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Building Elements from Straw: Challenges of a Circular Business Model

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ABSTRACT:
The transition to a circular and bio-based economy is critical for achieving sustainable development in the construction sector. This study explores the viability of straw, a widely available agricultural residue, as a sustainable building material within a circular business model. Using the case of prefabricated straw panels in Denmark and Sweden, the research applies the Triple-Layered Business Model Canvas (TLBMC) to assess challenges for a successful business model within the economic, environmental, and social dimensions. A mixed-methods approach, including stakeholder workshops, document analysis, and expert interviews, reveals that straw-based construction offers significant benefits, such as carbon sequestration, reduced material use, and local value creation. However, challenges persist, including seasonal supply constraints, high transport costs, regulatory complexity, and limited public awareness. The findings underscore the need for supportive policy frameworks, certification pathways, and public procurement incentives to scale up straw-based construction. This paper contributes to the discourse on sustainable building practices by highlighting the potential of agricultural byproducts to foster circularity, reduce emissions, and enhance regional resilience.

Keywords: bioeconomy; straw; circular business model; circular economy.

1. Introduction

The building sector is under increasing pressure to reduce its environmental footprint and contribute to the transition towards a more sustainable and circular economy. In the Nordic countries, including Denmark and Sweden, this pressure is particularly pronounced due to national commitments to address sustainability challenges and operate within planetary boundaries (Madsen et al., 2021). One promising pathway to achieve this is through the promotion of a bioeconomy, which emphasizes the use of renewable biological resources to replace fossil-based and resource-intensive materials (Salvador et al., 2025).

Within this context, bio-based building materials have gained attention for their potential to reduce greenhouse gas emissions, enhance circularity, and support local economies. It is estimated that between 30–70% of the carbon footprint of the building industry can be reduced if biobased materials replace conventional ones (Pedersen, 2021). Among these materials, straw stands out as a particularly compelling option. As a byproduct of cereal production, straw is abundantly available and currently underutilized.

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In Denmark alone, approximately 3.4 million tons of straw remain unused annually, while the construction sector consumes around 320,000 tons of fiber insulation per year, highlighting a significant opportunity for substitution (Agriwatch, 2022).

Using straw for construction can offer several environmental and economic advantages. Since the land is already used for growing crops, utilizing straw avoids the need for additional land use (Madsen et al., 2021) to produce alternative products. Moreover, straw-based products can be designed for disassembly and reuse, contributing to circular construction practices. For example, the company EcoCocon makes prefabricated straw panels which are assembled using screws rather than nails, enabling recovery and reuse at the end of life (Teknik & Miljø, 2024). These panels are also treated with natural oils instead of paints or varnishes, avoiding harmful chemicals and simplifying maintenance.

EcoCocon has already supplied materials for projects such as the school in Feldballe, Denmark, and is planning the establishing of a factory in Denmark (Agriwatch, 2022). This would not only create local value but also help scale up the use of straw in construction. The company's panels are capable of storing more CO_2 than is emitted during their production, making them a potential net carbon sink (EcoCocon, 2024a). Despite these benefits, straw-based construction remains a niche market and faces challenges such as seasonal availability, quality control, and limited public awareness.

The objective of this paper is to explore the main challenges of using straw as a building material within a circular business model. Focusing on the case of EcoCocon and its potential application in Denmark and Sweden, the study maps out the key elements of a viable business model and identifies barriers for broader adoption.

The paper is structured as follows: Section 2 provides a literature review addressing the benefits and challenges of building elements from straw and their respective business models. Section 3 presents the methodology, including stakeholder engagement, documental analysis, and interviews. Section 4 outlines the results using the Triple-Layered Business Model Canvas (TLBMC) framework. Section 5 discusses the main challenges for a successful circular business model to create value locally. Finally, Section 6 concludes with key insights and recommendations.

