How to build a circular economy for wind turbine blades through policy and partnerships

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Executive Summary

The wind industry is committed to the transition to a circular economy in line with the new EU Circular Economy Action Plan. To further accelerate this transition, support from policymakers and strategic cross-sector partnerships are necessary.

Based on the European Composites Industry Association (EuCIA) estimates, wind will contribute 10% of the total estimated thermoset composite waste (and less than 5% of the total estimated composite waste combining thermoset and thermoplastics) by 2025. Although it is a relatively small source of composite waste, the wind industry wants to lead on advancing sustainable methods to recycle composite material by calling for a European landfill ban on decommissioned blades by 2025.

This means the industry commits to re-use, recycle or recover 100% of decommissioned blades. The ban should also apply to other large composite components that can be found in the nacelle.

This will require the large-scale deployment of waste treatment routes like pyrolysis, mechanical grinding and cement co-processing to accommodate the coming volumes of decommissioned blades. The paper also highlights four pillars of action to achieve full recyclability in the future:

- Increasing funding on research and development (R&D) for evaluating and scaling-up diversified blade recycling technologies;
- Incentivising the use of recycled composite materials in new products;
- Increasing funding on R&D for the development and use of new (recyclable) blade materials; and
- Establishing a European cross-sectorial platform (including all composite waste producing sectors) and sharing good practice.

The wind industry will develop an industry roadmap further detailing the steps required to accelerate wind turbine blade circularity. This roadmap will focus on four workstreams: 1) implementing the landfill ban, 2) achieving full recyclability of existing blades in the future, 3) making future blades fully circular and 4) engaging with other sectors.

It will require commitment from policy makers, other composite users and recovery and recycling players to make these commitments a reality. This will help us build a future-oriented circular economy for wind turbine blades but also for other composite using sectors across Europe.

Contents

1. CONTRIBUTIONS OF THE WIND INDUSTRY TO SUSTAINABILITY AND CIRCULARITY

The wind industry is committed to the transition to a circular economy[1] in line with the new EU Circular Economy Action Plan[2]. To further accelerate this transition, support from policymakers and strategic cross-sector partnerships are necessary. Already today the wind industry actively seeks to improve the wind energy's (high) environmental performance and further reduce environmental impacts throughout the wind turbines' lifecycle. For example:

- Wind energy has one of the lowest greenhouse gases emissions throughout its life cycle compared with other energy sources[3];
- Wind turbines are long-life products - the standard design lifetime of a wind turbine is 20-25 years, with some turbines now reaching up to 35 through lifetime extension;
- During sourcing, the environmental footprint of suppliers is taken into account and calculated in wind turbine's life cycle assessments;
- During siting and installation developers optimise the positioning of wind farms via environmental impact assessments as well as engagement with local stakeholders to minimise impacts;
- During operation, direct environmental impacts are very limited; and
- At decommissioning, around 85 to 90% of wind turbines' total mass can be recycled[4]. Most components of a wind turbine – the foundation, tower and components in the nacelle – have long-established recycling practices.

But challenges remain: wind turbine blades are challenging to recycle due to the bonds of the thermoset plastic in the composite materials used in their production. While various technologies exist to recycle the composite materials in blades and an increasing number of companies offer composite recycling services, these solutions are not yet mature enough, widely available at industrial scale and/or cost competitive.

This paper sets out WindEurope's position on how to accelerate the circularity of decommissioned wind turbine blades and other large composite materials that are found in the nacelle. The wind industry is ready to lead on finding sustainable methods to recycled composite material although it is a relatively

[1] WindEurope, 2017. Background paper on the environmental impact of wind energy – a contribution to the circular economy discussion. Available online at https://windeurope.org/wp-content/uploads/files/policy/topics/sustainability/Circular-Economy-paper-20170418.pdf

[2] European Commission (2020) Circular Economy Action Plan: For a cleaner and more competitive Europe. Available online at https://ec.europa.eu/environment/topics/circular-economy_en

[3] IPCC,2018. Chapter 7 Energy Systems (Figure 7.6 p.539) Available online at https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf

[4] Cefic, EuCIA, WindEurope, 2020. Accelerating Wind Turbine Blade Circularity. Available online at https://windeurope.org/wp-content/uploads/files/about-wind/reports/WindEurope-Accelerating-wind-turbine-blade-circularity.pdf [accessed 20 July 2020].

small source of composite waste. Based on EuCIA estimates, wind will contribute only 10% of the total estimated thermoset composite waste (and less than 5% of the total estimated composite waste combining thermoset and thermoplastics) by 2025[4].

