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Acoustic Panels from Waste Eelgrass: Benefits and Challenges of a Circular Business Model

By Niels C. Kjærsgaard[1,*], Rodrigo Salvador[1], M. Lynn Eriksen[1], Michael Hedegaard[1], Victor Lund[1], Torben Knudby[1]

ABSTRACT:
This paper explores the transformation of waste eelgrass (Zostera marina), commonly found along European coastlines, into sustainable acoustic panels through circular business models (CBMs). The study adopts a qualitative, exploratory approach involving literature review, participatory stakeholder workshops to identify and assess the challenges and opportunities in this innovation ecosystem. Key insights are derived from the Power Bio project, which facilitated co-creation of business model prototypes with municipalities, producers, and biomass collectors.
The research highlights significant environmental benefits such as carbon reduction and beach aesthetics improvement, alongside economic advantages including premium pricing and cost avoidance. However, it also uncovers barriers like supply chain instability, regulatory fragmentation, and low public awareness. Methodologically, the study draws on tools like the Triple Layered Business Model Canvas (TLBMC) and design thinking to integrate sustainability and stakeholder engagement.
By aligning theoretical insights with empirical stakeholder input, the paper offers a grounded model for municipalities and entrepreneurs aiming to repurpose coastal biomass waste. It contributes both to the academic discourse on circular bioeconomy and provides actionable recommendations for sustainable building practices. The findings align with EU goals on climate neutrality and sustainable construction, offering a scalable pathway from coastal nuisance to green innovation.

Keywords: Circular Economy; Bioeconomy; Biomass Waste; Circular Business Model; Acoustic Panels; Build Environment

1. Introduction

The transition toward sustainable production systems and circular economy principles has become an imperative for addressing global environmental challenges, including resource depletion, climate change, and biodiversity loss (Geissdoerfer et al., 2016; Kirchherr & Hekkert, 2017). One promising strategy within this transition is the revalorization of organic waste materials—such as marine biomass—for use in high-value applications. Among these, eelgrass (Zostera marina), a marine plant often found washed ashore along European coastlines, remains underutilized and is frequently managed as a nuisance or waste by local municipalities (Salvador et al., 2025).
The specific objectives of this study are to:

|[1]Technical Universtity of Denmark (DTU), Department of Engineering Technology and didactics, Lautrupvang 15, Ballerup Campus, DK-2750 Ballerup, Denmark;
[*]Corresponding Author:; Technical Universtity of Denmark (DTU), Department of Engineering Technology and didactics, Lautrupvang 15, Ballerup Campus, DK-2750 Ballerup, Denmark.

- Examine the material and process requirements for converting waste eelgrass into viable acoustic panels;
- Explore and map circular business models that support such a conversion, including stakeholder roles, customer segments, and revenue mechanisms;
- Assess the benefits and challenges associated with such CBMs from technological, environmental, and market perspectives.

To operationalize these goals, a co-creation workshop was held with stakeholders from the Power Bio project (Gate 21, 2023), including municipal officials, researchers, industry representatives, and product developers. This participatory process informed the drafting of preliminary business models.

The novelty of this research lies in its interdisciplinary integration of biomass valorization, business model innovation, and stakeholder engagement, centered around a concrete and scalable product. It contributes both theoretically—by expanding the literature on CBMs for marine biomass—and practically—by providing insights for municipalities and entrepreneurs aiming to transform coastal waste into sustainable value. Moreover, the study aligns with broader EU policy goals on circular economy, climate neutrality, and sustainable building practices (European Commission, 2020).

In summary, this thesis investigates how waste eelgrass—currently viewed as a disposal challenge—can become a valuable input in sustainable product systems, contributing to a more circular, low-carbon, and resource-efficient economy. Through a combination of literature synthesis, stakeholder input, and empirical case comparison, the study aims to produce both actionable knowledge and theoretical advancement in the field of sustainable business model innovation.