2. Literature Review

The transition to circular and bio-based building has gained momentum as a response to the environmental impacts of the building sector. Straw, an agricultural byproduct, has emerged as a promising material due to its carbon sequestration potential, local availability, and compatibility with circular design principles (Dovgal, 2022; Spyridonos et al., 2024). However, the successful integration of straw into construction business models requires a nuanced understanding of both systemic benefits and implementation challenges.

Circular business models (CBMs) are increasingly recognized as enablers of sustainable innovation, particularly when aligned with sector-specific dynamics (Zamfir et al., 2017; Opferkuch et al., 2021). In the construction sector, CBMs can support value creation through material reuse, modularity, and local supply chains (Aithal & Aithal, 2023; Zhang, 2023). Yet, as Johnson and Schaltegger (2015) highlight, small and medium-sized

enterprises (SMEs), often central to such innovations, face barriers including limited resources, regulatory complexity, and lack of tailored sustainability tools.
Straw-based construction exemplifies these tensions. Studies identify several recurring challenges. First, straw's seasonal availability and sensitivity to moisture complicate supply chain reliability and quality control (Kanters et al., 2023; Podmolík, 2024). Transport and storage costs are also significant due to straw's bulkiness and the need for dry, ventilated storage (Dovgal, 2022; Spyridonos et al., 2024). Second, regulatory and certification hurdles persist, as straw-based materials often fall outside conventional building codes, requiring additional approvals and documentation (Zamfir et al., 2017; Muriithi & Ngare, 2023). Third, market perception remains a barrier: straw is frequently viewed as a low-tech or "alternative" material, limiting its appeal despite its technical performance (Kanters et al., 2023; Podmolík, 2024).
Moreover, most straw-based businesses operate on a project-by-project basis, limiting economies of scale and increasing unit costs (Johnson & Schaltegger, 2015; Dey et al., 2020). Policy support is uneven, with limited access to subsidies, green procurement, or carbon credit markets that could improve the business case (Ho & Lin, 2024; Zhang, 2023). Finally, while straw is inherently circular, end-of-life reuse systems and reverse logistics are not yet standardized, limiting the realization of full circularity benefits (Dovgal, 2022; Versino & Cesaro, 2023).
In sum, while straw-based building elements offer compelling sustainability benefits, their integration into viable business models depends on overcoming structural, perceptual, and institutional barriers. Future research and policy must focus on enabling frameworks that support innovation, reduce risk, and foster cross-sector collaboration.

3. Methods

The scope of this study encompasses the use of straw (from different origins, such as barley, wheat, etc.) in the regions of Southern Sweden and Western Denmark to make building elements. Given the study's aim of investigating the main challenges of using straw as a building material within a circular business model, an illustrative product is used as an example, using EcoCocon as the illustrative business model. While EcoCocon provides a rich and illustrative case, it represents a specific business model and context. Therefore, the findings may not be fully generalizable to other companies or regions with different regulatory, supply chain, or certification conditions. Nonetheless, as this research is part of a specific project, we must remark that EcoCocon was selected for being representative of the use of straw in buildings in the region (Agriwatch, 2022; Teknik & Miljø, 2024).

This study employed a mixed-methods approach to evaluate the viability and systemic integration of straw-based building elements within circular construction models. The research design combined (i) stakeholder engagement through a structured workshop, (ii) the analysis of technical documentation and academic literature, (ii) a series of interviews with stakeholders.

3.1 Stakeholder engagement through a structured workshop

A workshop was conducted during a partner meeting. The workshop followed a semi-structured interview guide developed around the Triple-Layered Business Model Canvas (TLBMC) framework (Joyce & Paquin, 2016). The guide included open-ended questions across the blocks of the canvas, grouped into three layers, economic, environmental, and social. The interview guide is available upon request.

The workshop lasted 1h30min and counted on the participation of 4 specialists (see Table 1). The scope of the workshop was to identify (a) the main stakeholders within a potential business model for building elements from straw, and (b) the main challenges for such a business model. The time divided evenly across the different building blocks, and the prompting questions for discussion around each building block was based on an interview guide (see section 3.3). Responses were recorded in post-its which were placed on a containing with the TLBMC framework. These were later synthesized into a structured summary aligned with the TLBMC framework. This synthesis was used to identify key themes, stakeholder priorities, and perceived barriers and enablers for straw-based construction.