2. CALL FOR A EUROPE-WIDE LANDFILL BAN

As the wind farms from the early days of the onshore wind industry are reaching the end of their operational lifetime, the volume of decommissioned blades will increase throughout Europe. Annex 1 presents the latest data on these expected volumes.

The wind industry recognizes landfill disposal of decommissioned wind turbine blades as a waste of valuable resources. As a strategic industry, the wind industry also strives to be a leader in Europe's transition to a more sustainable, circular approach to managing resources. Through a circular economy approach, decommissioned wind turbine blades can be circulated into continual use of resources, along with the composite materials disposed of by other sectors (i.e., marine, construction, aviation, etc.).

To accelerate circularity, the wind industry calls for **a Europe-wide landfill ban on decommissioned wind turbine blades by 2025. This means the industry commits to re-use, recycle or recover 100% of decommissioned blades (as defined in Table 1). The ban should also apply to other large composite components that can be found in the nacelle.**

With the implementation of the European landfill ban in 2025, the wind industry also commits not to send decommissioned blades to other countries for landfilling. Such a ban would remove any doubts that wind turbine blades from Europe are not being landfilled.

Table 1: Definitions

Re-use (or re-purposing)	Re-using an existing part of the blade for a different application. For example, reusing blades for street furniture or building structures.
Recycling	The blade is reprocessed into a new product, material or substance with the same or different functional use. For example, mechanical grinding, pyrolysis and solvolysis.
Recovery	As defined in the EU Waste Framework Directive (2010) includes processes that enable energy or material recovery, or both. It means removing all individual components that can be used again and turning the remaining waste into a fuel or thermal energy after. For example, cement co-processing* and incineration with energy recovery.
* The 2012 EC guidance on the interpretation of key provisions of the Waste Framework Directive states that in certain production processes such as co-processing, waste can be used in an operation combining two waste management options at the same time. The organic content of the waste is	

recovered as thermal energy (recovery) while the mineral fraction of the waste can be integrated (hence recycled) in the matrix of product or material produced e.g. cement clinker.

The report 'Accelerating Wind Turbine Circularity' published in May 2020 presented the state-of-play in the recycling of composites materials used in wind turbine blades. Wind turbine decommissioning and end-of-life blade circularity is currently subject to much media attention and stakeholder interest. Four European countries have landfill bans in place for composites, including wind turbine blades (Austria, Finland, Germany and the Netherlands). Some Member States are implementing or considering specific legislation on turbines and blade circularity (e.g. France and Germany).

In pursuit of the common goal to advance circularity, the following section outlines the policies and partnerships required to support the wind industry's ambitious Europe-wide landfill ban on large composite components.

2.1. WHAT WILL IT TAKE TO SCALE UP CAPACITIES FOR TREATING DECOMMISSIONED BLADES?

In the next five years, efforts on making recycling and recovery options available and also commercially viable need to continue. **To accommodate the coming volumes of blade waste, European countries need to scale up the deployment of existing treatment routes taking into account the environmental impacts of each solution. And more importantly, the demand for recycled material must also be developed thus defining the route to market for companies and processes.** Creating these new markets and upscaling the technology does not depend solely on the wind industry. It is a task for all the actors in the value chain: research institutions, composite/material manufacturers, blade manufacturers, turbine operators, end of life treatment facilities, users of composites as well as governments.

Mechanical grinding and pyrolysis are the most mature technologies to recycle wind turbine blades. But more work and industrial upscaling is needed for pyrolysis to become more competitive and reach the required matureness to be widely deployed. And there needs to be a market for the granulates/powder (output of mechanical grinding process), recycled fibres and oils from the pyrolysis process. There are other recycling technologies such as high voltage pulse fragmentation, microwave pyrolysis and solvolysis in earlier development phases that still need to be demonstrated at industrial scale and on environmental aspects.

Cement co-processing is another tested and available measure to treat composite waste in the coming years. This technology avoids landfilling and makes the cement industry less energy intensive and more resource efficient[5, 6]. Currently, only one plant in northern Germany treats decommissioned blades with

[5] Thomas Wegman (EuCIA), 2020. Recycling Composites: Integral Part of Wind Turbine Blade Life Cycle presentation at the First Value Chain Meeting of the Moonshot Project, August 28 2020.