2. Literature Review

2.1 Introduction to literature review

In recent years, the increasing urgency of climate action and sustainable resource management has prompted the search for innovative, circular solutions to existing environmental problems. One such opportunity lies in the revalorization of eelgrass (Zostera marina) — often treated as coastal waste — into high-value building materials, such as acoustic panels. While interest in sustainable construction and bio-based materials is expanding, the specific application of waste eelgrass in circular business models remains an underexplored field. This chapter presents a critical review of existing literature, focusing first on the niche area of business models related to the use of seagrass in construction, then expanding to include relevant insights from broader biomass-based circular innovations.

2.2 Narrow Literature Search: Eelgrass and Business Models for Building Materials

A focused literature search was conducted using Scopus, applying a combination of search terms related to eelgrass, building materials, and business modeling. This yielded only four articles, reflecting the limited academic engagement with the specific use of eelgrass in commercial building products. Among these, the study by Rothstein et al., 2025 stands out as the most directly relevant. It explores the performance of seagrass as an insulation material in tropical climates, emphasizing both its thermal properties and environmental benefits, including reduced carbon footprint and biodegradability. However, the paper does not address the business model dimensions of such applications, nor the operational challenges involved in sourcing and processing waste eelgrass.

Other articles within the narrow search domain tended to focus on ecological functions or the material potential of aquatic plants but lacked economic or commercial integration. This reveals a notable gap in the literature at the intersection of environmental sustainability, circular economy, and entrepreneurial viability for eelgrass-based innovations. There is an evident absence of comprehensive studies linking eelgrass valorization with frameworks such as the Business Model Canvas or circular value propositions.

This research gap reinforces the novelty and relevance of this study, which directly addresses how waste eelgrass can be incorporated into a functioning circular business model, considering environmental, operational, and market factors.

2.3 Broader Literature Search: Including Seaweed, Grass, and Straw

To enrich the analysis and draw on comparable cases, a broader literature search was conducted by expanding the scope to include other biomasses — namely seaweed, grass, and straw — often used in bio-based construction or energy applications. This broader search yielded an additional 51 results, providing more insights into the development of bioeconomy-based business models for waste valorization.

For instance, Rossignolo et al., 2022 reviewed the potential use of Sargassum seaweed in civil construction, identifying applications in composite panels and biocement. They emphasized that seaweed's functional characteristics - such as fibrous texture and natural chemical resistance - support material substitution in green construction. However, while technical feasibility was discussed, the paper lacked detailed exploration of stakeholder dynamics, customer segments, or economic scaling - critical elements in circular business model development.

Similarly, Salvador et al., 2025 conducted a systematic review of biomass waste streams in the circular bioeconomy, evaluating both aquatic (seagrass, seaweed) and terrestrial (straw, grass) sources. The study mapped high-value product applications along a biomass value pyramid, highlighting the potential of biomasses for chemicals, materials, and energy production. Importantly, it underscored that barriers to upscaling include technological readiness, seasonal variability, and the lack of standardized supply chains - challenges directly relevant to the eelgrass case.

While the broader literature affirms the theoretical and environmental potential of biomass-to-material innovations, most studies focus either on technical feasibility or environmental impact, with minimal integration of business model theory or customer-oriented value creation. This reinforces the need for practice-oriented research that bridges design, sustainability, and entrepreneurship.

2.4 Business Model Tools and Theoretical Anchors

To fill this gap, the present study draws upon established frameworks in sustainable business model innovation. One such approach is the Triple Layered Business

Model Canvas (TLBMC), developed by Joyce & Paquin, 2016, which integrates economic, environmental, and social value creation in one coherent visual tool. The TLBMC is especially suited for circular economy contexts, as it expands the traditional canvas to account for lifecycle analysis and stakeholder engagement — both highly relevant in cases involving marine biomass collection and community-based resource management.