3.2 Document and data analysis

A comprehensive review of technical documentation was conducted. This included product specifications, environmental product declarations (EPD), certification reports (e.g., Passive House, Cradle to Cradle), and internal planning and logistics guides for a specific product example. These documents were analyzed to extract information on material composition, product performance (in relation to both techno-economic and environmental aspects). After the scope of the project was determined (with the scope being building elements from straw), the documents were gathered by going to a company website and collecting all relevant information guides available on the website, reaching out to relevant stakeholders, including all participating in the workshops and interviews, and asking them about relevant materials for revision. A total of 43 documents were gathered and reviewed, including technical specification guides for the product, certifications, context-building news, and targeted academic papers. The information extracted from these documents was coded in the format of the TLBMC framework (Joyce & Paquin, 2016). This analysis complemented the initial summary resulting from the workshop described in section 3.1. We remark, though, that while document analysis provided structured insights, it may omit tacit knowledge held by practitioners, this is one of the reasons why we carried out interviews using a multi-stakeholder approach.

3.3 Interviews with stakeholders

A series of interviews were conducted with specialists in (i) straw collection, commercialization and processing, (ii) research in straw as a biobased building material, and (iii) industrial production and commercialization of building elements from straw. The position/title, institutional affiliation, and country of each interviewee, experience in the area (years), and the duration of each interview, is provided in Table 1 (same ID means same participant).

The interviews were conducted using an interview guide that was sent to interviewees a few days prior to the interview. Out of four interviews, three took place on a video call with automatic recording and transcription, and one took place physically, being voice-recorded and later transcribed using the tool Otter.Ai. The interviews took place between May 14th and June 19th, 2025. All interviews were conducted in English.

After transcribed, all interviews were coded into the TLBMC framework, thus complementing the information acquired from the two previous steps. The purpose of the interviews was mainly to fill information gaps, based on the documental analyses and the workshop, and to acquire views from different stakeholders on how to establish a successful business model for building elements from straw.

Table 1: Stakeholders interacted with during workshops and interviews

Event	Duration (h:min)	ID	Position/title	Affiliation	Country	Experience in the area (years)
Workshop on Business Model	1:30	A1	Researcher in sustainable building materials	Lund University	Sweden	20
	1:30	A2	Researcher in sustainable and value-added use of straw	Roskilde University	Denmark	26
	1:30	A3	Researcher in Circular Bioeconomy and Circular Business Models	Technical University of Denmark	Denmark	8
	1:30	N1	Project manager in circular economy	Gate 21	Denmark	7
Interview	1:00	I1	Chief Executive Officer	EcoCocon	Denmark	28
	0:35	I2	Chief Consultant; Secretariat	Danish Agriculture and Food Council; Danish Straw Association	Denmark	19
	0:45	A1	Researcher in sustainable building materials	Lund University	Sweden	20
	1:35	A2	Researcher in sustainable and value-added use of straw	Roskilde University	Denmark	26

4. Results - Triple-Layered Business Model for Building Elements from Straw

A summary of the business model of building elements from straw, using the framework of the Triple-layered Business Model Canvas, for the economic, environmental, and social dimensions, is presented hereafter. For reasons of conciseness, not all building blocks for each layer (economic, environmental, social) are present in the analysis. The building blocks not presented were not addressed or addressed to a limited extent during the interviews, workshop, and documental analysis. We do not argue for their relevance or lack thereof.