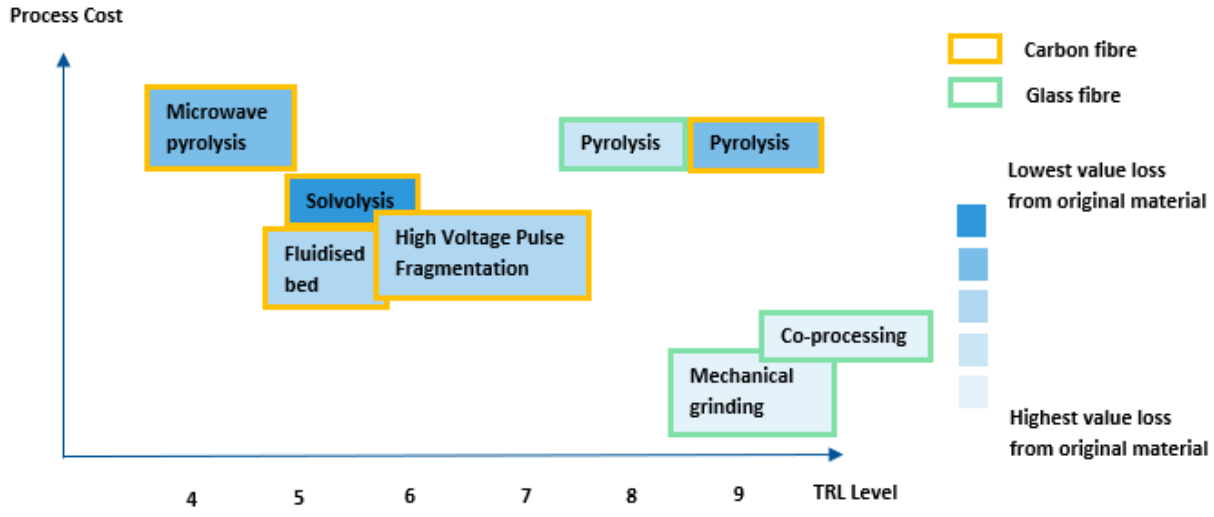
[6] Cefic, EuCIA, WindEurope, 2020. Accelerating Wind Turbine Blade Circularity. Available online at https://windeurope.org/wp-content/uploads/files/about-wind/reports/WindEurope-Accelerating-wind-turbine-blade-circularity.pdf [accessed 20 July 2020].

this technology. More plants throughout Europe could potentially adapt to use decommissioned blades as one of the main input materials. The wind industry is already working with the cement industry on an assessment of expected waste volumes, waste-handling capacities and regional distribution. This work needs to continue.

Currently there are at least seven potential routes to treat wind turbine blades. A full analysis of maturity levels, advantages and disadvantages can be found in the background report "Accelerating Wind Turbine Blade Circularity". **As of today, the technology race is still open – the coming years will show which technologies will be the most economical and the most sustainable.**

Figure 1 provides a comparison of the exisitng composite treatment technologies considering technological readiness level (TRL), costs and value of the recovered material. Another key dimension to consider is the potential environmental impacts of each technology but these have yet to be fully assessed in a standardised way. This overview is indicative, based on current knowledge and will be further refined as the technologies are developed.

Figure 1: Comparison of Recycling and Recovery Technologies



Source: Adapted from Bax & Company[7] & ETIPWind[8]

[7] Bax & Company (2019). Wind turbine blade circularity: Technologies and practices around the value chain. Available online at http://baxcompany.com/wp-content/uploads/2019/06/wind-turbine-circularity.pdf
[8] ETIPWind (2019) How wind is going circular: blade recycling. Available online at https://etipwind.eu/files/reports/ETIPWind-How-wind-is-going-circular-blade-recycling.pdf

3. POLICY AND PARTNERSHIP TO SUPPORT FULL RECYCLABILITY

In pursuit of Europe's decarbonization goals, policymakers play a critical role in accelerating the development of viable, cost-efficient, environmentally friendly solutions to enable full recyclability of wind turbines (including blades). To accelerate the wind industry's transition to a circular economy for the composite materials used in blades, **governments and funding bodies should direct their support to the following four pillars:**

- Increasing funding on research and development (R&D) and commercialisation for evaluating and scaling up diversified recycling technologies;
- Incentivising the use of recycled composite materials in new products;
- Increasing funding on R&D for the development and use of new (recyclable) blade materials; and
- Establishing a European cross-sectoral platform (including all composite waste producing sectors) to bring composite recycling to the next level.