Additionally, Geissdoerfer et al., 2016 propose a design thinking methodology for sustainable business modelling. Their value ideation process includes stakeholder mapping, co-creation, and value proposition prototyping, aligning well with participatory approaches like the Power Bio workshop conducted in this study. By incorporating tools from creative problem-solving, the design thinking approach supports the development of more robust and stakeholder-validated business models.

Moreover, Bocken & Geradts, 2020 introduce a multi-level framework for identifying barriers and drivers to sustainable business model innovation (SBMI), focusing on institutional, strategic, and operational levels. This framework is especially helpful in identifying systemic constraints, such as misaligned regulations or short-term corporate goals, that may hinder the implementation of SBMI despite evident sustainability potential.

2.5 Summary and Research Gap

To summarize, the literature demonstrates strong academic interest in bio-based and circular materials but shows a lack of specificity in the context of waste eelgrass and its market integration as an acoustic panel. While broader insights from seaweed, straw, and grass indicate potential environmental and functional benefits, they rarely include comprehensive business model development or stakeholder validation processes.

This study therefore addresses a crucial gap by:

- Exploring eelgrass valorization from a product-specific, business model perspective;
- Integrating findings from design thinking, TLBMC, and barrier/driver frameworks;
- Bridging theory with practice through workshops and interviews in a real-life case.

Such an approach contributes not only to the academic discourse on circular bioeconomy but also to practical pathways for municipalities and companies aiming to turn biomass waste into value-adding products.

Building on these gaps and insights, the following section outlines the methodological design adopted to explore eelgrass-based CBMs.

3. Methods

3.1 Research Design and Approach

This study adopts a qualitative, exploratory case study design aimed at investigating the development of circular business models (CBMs) for the transformation of waste eelgrass into acoustic panels. A mixed-method qualitative strategy was employed, combining literature synthesis and co-creative stakeholder engagement, framed by established business model innovation theories.

The methodological framework draws on the Business Model Generation approach by Osterwalder & Pigneur, 2010 and is further informed by sustainable business model innovation literature such as the Triple-Layered Business Model Canvas (TLBMC) (Joyce & Paquin, 2016), Design Thinking methodologies for sustainable value ideation (Geissdoerfer et al., 2016), and barrier-driver frameworks in organizational innovation (Bocken & Geradts, 2020).

3.2 Literature Review Strategy

The literature review followed a two-tiered search strategy to establish the state-of-the-art in eelgrass valorization and related circular business models. Initially, a narrow search was conducted in Scopus, targeting publications that intersected "eelgrass" or "seagrass" with "building materials" and "business model" or "commercialization." This search returned four articles, which were analyzed for their relevance to the specific product application under study — acoustic insulation panels from waste eelgrass.

Given the limited volume of domain-specific literature, a broader search was conducted, expanding the biomass scope to include seaweed, grass, and straw, which are more commonly explored in the context of circular bioeconomy and material substitution. This expanded search yielded 55 articles, which were reviewed thematically to extract lessons on material properties, conversion technologies, market integration, and innovation barriers.

3.3 Workshop: Participatory Business Model Development

To contextualize and ground the business model development in real-world stakeholder experience, a participatory Business Model Canvas workshop was conducted under the auspices of the Power Bio project. The workshop engaged actors from municipalities, academia, production firms, and other key stakeholders in the Danish and Swedish bioeconomy sector. The purpose was to co-create a prototype CBM for the production of eelgrass-based acoustic panels.

The workshop was structured around Osterwalder's Business Model Canvas, supplemented by sustainability considerations derived from the TLBMC (Joyce & Paquin, 2016). Participants were divided into mixed groups and used color-coded post-its (e.g., municipal, industry, research) to capture insights across the BMC's nine building blocks. The workshop was documented and subsequently coded for content analysis, focusing on key themes such as value propositions, customer segments, operational logistics, and sustainability impacts.

