Exploring the applicability of business model life cycle assessment

Wind turbine blade cement co-processing compared to fibre reinforced concrete production.

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Extended abstract

Many different tools have been developed in the last decade to support sustainable business model (SBM) innovation, understood as "*innovations that create significant positive and/or significantly reduced negative impacts for the environment and/or society, through changes in the way the organisation and its value-network create, deliver value and capture value or change their value propositions*" (Bocken et al. 2014, p. 44). However, existing tools have a narrowed approach, which can drive to undesired outcomes.

For instance, Bocken et al. (2019) conclude that most of the existing tools focus only on the ideation and (early) design phases of innovation processes and are (semi-) qualitative in nature. These tools are mostly based on the application of design thinking approaches (e.g. Santa-Maria et al. 2022), the evaluation and adoption of business model patterns (e.g. Ludeke-Freund et al. 2022, Schroedel 2023), the use of alternative versions of the original (conventional) business model canvas (Osterwalder and Pigneur 2010), such as the flourishing business model canvas (Flourishing Businesses 2014), the circular economy business model canvas (Pieroni et al. 2021) or the triple layered business model canvas (e.g.

Joyce and Paquin 2016), and the use of cards (e.g. Circular Economy Pattern Cards - BMI Lab 2024 or the Circularity Card Deck – Konietko et al. 2020) and/or games (e.g. In the Loop - Whalen 2024, The Blue Connection – Inchainge B.V. 2024 or ECOCEO - VITO 2024).

All these tools are useful as they can support training processes and facilitate the evaluation of business models and value chains from multiple approaches, while inspiring industry professionals to take action towards the development of more sustainable production and consumption systems in different sectors (e.g. Mendoza et al. 2019, Pollard et al. 2023). However, limited assessments of sustainability due to the lack of system thinking integration and the use of suitable quantitative metrics in the available SBM tools, can lead to unintended consequences, negative trade-offs, greenwashing or be misleading for business sustainability, as happens with many of the available sustainability reporting frameworks, ratings, rankings and standards (Schluter et al. 2023, Kurucz et al. 2017). Consequently, it is crucial to rely on the use of quantitative and system-oriented tools to support SBM innovation processes (Ibarra and Mendoza 2023).

Business model life cycle assessment (BM-LCA) is emerging as a suitable systematic approach for the evaluation of the (environmental) sustainability performance of business models (Bockin et al. 2022). While product-based life cycle assessments (LCA) fail to capture the impacts of business model developments by understanding the business-related socio-technical and economic dimensions, SBM assessment tools usually lack the consideration of quantitative product-related indicators and functional aspects (such as quality, efficiencies, and alike) from a life cycling thinking perspective. Accordingly, BM-LCA can, on the one hand, enable the quantitative environmental assessment of business models and can, on the other hand, be used to compare the environmental performance of different business models to determine if actual decoupling is being achieved (Bockin et al. 2022). Nevertheless, as this technique is quite novel, there is a very limited number of case studies analysing its application in practice to demonstrate its usefulness and value to support the development of SBMs and value chains, while helping to improve the BM-LCA method further.

This conference paper explores the barriers and opportunities for the practical application of the BM-LCA framework, by following the guidelines from Bockin et al. (2022), Goffetti et al. (2022) and Claesson et al. (2023), to analyse and compare the environmental and economic sustainability performance of two alternative business models for the end-of-life (EoL) management of wind turbine blades (WTBs): i) WTB-based clinker co-processing (Nagle et al. 2022) and ii) WTB waste use for fibre reinforced concrete production (Revilla-Cuesta et al. 2023).

These WTB-EoL management business models are recognized for their advanced Technology Readiness Level (TRL), providing robust cases for investigation to respond to the following key research questions:

- What are the advantages and disadvantages of each WTB-EoL management system based on the environmental and economic performance of these business models? Hence, which model is best?
- Given the significant volume of WTB waste anticipated in the near future, are these EoL business models suitable long-term sustainable solutions, or merely temporary fixes awaiting for more resource efficient and economical alternatives?

Accordingly, the research methodology relies on data gathered from real-life applications. On the one hand, the WTB waste-based fibre-reinforced concrete production scenario involves the use of secondary raw material obtained from crushing the WTBs. The crushed material, referred to as "raw crushed WTB", replaces common aggregates, such as sand or gravel used in concrete production (Revilla-Cuesta et al. 2023). On the other hand, the WTB waste-based clinker co-processing scenario is based on the production of clinker by integrating secondary raw material from residual WTBs in substitution of silica and other aggregates (Nagle et al. 2022). First the environmental impact of each production system is calculated by means of life cycle assessment (LCA) (ISO 2006) considering the treatment of 1 tonne of WTB-waste material. Subsequently, the study is extended by exploring, from a qualitative standpoint, the applicability of BM-LCA (Bockin et al. 2022) to determine their economic sustainability by relying on the consideration monetary flow diagrams and cost and revenue equations that depict both economic transactions and material exchanges. As a result, barriers, opportunities and practical guidelines for the application of the BM-LCA framework within this industry are provided.

WTB-EoL management is used as case study because forecasts indicate that between 185 kt and 570 Mt of blade waste will have been generated by 2030 in the European Union alone due to wind farms decommissioning and/or repowering (Díez-Cañamero and Mendoza 2023). This represent both a challenge and an opportunity to develop new circular and sustainable business models and value chains around the life cycle management of wind farms, and particularly, WTBs (Mendoza et al. 2022).

Keywords

Business model innovation, circular economy, life cycle thinking, sustainable business models, wind turbine blades.

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