The wind industry will **develop an industry roadmap** further detailing the steps required to accelerate wind turbine blade circularity. This roadmap will focus on the following workstreams, including the above pillars.

3.1. IMPLEMENTING THE LANDFILL BAN IN 2025

1. Engaging with waste treatment providers

The wind industry will continue engaging with the cement industry and recycling technology providers to ensure commercially viable and environmentally sound recycling and recovery options become available across Europe.

2. Industry reporting

Appropriate reporting metrics will be developed to increase transparency over the treated waste volumes and support monitoring.

As part of the reporting, the industry will investigate whether a single waste code for blade waste would help improve monitoring. Or whether existing tools such as the serial number are enough.

3.2. ACHIEVING FULL RECYCLABILITY OF EXISTING BLADES IN THE FUTURE

1. **Increasing funding on research and development (R&D) and commercialisation for evaluating and scaling-up diversified blade waste treatment technologies**

The wind industry is already engaging in R&D projects together with research institutes and/or recycling industry[9]. So far projects have focused on demonstration. Recyclers are often start-ups or small companies with limited capacities. The next steps need to be in industrial upscaling and commercialisation.

The Commission and Member States should therefore prioritise funding for this area under their respective R&D and recovery funds. The wind industry, research institutions as well as waste treatment companies will come up with projects to advance circularity through the following focus areas:

- Improve the scientific understanding of the carbon footprint and environmental impacts associated with the different blade waste treatment technologies;
- Diversify, develop and scale up recycling technologies for composite material, which produce higher value recyclates for new products, including new composites; and
- Prioritise upscaling of recycling technologies with highest benefits.

2. **Incentivising the use of recycled composite materials in new products**

In parallel with the development of separating/recycling technologies, it's also necessary that the demand for recycled composites develops. There is currently no market for the recycled composites. Recycled composites cannot compete with the price of virgin materials.

A system of incentives could be envisaged to ensure downstream users use the recycled composites from blades or buy the recycled end products. Therefore, improving the business case for the recycling industry to develop the necessary technologies. This system could include support for companies seeking to incorporate recycled materials into their products, for example, standards and certification to classify the recycled material performance. Another option could be to provide (interim) funding to support new manufacturing processes using recycled materials from wind turbine blades (and composite material from other sectors) for production of:

a. new materials; or

b. new composites for both the wind industry and other sectors.

These mechanisms (and others) to establish markets for recycling solutions within a circular economy require further investigation and development. More initiatives and funding support are needed on this front.

[9] A list of projects can be found here.

3. **Increasing funding on R&D for the development and use of new (recyclable) blade materials**

Continued R&D investment throughout the value chain is necessary to develop new, high performance materials with enhanced circularity and recycling abilities for composites in blades and other parts of the wind turbines;

The wind industry is already developing new material solutions. For example the ZEBRA project which brings together industrial companies (Arkema, Owens Corning, LM Wind Power, SUEZ and ENGIE) and technical centres (IRT Jules Verne / Plateforme Canoe) and aims to design and manufacture the wind industry's first 100% recyclable wind turbine blade, in a circular approach. Funded by the French government, the project has been launched for a period of 42 months. It has the target to manufacture, test, treat and recycle two prototype blades.

The Commission and Member States should prioritise funding for this area under their respective R&D and recovery funds.

4. **Setting recycling targets**

Through the roadmap process and based on progress made on the elements above, the wind industry will develop appropriate recycling targets.

3.3. MAKING FUTURE BLADES FULLY CIRCULAR

1. **Investigate the use of recycled composite materials in new wind blades**

Today the mechanical properties of recycled composites do not allow reuse into blades as the main properties cannot be maintained. In the longer term however, the industry aims to integrate recycled blade composites into the production of new blades (if this becomes technologically possible).

3.4. ESTABLISHING A EUROPEAN CROSS-SECTORIAL PLATFORM TO SUPPORT VIABLE COMPOSITE RECYCLING SOLUTIONS

1. **Engaging with other composite using sectors**

Composite recycling is not solely a challenge for the wind industry but rather a cross-sector challenge. Other industrial scale composite waste producing sectors include building & construction, electrical & electronics, automotive, marine, aeronautics, consumer and tanks & pipes. Active engagement from all composite-using sectors as well as support from authorities will be required to develop strong and competitive European value chains.