3.4 Business Model Synthesis and Theoretical Integration

Based on the outputs from the literature review, workshop, and interview, a series of circular business model scenarios were synthesized using Osterwalder's Business Model Generation framework. Each scenario was analyzed against the Triple Bottom Line (Elkington, 1999) and evaluated through the Design Thinking lens of ideation, prototyping, and stakeholder co-creation (Geissdoerfer et al., 2016).

To critically assess viability and innovation potential, the resulting models were further analyzed using the barrier-driver framework developed by Bocken & Geradts, 2020, which identifies key institutional, strategic, and operational factors that enable or hinder the implementation of sustainable business models. This triangulated approach ensured that the final model was not only creative and stakeholder-aligned, but also empirically grounded and strategically informed.

Scholar GPT (by OpenAI) was used to support the research process, including idea generation, preliminary literature exploration and language refinement. All AI generated outputs were critically reviewed, revised, and are solely the responsibility of the authors.

4. Results

4.1 Business Model Canvas and Stakeholder Overview

The Business Model Canvas (BMC) for eelgrass-based panel production was developed based on workshop outcomes and literature insights, with findings categorized across economic, environmental, and social dimensions.

Table 1: Business Model Canvas for eelgrass-based acoustic panels

BMC Building Block	Description
Key Partners	• Machinery developers for harvesting, drying, and processing (workshop) • Municipalities and contractors for collection and logistics (workshop) • Research institutions (workshop)
Key Activities	• Collection, desalination, drying of eelgrass (workshop) • Product development, testing (CO_2, LCA, acoustics) (workshop) • Quality assurance and certification (workshop) • Monitoring and managing seasonal variation in eelgrass biomass availability to optimize supply chain continuity (Rothstein et al., 2025)
Key Resources	• Biomass quality standards and specifications (workshop) • Access to processing facilities and laboratory infrastructure (Salvador et al., 2025; Geissdoerfer et al., 2018) • Access to reliable coastal data for biomass prediction and planning (Rothstein et al., 2025) • Collaboration with environmental scientists for impact minimization (Hernández-Delgado, 2015)
Value Propositions	• Sustainable, low-carbon alternative to mineral wool (workshop) • Environmental branding for customers and municipalities (workshop) • Improved indoor climate and aesthetics (workshop) • Cost savings from avoided beach cleaning (workshop) • Contributes to circular economy through use of waste biomass in construction (Rossignolo et al., 2022) • Utilizes a regenerative material that helps sequester carbon and prevent marine pollution (Rothstein et al., 2025)
Customer Relationships	• Personal engagement and pilot demonstrations (workshop) • Joint community construction projects (workshop)

	• Green marketing and public outreach (Bidmon & Knab, 2018) • Potential alliances with green building certification bodies to increase buyer trust (Rossignolo et al., 2022) • Engage local communities through education and shared sustainability projects to strengthen trust (Heinen, 1993)
Channels	• Direct negotiation with institutional buyers (workshop) • Market dialogues and conferences (workshop) • Public procurement portals and local government networks (workshop) • Publication in sustainability and green architecture journals to reach architects and consultants (Rossignolo et al., 2022)
Customer Segments	• Public institutions: schools, cultural centers, universities (workshop) • Architects and firms in green building sector (workshop) • Municipalities as both customers and suppliers (workshop) • Coastal infrastructure developers seeking climate-adaptive and low-carbon materials (Hernández-Delgado, 2015)
Cost Structure	• Biomass collection and logistics expenses (workshop) • Capital investment in washing, drying, and testing equipment (Geissdoerfer et al., 2018) • Risk mitigation and storage costs due to seasonal unpredictability of biomass (Rothstein et al., 2025)
Revenue Streams	• Sales of finished acoustic panels to premium and green markets (workshop) • Rental or custom product offerings (e.g., acoustic pods) (workshop) • Royalties from IP or international licensing (workshop) • Grants, subsidies, and carbon credit monetization (Pieroni et al., 2019) • Potential income through ecosystem service credits or environmental offsetting frameworks (Hernández-Delgado, 2015)

