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OPEN LETTER

Creating circular industrial symbiosis for end-of-life wind turbine blades from wind power and construction value chains

[version 1; peer review: 1 approved, 1 approved with reservations]

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Abstract

The upcoming scarcity of certain mineral resources in the construction industry has been known for years, with some warning that extractable ores may be exhausted within several decades. [1] Although this has been accepted for scarcer elements such as molybdenum or zinc, the scarcity of preconceived “abundant” resources such as sand or gravel is difficult to acknowledge. Nevertheless, recent studies have highlighted this scarcity at the local scale and connected it to its intense use by the construction industry as an aggregate. [2,2] The construction industry is the sink for a large fraction of mineral

Open Peer Review

Approval Status ? ✓

	1	2
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resources extracted (e.g., [3]) and therefore should also lead the way in reducing the use of virgin materials while also finding ways to recirculate waste materials.

Any reports and responses or comments on the article can be found at the end of the article.

Keywords
Construction materials, Wind power, Circular economy, Recycling, Repurpose, Repair, Reuse, end-of-life, wind turbine blades, value chain partnerships



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Author roles: Lima AT: Conceptualization, Data Curation, Funding Acquisition, Project Administration, Writing – Original Draft Preparation, Writing – Review & Editing; **Tyurkay A**: Writing – Review & Editing; **Romero-Gil J**: Writing – Review & Editing; **Paraskevoulakos C**: Writing – Review & Editing; **Liu T**: Writing – Review & Editing; **Fæster S**: Writing – Review & Editing; **Mishnaevsky Jr L**: Writing – Review & Editing; **Korsali M**: Visualization, Writing – Review & Editing; **Tung Dao D**: Writing – Review & Editing; **Pacheco V**: Conceptualization, Writing – Review & Editing; **Colomino G**: Writing – Review & Editing; **Gauvin F**: Writing – Review & Editing; **Lushnikovah N**: Writing – Review & Editing; **Skelton K**: Writing – Review & Editing; **Philipsend M**: Writing – Review & Editing; **Gómez A**: Writing – Review & Editing; **Resat HG**: Writing – Review & Editing; **Matschei T**: Writing – Review & Editing; **Vollpracht A**: Writing – Review & Editing; **Morales Cruz C**: Writing – Review & Editing; **Modestou M**: Writing – Review & Editing; **Semitekolos D**: Writing – Review & Editing; **Charitidis C**: Writing – Review & Editing

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Simultaneously, the wind power industry must address the increasing stream of end-of-life (EoL) wind turbine blades, whose primary materials are fiber-reinforced plastics (FRP). Europe's wind energy generation is expected to expand from 200 GW to 2,300 GW in the coming 30 years[4] by using larger and more resistant blade structures (the capacity of wind turbines will increase from 5–10 MW to over 25 MW). With repowering, there are a considerable number of EoL wind turbine blades. Despite various existing technologies for recycling composites, these solutions are not available at an industrial scale or economically competitive, with cement co-processing and landfills being the most widely used methods today. An estimated total–40-60,000 tons of wind turbines are likely to be decommissioned in Europe by the end of 2023, with an expected increase to 325,000 tons by 2050.[5] Waste management has become a key priority in the wind industry with the increasing number of wind turbines that come to the end of their operating lifetime.[6]

Circular economy across 2 value chains

Circular Economy (CE) has been proposed as a material and energy-efficient solution for product value chains (e.g., the Ellen MacArthur Foundation). The concept has gained considerable momentum in recent decades and has been adopted across sectors and disciplines. The current accepted framework establishes (from high to low circularity) Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover. We reduce and optimize resource and material use as we increase the circularity ladder. In summary, reuse is more energy-, material-, and resource-efficient than recycling. The success of the R framework resides in its versatility in cross-sectoral applications, with numerous products and applications fitting the CE concept.

Composite recycling is a cross-sector challenge, and cross-value chain cooperation is imperative for closing the loop of EoL wind turbine blades. By bringing the wind energy and construction value chains together, we aim to create a symbiotic relationship that avoids sending EoL wind turbine blades to landfills by using them as a secondary resource in the construction industry, thereby reducing its dependency on raw virgin resource materials such as reactive binders and fine aggregates, such as siliceous sand or fillers.[7] This is precisely what the project Blades2Build aims to support in achieving the EU's 2050 Environmental Goals and Sustainable Development Goals (SDGs). Blades2Build is a new Horizon Europe Innovation project that demonstrates at an industrial scale the ambitious goal of improving and supporting circularity solutions for EoL wind blades by exploring three different circular stages (Figure 1):

- Direct reuse of EoL wind turbine blades with minimal refurbishment or processing.