Recyclers also face a supply challenge when developing a business case for composite material recycling and for blade material recycling in particular. There are difficulties in securing a stable stream of blade material feedstock as this is dependent on decommissioning decisions by wind farm owners and blade composition differs.

To better support industry in finding solutions for end of life composites, the European Commission and Member States should consider setting a European platform in order to:

a. share best practices in recycling composites; and

b. investigate the possibilities of combining composite waste volumes from all sectors. This will help reduce the supply challenge and decrease recycling costs.

ANNEX 1: EXPECTED VOLUMES OF DECOMMISSIONED BLADES

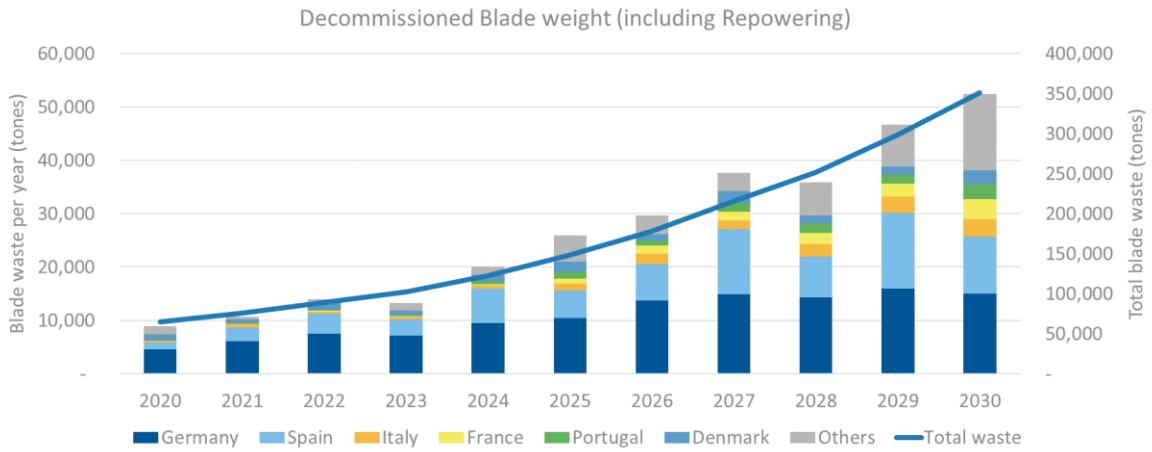
Today 34,000 turbines are 15 years or older, representing 36 GW of onshore wind capacity. Out of the 36 GW some 9 GW are 20-24 years old and around 1 GW are 25 years or older. Most of the ageing capacity is in Germany, followed by Spain, Italy, France and Portugal.

Timing of decommissioning is not uniform. Turbines can be operated beyond the time of the respective compensation scheme (e.g. through power purchase agreements (PPAs)). Although there aren't any incentives for repowering or life-time extension currently in Europe a couple of countries are discussing specific measures for their first generation of wind farms. Germany aims to support repowering, at the same time also allowing PPAs once their 20 years feed-in-tariff (FIT) expires. In Spain repowering projects could have stand-alone auctions.

To date, about 4 GW of capacity have been decommissioned in Europe, representing almost 50,000 tonnes of composite waste. In the next years, the amount of annual decommissioned turbines will largely depend on the policies and incentives being implemented as well as on the wholesale electricity price. While some turbines may be decommissioned after only 15 years, we can confidently say that the bulk of turbines will be decommissioned between their 20 and 30 years of lifetime. By 2030, the onshore wind industry will potentially decommission an additional 300,000 tonnes of blades. This is only a fraction of the total estimated composite waste.

Starting at less than 9,000 tonnes annually, we can expect blade waste to reach about 25,000 tonnes per year by 2025 and up to 52,000 tonnes per year by 2030[10]. Most of the turbines will be first decommissioned in Germany and Spain, with some activity as well in Denmark. Toward the end of the decade Italy, France and Portugal will also decommission a large number of ageing wind turbines. See Figure 2 below.

Figure 2 Expected Wind Turbine blade decommissioned (by volume)



Source: WindEurope

[10] We assume that 20% of the capacity is decommissioned after it reaches 20 years of operation, 40% is decommissioned after 25 years and that every wind turbine is decommissioned after 30 years.

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