4.2 Economic Dimension

The economic viability of eelgrass-based acoustic panels is defined by a complex interplay between cost structure, market access, and supply chain dynamics. From the producer's perspective, one of the most critical barriers is the high upfront investment required for processing infrastructure, including washing, drying, and certification tools (Geissdoerfer et al., 2018). These costs were highlighted both in the workshop and in literature, with several sources noting that environmental product declarations (EPDs) and lifecycle assessments (LCAs) are often prerequisites for public sector market access (Joyce & Paquin, 2016).

Despite these challenges, the workshop revealed a premium pricing potential for bio-based insulation in the green construction segment. This is reinforced by studies identifying consumer preferences for low-carbon building materials, particularly in government or donor-funded projects (Bidmon & Knab, 2018). Moreover, grant-based revenue and carbon credit monetization were cited as diversification strategies in the broader literature (Pieroni et al., 2019).

Municipalities noted economic benefits such as avoided costs for eelgrass removal from beaches (workshop and Salvador et al., 2025), though they also face barriers like rigid public procurement cycles and limited budgets to support pilot projects (Antikainen & Valkokari, 2016). For collectors, while a new biomass service niche is emerging, the model remains unstable due to irregular contracts and seasonal biomass flows (Bocken et al., 2014 and Salvador et al., 2025).

4.3 Environmental Dimension

Environmental motivations are a key unifier across all actors. Eelgrass panels have a low embodied energy and reduce GHG emissions compared to mineral wool (Joyce & Paquin, 2016). Workshop participants emphasized this, especially under carbon-aware building regulation contexts.

For municipalities, improved coastal cleanliness and aesthetics were viewed as dual benefits of biomass reuse (workshop and Salvador et al., 2025). However, variability in eelgrass availability and long-distance transport of wet biomass may challenge overall emissions savings (Geissdoerfer et al., 2018 and Pieroni et al., 2019).

Biomass collectors serve as environmental agents by reducing eutrophication and contributing to shoreline ecosystem health, but face gaps in logistics optimization and a lack of operational guidelines (Antikainen & Valkokari, 2016 and Salvador et al., 2025).

4.4 Social Dimension

Socially, the innovation supports sustainable branding and offers municipalities and producers symbolic leadership in climate action (workshop and Bidmon & Knab, 2018). Panels placed in public buildings like schools or libraries were seen as visible commitments to sustainability (workshop and Joyce & Paquin, 2016).

Yet public awareness remains low, and few communication strategies exist to highlight safety or benefits of eelgrass reuse, particularly in areas sensitive to tourism or odor concerns (Pieroni et al., 2019 and Salvador et al., 2025).

For collectors, job creation in rural areas is a positive outcome (workshop), although informality and the lack of standardized procedures or safety regulation pose structural vulnerabilities (Geissdoerfer et al., 2018 and Salvador et al., 2025).

4.5 Stakeholder Challenge and Opportunity Tables

Table 1: Levels and key categories for change factors towards sustainability at the example of hospitals' secondary processes

Dimension	Type	Title	Description	Applies to	Source
Economic	Challenge	High Initial Costs and Budget Constraints	Both producers and municipalities face financial barriers due to investment in processing and certification infrastructure, and municipalities due to short-term budgeting limitations for	Producer, Municipality	Workshop; Salvador et al., 2025

