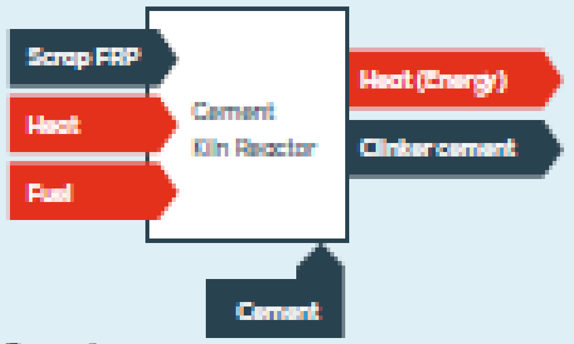
Strengths:
- Efficient and high throughput rates.

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.

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.

Author: ETIPWind Executive Committee
Content coordinator: Sabina Potestio
Design by: www.formasdopossivel.com

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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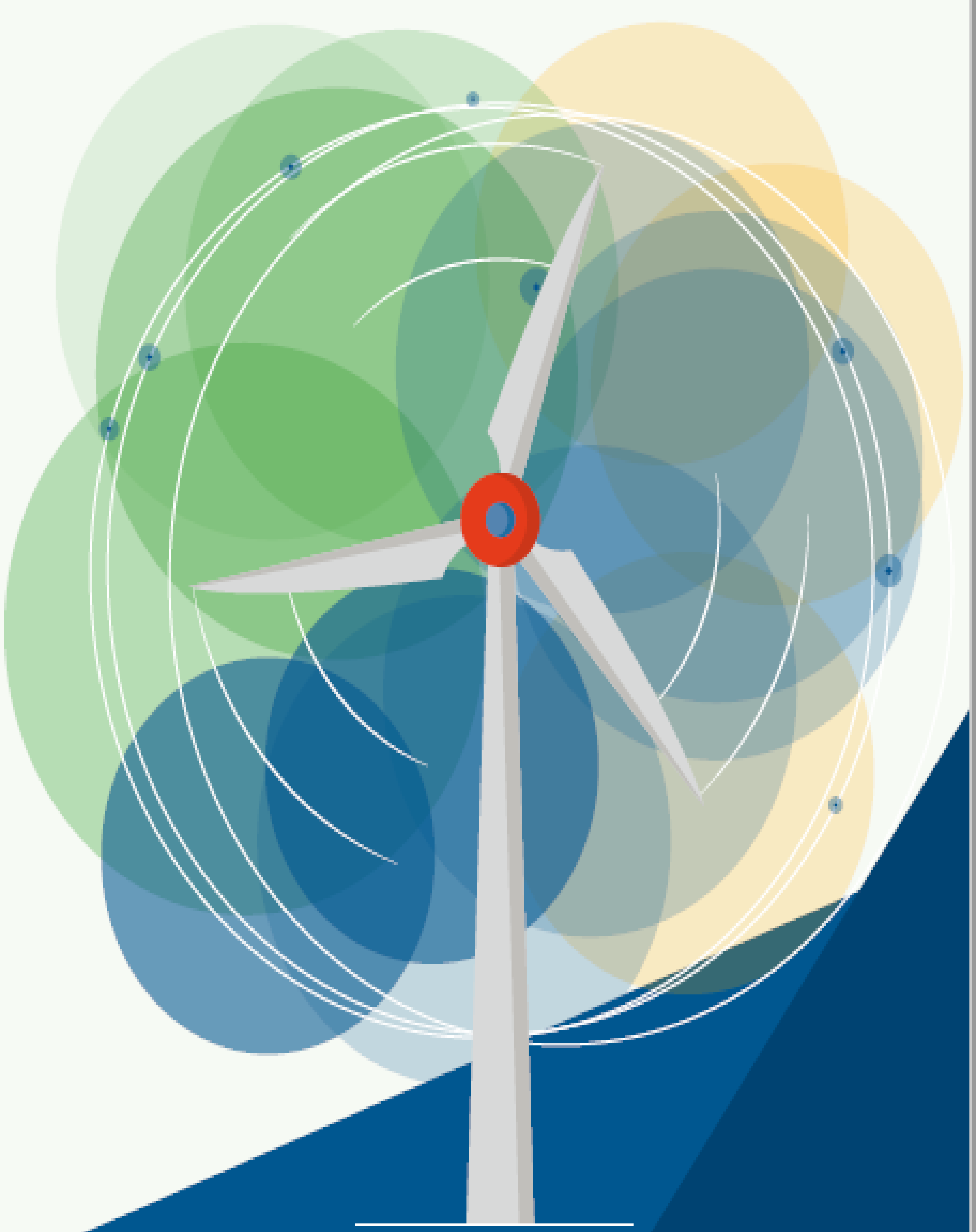