4.1 Economic

Value proposition: The value proposed by building materials from straw spans a range of stakeholders. For builders, engineers and architects, it can be a matter of status and compliance with legislation before the so-called green transition, where "green buildings are the future", but also a source of agility in construction, with dry processes speeding up the time to build. For local farmers it can mean valorisation of the local agriculture, as byproducts of different crops are used as feedstock. For building owners, it can mean low energy demands, and less money spent on the foundation (due to lighter materials) and better indoor climate, due to effusivity (how quickly a material can exchange heat with its surroundings) and diffusivity (allowing moisture exchange). Another advantage of the product is that it is assembled using screws, not nails, which allows recovery of the parts at their end-of-life for subsequent use.

Customer Segments: Key customer groups include architects (attracted by the green image), private homeowners (interested in cost and speed), developers, housing cooperatives, and renovation contractors. The appeal depends on aesthetics, ease of use, and technical performance. The potential for reuse could expand the customer base (I1).

Customer Relationships: The sales process is highly customized. Clients initiate orders, receive a price estimate within three days, and a detailed panel project within four weeks. Production takes 4-12 weeks, followed by delivery in 2-4 days. Long-term relationships are built on trust, technical support, and warranty assurances (50 years for structure, 25 years for insulation) (EcoCocon, 2023f).

Revenue Streams: Primary revenue derives from panel sales (~€150/m²). There is potential for additional income through CO_2 credit monetization, especially given the panels' carbon sequestration capacity (A1; EcoCocon, 2024a). However, this aspect needs further exploration, as the carbon credit market does not yet seem to be established in this segment in the local context of Denmark and Sweden.

Key Resources: Critical resources include well-rounded contracts with farmers or associations for straw supply, which is dependent on market competition with the energy sector where straw is a key supplier. Specialized machinery in production facilities for straw compression is also needed. Intellectual assets include proprietary panel designs, certifications, and software for design integration (EcoCocon, 2023e).

Key Activities: Core activities include straw sourcing, which is carried out by farmers, to whom straw is a byproduct; storage of straw in bales and later transport to the manufacturing site where the panels are made; quality control (especially moisture management), and general logistics across the life cycle (I1). Communication with farmers and clients is essential (I2).

Key Partnerships: Strategic partners include farmers and their associations, for raw material supply, government bodies, for regulatory alignment, and research institutions, for innovation and validation (A1, A2, I2; N1).

Cost Structure: Major cost drivers include transport, processing, and quality assurance. Costs are categorized into fixed (e.g., facilities) and variable (e.g., straw, transport). Seasonal availability of straw introduces inventory and sourcing challenges. However, the use of agricultural byproducts and reduced foundation needs help offset costs (EcoCocon, 2025; I2).

4.2 Environmental

Value Proposition: The panels are composed of 98% renewable materials and sequester approximately 97.6 kg CO_2/m^2, and can result in a net negative carbon footprint. The system is diffusion-open yet airtight, providing moisture and thermal buffering. It supports biodiversity by using local, low-impact materials and reduces energy demand through superior insulation (EcoCocon, 2024a; EcoCocon, 2023b).

Key Activities: Environmental performance is enhanced through careful straw selection, moisture control, and minimal processing. The production process has potential to be zero-waste and water-free, with low primary energy use (EcoCocon, 2023e).

Key Resources: Straw and wood can be sourced locally and used in raw form. An airtight membrane and clay plaster contribute to the system's hygrothermal performance. Certifications (e.g., Passive House, Cradle to Cradle) validate environmental claims (EcoCocon, 2024b; EcoCocon, 2023a).

Cost Structure: Environmental costs can be minimized through efficient logistics and material use. The lightweight nature of the panels reduces transport emissions and the need for heavy and material-demanding foundations. The potential for reuse at end-of-life enhances circularity (EcoCocon, 2023c; EcoCocon, 2023f).

4.3 Social

Value Proposition: Panels contribute to the occupant's well-being through improved indoor air quality, thermal comfort, and acoustic performance. The use of natural, untreated materials supports health and safety (A1; EcoCocon, 2023b).

Customer Segments: The system appeals to socially conscious consumers, public sector clients (e.g., schools, housing), and communities seeking healthier living environments (A1; I1).