			innovation procurement.		
Economic	Opportunity	Premium and Circular Market Access	Bio-based eelgrass panels offer producers access to green building markets, while municipalities can benefit from circular procurement alignment.	Producer, Municipality	Bocken et al., 2014; Workshop
Economic	Challenge	Market and Contract Volatility	Uncertain demand, seasonal biomass availability, and lack of stable contracts challenge both producers and collectors.	Producer, Biomass collector	Salvador et al., 2025
Economic	Opportunity	Emergence of New Service Niches	The development of eelgrass-based products opens opportunities for SMEs in biomass logistics, coastal maintenance, and local supply systems.	Biomass collector	Bocken et al., 2014
Environmental	Opportunity	Carbon Reduction and Ecosystem Benefits	Use of eelgrass panels reduces GHG emissions compared to mineral wool. Collection also reduces eutrophication and improves beach aesthetics.	Producer, Biomass Collector, Municipality	Pieroni et al., 2019; Workshop
Environmental	Challenge	Supply Chain Fragility and Transport Emissions	Irregular eelgrass availability and long-distance transport challenge consistent and low-carbon supply chains.	Producer, Biomass Collector	Workshop; Salvador et al., 2025
Environmental	Challenge	Fragmented Governance and Coordination	Coastal management involves overlapping jurisdictions, which hinder effective biomass collection and reuse integration.	Municipality	Salvador et al., 2025

Social	Opportunity	Sustainable Branding and Public Leadership	Municipal use of eelgrass panels in public buildings signals leadership in sustainability, while producers benefit from green branding.	Producer, Municipality	Joyce & Paquin, 2016; Salvador et al., 2025
Social	Challenge	Low Awareness and Knowledge Gaps	Citizens and building professionals are often unaware of the safety, benefits, or use cases of eelgrass panels.	Producer, Municipality	Salvador et al., 2025
Social	Opportunity	Local Employment and Inclusive Transition	Seasonal collection creates job opportunities in rural areas, supporting just transition objectives.	Biomass Collector	Workshop
Social	Challenge	Lack of Operational Guidelines and Incentives	Collectors and producers alike face insufficient technical standards and policy incentives for bio-based materials.	Producer, Biomass Collector	Salvador et al., 2025; Bidmon & Knab, 2018
Social	Opportunity	Municipality-SME Collaboration	Public-private cooperation on biomass valorization supports both local economic development and environmental goals.	Municipality, Biomass Collector	Bidmon & Knab, 2018

5. Discussion

5.1 Interpretation of Findings

The preceding results reveal a complex yet promising landscape for circular innovation using eelgrass. This section discusses key implications. However, the implementation landscape is complex. The seasonal and geographic variability of eelgrass complicates logistics and hinders scalability (Geissdoerfer et al., 2018). Producers also face significant barriers related to capital investment, processing infrastructure, and certification demands, which delay market readiness and increase risk in early stages (Bocken et al., 2014 and Salvador et al., 2025). Municipalities showed interest in cost-saving and sustainability alignment yet often lack the institutional and financial mechanisms to pilot or procure such products (Antikainen & Valkokari, 2016 and Salvador et al., 2025).

On the social side, innovation fosters potential for rural job creation and local identity-building. But this is constrained by low public awareness, ambiguous regulatory status, and insufficient experience among building professionals with bio-based materials (Bidmon & Knab, 2018 and Antikainen & Valkokari, 2016).

5.2 Systemic Barriers and Enablers

The analysis demonstrates that while technical feasibility is proven, institutional and system-level misalignments remain a key bottleneck. These include fragmented governance across coastal and waste management agencies, unclear division of responsibilities between municipalities and collectors, and the absence of long-term contracting frameworks (Antikainen & Valkokari, 2016 and Salvador et al., 2025).

Enabling conditions such as growing political interest in circular economy policy, available research collaborations, and evolving procurement standards offer some traction points (Bidmon & Knab, 2018 and Pieroni et al., 2019). Early-stage collaboration between producers and municipalities is especially valuable for de-risking innovation and demonstrating practical applications (workshop).