HOW WIND IS GOING CIRCULAR
blade recycling

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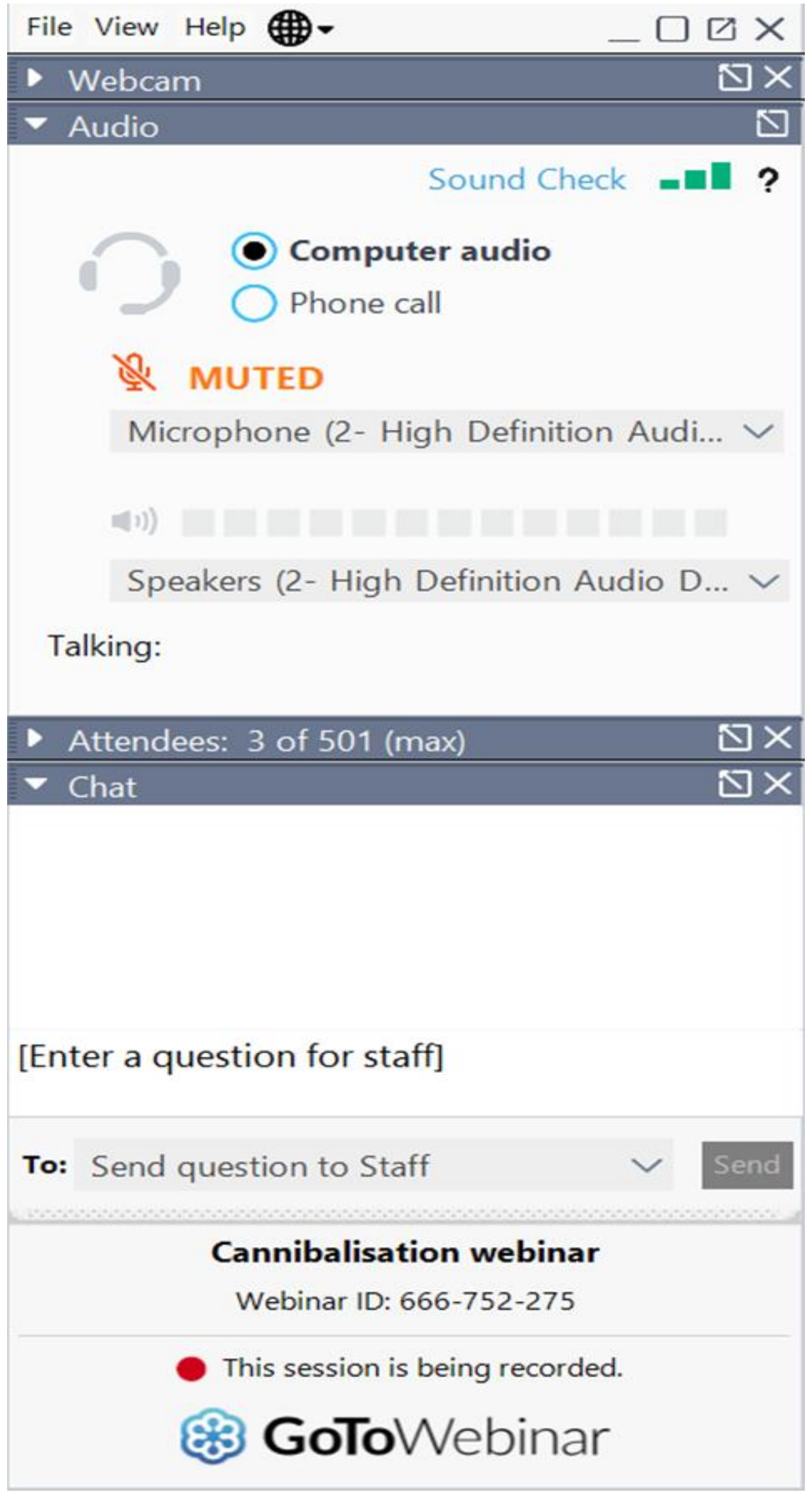

Thanks for your attention