Circular business model patterns for wind turbine blades recycling

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Extended abstract

In the upcoming years, a significant increase in the volume of wind turbine blades (WTBs) reaching their end-of-life (EoL) is anticipated (Lund and Madsen, 2024). Currently, between 85% and 90% of the total mass of wind turbines can be recycled (Khalid et al., 2023). Most components of a wind turbine - the foundations, tower, and nacelle components - have established recycling practices. However, WTBs are more challenging to recycle due to their thermoset composite construction (Delaney et al., 2021). It is estimated that 2.5 million tons of composite materials are used in the wind energy sector worldwide (ETIPWind, 2019). WindEurope et al. (2020) estimated that by 2023, around 14,000 blades could be decommissioned, which equates to between 40,000 and 60,000 tons. Recycling these old blades is an absolute priority for the wind industry, creating an urgency for logistical and technological solutions for disassembly, collection, transportation, waste management, and reintegration into the value chain (WindEurope et al., 2020).

This approach needs to be supported by the development and implementation of circular business models (CBM) and value chains. Recycling CBMs can be understood as companies that contribute to increasing the value of resources by enabling the recovery and reprocessing of materials into new components and products (Pieroni et al., 2020), which translates into new business opportunities while generating environmental savings. Moreover, recycling CBMs extend beyond the wind industry, where recyclates (e.g. fillers, fibres, resins and hydrocarbon products obtained through blade recycling) are used in other industries, such as construction industry for cement production, chemical industry through bulk moulding compounds production and oil industry, i.e. using hydrocarbon products generated through pyrolysis (Mendoza et al., 2022).

However, the establishment of circular and sustainable business models and value chains for WTB management remains in its nascent stage (Lund and Madsen, 2024; Mendoza and Ibarra, 2023). Stakeholders in the wind industry need guidance, experience and convincing evidence to initiate experimentation with CBMs and value chains (Mendoza et al., 2022; Mendoza and Ibarra, 2023). CBM experimentation can be driven by approaches that demonstrate the advantages, feasibility, and economic viability of different CBMs (Bocken et al., 2019; Pieroni et al., 2021; Schroedel, 2023). In this sense, it is believed that the use of generic CBM patterns (Lüdeke-Freund et al., 2019), industry specific CBM patterns (Pieroni et al., 2020) and inspiring cases of companies that have successfully implemented CBMs (Mendoza et al., 2022; Mendoza and Ibarra, 2023) can help stakeholders in the wind industry to build experimentation capabilities with CBMs and value chains.

The literature addresses reviews on processes and technologies for sustainable EoL routes of WTBs (Lund and Madsen, 2024), the mechanical, thermal, and chemical recycling methods for EoL-WTBs and their corresponding recycled products (Zhang et al., 2023), and the available wind-blade recycling processes, evaluating their economic, technical, and environmental performance (Sorte et al., 2023). Some authors making a clear contribution towards becoming more circular in the wind energy supply chain (Kramer and Schmidt, 2023). However, to the best of the authors knowledge, no contributions have been identified offering a holistic overview of recycling CBMs and value chain alternatives. Moreover, more research based on empirical data is necessary, as Lund and Madsen (2024) identified in their systematic literature review on sustainable end-of-life wind turbine blades, where they analyzed in depth 61 relevant publications; none of the reviewed literature contained empirical data from end-of-life blade projects.

As part of an ongoing research project, the objective of this paper is to develop a practical circular business model innovation tool (in the form of business model patterns) that integrates both industry-specific cases and generic circular economy strategies to guide actors in the wind industry in the ideation and design of business model alternatives for the EoL of WTB. The methodology consists of a literature review covering 1) existing circular business model patterns in the literature and 2) specific real cases of the EoL value chain of WTBs. Based on the results, a set of CBM patterns will be define, including both generic (e.g. Lüdeke-Freund et al., 2018; Schroedel, 2023) and industry-specific, evidence-based, ones. Pattern development will follow well established approaches (see Lüdeke-Freund et al., 2018, 2024; Pieroni et al., 2021; Remane et al., 2017). These findings will enable companies in the sector to benchmark and devise new, more circular and sustainable business models and value chains. It is also expected that the results will show which generic CBM are currently being applied in the EoL of WTB and what innovative CBM patterns may be emerging.

Keywords

Business model pattern, business model design, circular economy, wind industry, End-of-Life (EoL)

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