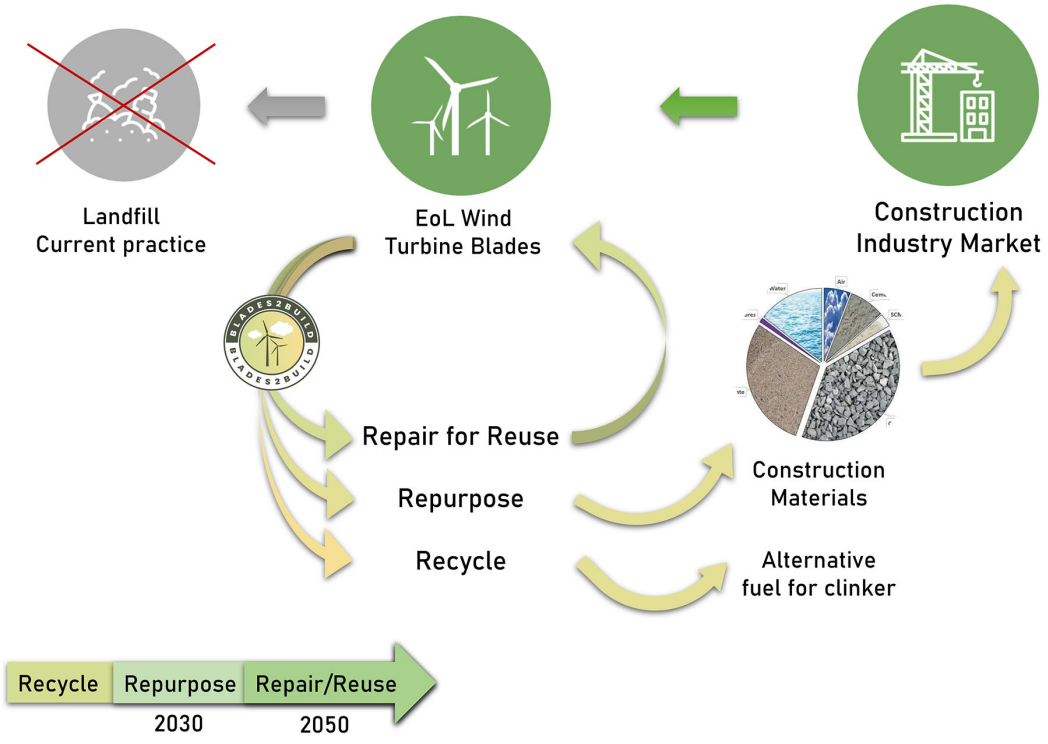

Figure 1. The circular options put forward by Blades2Build to simultaneously reduce waste from wind power generation and pressure on raw materials by the construction industry.

- Individual material constituents of the blades (and wind turbine blade manufacturing waste) are repurposed for other uses/products, specifically in construction materials, with the use of concrete and asphalt mixtures as the first option, creating circular products.

- Recycling the blade and manufacturing waste containing resin in cement/clinker co-processing as alternative raw materials and fuel (the resin provides heat, while the fibers left after combustion can be used as raw materials).

From the repurposing and recycling routes, we will create new construction materials with FRP material waste from wind turbine blade structures.

Synergistic and multidisciplinary approaches are required to achieve a truly circular future. We cannot neglect that our society stands on "raw" materials exploitation and manufacturing, and that many products and services need these materials' conditions to function. As we strive for higher levels of circularity (reuse, reduce), we should cooperate with cross-value chains – in an open-loop supply chain fashion – to use waste materials from one value chain and relieve the pressure on raw materials of the other in an economical process. In this way, we guarantee that the future renewable energy supply and construction materials respond to policies that are responsible for zero waste and resource efficiency.

Authors' statement

The first author wrote the manuscript. The co-authors were equal collaborators in editing and revising this article.

Ethics and consent

Ethical approval and consent were not required.

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Data availability

No data was used in the writing of this statement paper – data used in this paper are from external references. All references are cited in the reference list.