Customer Relationships: Trust and transparency are central to stakeholder engagement. The provision of technical support, clear documentation, and long-term warranties fosters confidence among clients and partners (EcoCocon, 2023d; EcoCocon, 2023f).

Key Partnerships: Municipalities and local governments play a role in enabling adoption through procurement and regulation. Farmer cooperatives and community networks support local value creation (I1; Kjaer, 2024a).

Cost Structure: Social costs are mitigated through local sourcing, job creation, and reduced health risks. The system's modularity and reuse potential further enhance its social value (Kjaer, 2023; Kjaer, 2024b).

5. Discussion

The business model depicted in this study shows that recovering the value of straw to make building elements is beneficial in many aspects, although existing challenges cannot be disregarded. When analysing the potential business model, aspects that stand out to be further discussed are the challenges that need to be faced when establishing such business models. We summarise the main challenges in Table 2 and discuss them hereafter.

Table 2: Business Model Challenges for Straw-Based Building Elements

Layer	Category	Challenge	Sources
Economic	Cost Structure & Logistics	High transport costs for bulky panels, especially for long-distance deliveries	I2; Workshop; EcoCocon (2025); Dovgal (2022); Spyridonos et al. (2024)
	Revenue Streams & Pricing	Seasonal availability of straw requires storage and long-term supply agreements	A1; A2; I2; Workshop; EcoCocon (2023f); Kanters et al. (2023); Podmolík (2024)
	Scalability	Custom, project-based production limits economies of scale	I1; Workshop; EcoCocon (2023e); Johnson & Schaltegger (2015); Dey et al. (2020)
	Revenue Streams & Pricing	Uncertainty around monetizing CO_2 sequestration (e.g., carbon credits)	I1; I2; Workshop; EcoCocon (2023b)
	Policy & Institutional Support	Access to public procurement and subsidies is uneven and often favors conventional materials	A2; I1; I2; Workshop; EcoCocon (2023d); Ho & Lin (2024); Zhang (2023)
Environmental	Material Sourcing & Circularity	End-of-life reuse and recycling systems for panels are not yet standardized	A1; I1; Workshop; (EcoCocon, 2023b); Dovgal (2022); Versino & Cesaro (2023)
	Certification & Compliance	Navigating diverse national regulations on bio-based materials is complex	A2; I1; I2; Workshop; (EcoCocon, 2023e); Zamfir et al. (2017); Muriithi & Ngare (2023)
Social	Stakeholder Engagement	Limited public awareness and market acceptance of straw-based construction, perception of straw as an "alternative" or "hippie" material limits adoption	A1, I1; I2; Workshop; (EcoCocon, 2023d); Kanters et al. (2023); Podmolík (2024)

5.1 Economic challenges

In terms of pricing, while the product is competitively priced (~€150/m²), it competes with well-established conventional materials that benefit from economies of scale and often long-practiced policy favoring. Monetizing environmental benefits (e.g., CO_2 credits) is still underdeveloped and uncertain. Transport costs are significant, especially for long-distance deliveries (e.g., €2,000-€4,000 per lorry for long-distance/international deliveries), and the panels are bulky despite being lightweight.

Another economic aspect is storage. Seasonal availability of straw introduces inventory and sourcing challenges, potentially increasing storage and procurement costs. Moreover, supplier agreements are usually made one year in advance, and for use in buildings, straw needs to be high quality (yellow) and dry. Keeping adequate quality needs appropriate storage with correct ventilation and moisture control. Against this background, the energy market can be a fierce competitor, as it does not require as high-quality a straw even though paying less. Lastly, economies of scale are difficult to reach, since production is custom and project-based.

5.2 Environmental and regulatory challenges

The panels are designed not to need any heavy chemical coating and for easy disassembly at the end-of-life, thus designed to enable circularity. However, end-of-life reuse or recycling systems are not yet standardized or widely implemented, thus specific challenges in this regard are yet to be spotted and managed.