The availability of stranded biomass such as eelgrass constitutes a significant barrier to value creation (Salvador et al., 2025). They point to the need for improved forecasting technologies and standardized procedures for collection and transport. This supports the importance of exploring solutions for storage of the biomass – either in its raw form or as partially processed material - alongside seasonally aligned production planning, and geographic clustering. Considering both unprocessed and stabilized forms of biomass in storage strategies may enhance flexibility and reduce spoilage. Such measures could not only mitigate supply risks but also potentially transform biological variability into a strategic design advantage.

5.3 Strategic Considerations

To advance the eelgrass panel innovation ecosystem, targeted actions should be considered, though these must remain flexible and context-sensitive:

- Producers could benefit from stronger research-industry partnerships, demonstrations in public buildings, and simplified access to certification tools.
- Municipalities may act as conveners by creating pilot-friendly procurement conditions and supporting biomass collection through local partnerships.
- Biomass collectors should be integrated into regional development strategies, ideally through contracts and logistical co-design with producers.

5.4 Limitations of the Study

While the study provides novel insights at the intersection of circular economy theory, bio-based construction materials and stakeholder-driven business model innovation, a limitation of the study is its exclusive reliance on qualitative methods, without quantitative validation of scalability through pilot implementation, market performance data, or real procurement cycles. Furthermore, the study does not incorporate quantitative tools such as Life Cycle Assessment (LCA), cost-benefit analysis, or carbon offset estimation to empirically substantiate its sustainability and economic assumptions. The absence of such metrics limits the capacity to evaluate the full environmental and financial impacts of the proposed business models.

5.5. Future research

Future research should address this methodology gap by integrating quantitative validation tools to support more robust, data-driven assessments. This includes applying Life Cycle Assessment (LCA) to evaluate full life cycle emissions, conducting cost-benefit analysis to examine economic feasibility, and estimating potential carbon offsets when bio-based materials replace conventional ones. These tools would enhance the credibility of sustainability claims and provide empirical evidence necessary for policymakers to design procurement incentives, certification frameworks, or regulatory mechanism. Such quantitative insights would also assist private sector stakeholders in assessing commercial risks and investment potential in circular construction systems.

In addition, further research is needed to explore the institutional and contractual mechanisms required to support the scaling of eelgrass-based business models. While this study identifies the emergence of service niches involving municipalities and local collectors, it offers limited guidance on how stable, long-term collaborations can be structured. Future work should investigate the design of public-private contracts that ensure predictable biomass supply, inclusive employment and fair risk-sharing among participants.

Finally, the study briefly acknowledges the limited public awareness of eelgrass-based acoustic panels, but a more detailed explorations is needed. Future research should consider how communications strategies, such as demonstration buildings, educational outreach, or targeted social media campaigns, could foster citizen trust, normalize bio-based materials and enhance public familiarity. Raising awareness is critical to building consumer confidence and enabling broader market readiness for green construction solutions

6. Conclusion and recommendations

This study has examined the feasibility of developing a circular business model for acoustic panels made from waste eelgrass. Through stakeholder engagement, business model analysis, and targeted literature review, the research identified key opportunities in environmental performance, local economic potential, and sustainable procurement alignment.

Nevertheless, several systemic challenges must be addressed to unlock full-scale implementation. These include stabilizing eelgrass supply chains, creating regulatory clarity, fostering stakeholder coordination, and overcoming initial capital and certification hurdles for producers.

To support such coordination, further attention should be given to multi-level governance mechanisms that connect EU-level policy ambitions with local implementation practices. Translating circular economy goals and green transition funding into tangible support for municipalities and SMEs requires better alignment across procurement regulations, certification schemes, and standardization frameworks. Such integration could help institutionalize support for bio-based innovation and reduce administrative barriers that inhibit scaling.

The innovation provides a viable nature-based solution, but its long-term success hinges on system-level support mechanisms. Future efforts should prioritize the development of stable biomass supply systems, targeted incentives for bio-based materials, and pilot-driven public procurement frameworks. The path forward lies in adaptive, inclusive, and multi-level collaboration that allows such circular initiatives to scale sustainably and equitably.

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