References

1. Henckens MLCM, van Ierland EC, Driessen PPJ, *et al.*: **Mineral resources: Geological scarcity, market price trends, and future generations.** *Res. Policy.* 2016; **49**: 102–111.
Publisher Full Text

2. Ioannidou D, Meylan G, Sonnemann G, *et al.*: **Is gravel becoming scarce? Evaluating the local criticality of construction aggregates.** *Resour. Conserv. Recycl.* 2017; **126**: 25–33.
Publisher Full Text

3. European Commission: **Buildings and construction - Internal Market, Industry, Entrepreneurship and SMEs.** 2026. (accessed February 3, 2026).
Reference Source

4. Dickson G: **Electrifying Europe with wind energy – towards net-zero by 2050 - The European Files, The European Files.** 2021. (accessed March 23, 2023).
Reference Source

5. Lichtenegger G, Rentizelas AA, Trivyza N, *et al.*: **Offshore and onshore wind turbine blade waste material forecast at a regional level in Europe until 2050.** *Waste Manag.* 2020; **106**: 120–131.
PubMed Abstract | Publisher Full Text

6. WindEurope: *How to build a circular economy for wind turbine blades through policy and partnerships.* WindEurope, Wind Europe; 2021. (accessed March 23, 2023).
Reference Source

7. Liu T, Duyal C, Paraskevoulakos C, *et al.*: **Effect of wind turbine blade waste on cement hydration and gel structure: Competitive interaction of glass and polyester resin.** *Compos. Part B Eng.* 2026; **311**: 113273.
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Open Peer Review

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✓ **Hala Jarallah El-Khozondar**
Islamic University of Gaza, Gaza, Palestinian Territory

1. **Is the rationale for the Open Letter provided in sufficient detail?**
   Yes – The article clearly explains the growing scarcity of raw construction materials and the increasing challenge of end-of-life wind turbine blade waste. It effectively justifies the need for circular economy approaches and cross-sector collaboration between the wind energy and construction industries.
2. **Does the article adequately reference differing views and opinions?**
   Partly – The article discusses several circular economy pathways (reuse, repurpose, recycle, and co-processing) and acknowledges current industrial practices such as landfilling and cement co-processing. However, it does not deeply explore alternative viewpoints, limitations, or critical debates regarding the feasibility, environmental trade-offs, or economic barriers of these approaches.
3. **Are all factual statements correct, and are statements and arguments made adequately supported by citations?**
   Yes – The major claims are supported with references and quantitative estimates, including projected wind energy growth, expected blade waste volumes, and circular economy frameworks. The discussion appears scientifically grounded and appropriately referenced.
4. **Is the Open Letter written in accessible language?**
   Yes – The article is written in generally clear and accessible language. Key concepts such as circular economy, recycling routes, and value-chain cooperation are explained adequately, making the content understandable to a broad scientific and industrial audience.
5. **Where applicable, are recommendations and next steps explained clearly for others to follow?**
   Yes – The article clearly outlines practical circular economy pathways and explains how the Blades2Build project intends to implement reuse, repurposing, and recycling strategies at industrial scale. The recommendations are sufficiently detailed to encourage further engagement and collaboration within the research and industrial communities.

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is

explained)
Yes

Does the article adequately reference differing views and opinions?
Partly

Are all factual statements correct, and are statements and arguments made adequately supported by citations?
Yes

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)
Yes

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: renewable energy; solar cells, wind turbine, nanomaterials

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 07 April 2026

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This Open Letter introduces the Blades2Build project, a Horizon Europe-funded initiative aiming to establish a circular industrial symbiosis between the wind energy and construction sectors. The authors propose three circular pathways — direct reuse, repurposing into construction materials, and recycling via cement co-processing — to address the growing challenge of end-of-life (EoL) wind turbine blade waste. The topic is timely, relevant, and aligns well with EU sustainability goals. However, minor issues should be addressed before the article is considered fully satisfactory.

Insufficient critical discussion. The article does not adequately address potential limitations or risks. For instance:

1. What are the known technical barriers to incorporating fiber-reinforced plastic (FRP) waste into concrete and asphalt mixtures (e.g., fiber dispersion, long-term durability, potential leaching of chemical compounds)?
2.What is the economic feasibility of these pathways at industrial scale compared to current practices (landfill, cement co-processing)? A brief acknowledgment of these challenges would significantly strengthen the credibility of the article.

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)
Yes

Does the article adequately reference differing views and opinions?
Yes

Are all factual statements correct, and are statements and arguments made adequately supported by citations?
Yes

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)
Yes

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Wind turbine blade recycling

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.