Certifications and meeting regulatory requirements can be time and resource consuming. Maintaining and updating certifications (e.g., Passive House, Cradle to Cradle) requires ongoing testing and documentation. Moreover, as the product in the industry lacks a sturdier establishment, acquiring certification, on top of meeting regulatory requirements, can require submitting each building to an auditing process, if the product or material does not have its own certification yet. Moreover, navigating varying national regulations on bio-based materials can also be complex and resource-intensive. To facilitate broader adoption, clearer EU-level guidelines on bio-based construction materials are needed. Harmonized standards could reduce compliance costs, streamline certification, and improve market confidence in straw-based innovations. This is a critical point for enabling wider adoption of straw as a biobased building material, and to realise the benefits of its use.

Recent Environmental Product Declarations (EPDs) show that straw-based panels can sequester approximately 97.6 kg CO_2-e/m² (School of Natural Building, 2021; when adjusted for insulation thickness to achieve a U-value (overall heat transfer coefficient) of 0.14 W/m²K), whereas conventional insulation materials such as rockwool and fiberglass typically result in net emissions ranging from 10 to 30 kg CO_2-e/m² (ROCKWOOL Limited, 2015; When scaled to typical insulation thicknesses for building envelopes (e.g., 100–150 mm)). This significant difference in performance considering the products' life cycles strengthens the case for straw in procurement decisions focused on reducing embodied carbon.

5.3 Social Challenges

Building trust with municipalities, developers, and end-users is essential but time-consuming. Awareness of the benefits of straw-based construction is limited, among the public or even the governmental and industrial spheres, and thus requires sustained outreach and education.

To overcome the perception of straw as a "hippie" or alternative material, targeted outreach campaigns, demonstration projects, and integration into educational curricula could help reframe straw as a high-performance, sustainable option for mainstream construction.

While EU and national policies increasingly support bio-based construction, access to subsidies and incentives is uneven, and even public procurement frameworks often favor conventional materials due to familiarity and risk aversion.

6. Conclusions

This study demonstrates that straw, an abundant agricultural byproduct, holds significant promise as a sustainable building material within a circular economy framework. Through the case of EcoCocon, we explored how straw-based panels can deliver environmental, economic, and social value, ranging from carbon sequestration and reduced material use to local job creation and improved indoor environments.

However, realizing this potential requires overcoming several systemic challenges. These include logistical complexities, seasonal supply constraints and supplier agreements, regulatory hurdles, and limited public awareness. Addressing these barriers will depend on coordinated efforts among stakeholders, including policymakers, industry actors, and research institutions.

The findings suggest that with appropriate support mechanisms, such as subsidies, certification pathways, and public procurement incentives, straw-based construction can become a viable and scalable solution in Denmark, Sweden, and beyond. As the building sector continues its transition toward sustainability, integrating agricultural wastes like straw into construction practices offers a compelling pathway to reduce emissions, close resource loops, and foster local and regional resilience.

Further research is needed, nonetheless, to evaluate the long-term structural integrity and fire resistance of straw-based panels, particularly in multi-storey buildings. Establishing robust testing protocols will be essential for scaling adoption in urban environments.

Touching on the limitations of this research, having started from a documental analysis, we acknowledge that limited participatory methods (late interviews) might not have been able to capture all informal barriers, stakeholder intuition, and institutional dynamics that influence adoption. Moreover, while this study focuses on EcoCocon as an illustrative case, it is important to acknowledge that the company operates within a specific regulatory, geographic, and organizational context. As such, the findings may not be fully generalizable to other firms or regions. Broader validation through comparative studies involving multiple companies and market conditions would enhance the robustness and applicability of the conclusions drawn here.

To further strengthen the relevance of straw-based construction, future research should incorporate more quantitative comparisons with conventional materials such as rockwool and fiberglass. Additionally, engaging a broader range of stakeholders, including policymakers, architects, builders, and end-users, would provide a more comprehensive understanding of the systemic barriers and opportunities for adoption.

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