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Charting the Course: Real-World Application of Sustainability and Innovation Principles in the Portuguese Blue Economy Firms

Jennifer Nicole Elston¹  | Hugo Emanuel dos Reis Sales da Cruz Pinto^{1,2}  | Carla Filipa Sequeira Valente Nogueira^{1,2} 

¹Research Centre for Tourism, Sustainability and Well-Being (CinTurs), Faculty of Economics, University of Algarve, Faro, Portugal | ²Centre for Social Studies (CES), University of Coimbra, Coimbra, Portugal

Correspondence: Jennifer Nicole Elston (jnelston@ualg.pt)

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ABSTRACT

The blue economy has emerged as a key sector for linking sustainability and innovation, yet existing research has largely overlooked how firms operationalize these processes in practice. This study addresses that gap by asking: *How do Portuguese blue economy firms embed sustainability-oriented innovation (SOI) into their strategies, and what institutional conditions enable or constrain it?* This study explores SOI through an analysis of five Portuguese firms. Adopting a qualitative approach, it employs semistructured interviews, supported by content comparison techniques and thematic coding. The findings indicate that stakeholder collaboration, circular economy principles, and renewable energy integration support sustainability performance, whereas financial constraints, regulatory inefficiencies, and bureaucratic hurdles limit broader adoption. Drawing on institutional theory, the resource-based view, and the triple bottom line framework, the study contributes theoretically by showing how SOI is negotiated between institutional pressures and firm capabilities, revealing tensions between compliance and strategic agency. The study underscores the importance of institutional support, stakeholder engagement, and adaptive business strategies in overcoming systemic barriers. These results provide practical direction for policymakers and business leaders, highlighting the need for streamlined regulation, targeted financial incentives, and cross-sector collaboration. For policymakers, this means aligning incentives with SME capacities and building collaborative governance platforms; for firms, it means leveraging partnerships and resource-based advantages to scale sustainable business models. By clarifying both institutional dynamics and firm-level practices, the article advances understanding of how sustainability transitions are enacted within the blue economy.

1 | Introduction

Contemporary societies face complex and interlinked challenges, including climate change, inequality, and resource depletion, which require shifts in consumption patterns, production systems, and governance models. Climate change,

while critical, cannot be addressed through an environmental lens alone (Banikoi et al. 2023), as many issues are rooted in legacy economic structures that perpetuate unsustainable development. Modern capitalism has contributed to systemic inequities, environmental degradation, and unsustainable development models (Nogueira et al. 2023). This is demonstrated

This article investigates the real-world application of sustainability and innovation principles within firms operating in the Portuguese blue economy. Through qualitative case study methods, it explores how sustainability-oriented innovation (SOI) is implemented, and identifies institutional, financial, and governance-related barriers. The study contributes to understanding the practical integration of sustainability in marine-based industries and the challenges of embedding innovation in resource-constrained and policy-fragmented environments.

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by the policy initiatives of organizations like the European Commission, which aim to support environmental transitions, the circular economy, and green innovations (European Commission et al. 2024).

Traditional business models that focus only on profit have shown their limitations. In response, sustainable entrepreneurship often in the form of hybrid ventures balancing social, environmental, and financial goals, is gaining recognition (Breuer et al. 2018; Matzembacher et al. 2020). The blue economy (BE) encompassing industries such as fisheries, marine biotechnology, renewable energy, and tourism, offers a fertile context for this shift, as it seeks to reconcile ecological conservation with economic opportunity (Elston et al. 2024).

Despite growing scholarly and policy attention, empirical understanding of how sustainability and innovation are operationalized within BE firms remains limited. Much of the existing literature emphasizes conceptual debates and high-level frameworks, often without deeply engaging with industry-specific challenges, practical implementation strategies, or performance outcomes (Kennedy and Bocken 2020; Wenhai et al. 2019; Voyer et al. 2018). In particular, questions persist regarding how firms develop and manage sustainable business models, balance economic and environmental objectives, and navigate systemic constraints such as regulatory complexity, financial limitations, and institutional fragmentation (Choudhary et al. 2021; Breuer et al. 2018).

Recent research also highlights a scarcity of theoretical and empirical work on the development, governance, and value creation mechanisms of sustainable business models in practice. While the literature suggests the potential for holistic models that generate mutually reinforcing economic, environmental, and social outcomes, evidence from real-world cases remains sparse (Choudhary et al. 2021). Exploring how entrepreneurs can design new products, processes, and organizational models that generate systemic impact, while managing inherent tensions, is a necessary step forward (Matzembacher et al. 2020; Breuer et al. 2018). Sustainable business management, in this context, refers to the ability of firms to pursue triple bottom line (TBL) objectives within competitive markets (Mdlalose 2022).

This article responds to these gaps by asking the research question: *How do Portuguese blue economy firms implement sustainability-oriented innovation (SOI), and what institutional conditions enable or constrain these processes?* This question is especially relevant because Portugal, as a strategically positioned coastal country with the third-largest exclusive economic zone (EEZ) in the European Union, places the ocean at the center of its national strategy as both a development priority and a geopolitical asset, thereby shaping international debates and practices in the blue economy.

The contributions of this study are threefold. First, at the theoretical level, it integrates institutional theory, the resource-based view (RVB), and the TBL to explain how firms negotiate between institutional pressures and internal capabilities. Second, at the practical level, it identifies how firms translate sustainability into business strategy through mechanisms such as circular resource use, renewable energy integration, and cross-sector

collaboration. Third, at the policy level, it highlights implications for governance, emphasizing the need for regulatory simplification, targeted financial incentives, and collaborative platforms that bridge firm-level and institutional priorities.

In this way, the article builds a clear transition from the conceptual and empirical gaps identified in the literature to the proposed qualitative analysis of Portuguese firms, providing both academic and practical relevance. Using a triangulated qualitative case-study approach, it examines five Portuguese BE firms through semistructured interviews, corporate document analysis, and prior survey data from 40 firms. The study explores how sustainability becomes embedded in business strategy, revealing organizational tensions, enabling factors, and strategic adaptations. In doing so, it contributes to broader debates on how firms act as agents of sustainability in marine-based sectors.

2 | Sustainability and Innovation in the BE

2.1 | Theoretical Foundations of Sustainability in the BE

Sustainability in the BE refers to the integration of environmental protection, economic viability, and social equity to ensure long-term sectoral resilience (Elston et al. 2024). This study adopts a Brundtland-aligned view, meeting present needs without compromising the future (WCED 1987), and uses the TBL framework to highlight the balance essential in ocean industries, where resource efficiency, biodiversity preservation, and climate adaptation must align with economic development (Elkington 1998; van Hoof et al. 2019).

Environmentally, sustainability in the BE focuses on responsible resource management, pollution reduction, and preserving marine ecosystems critical for climate regulation and economic viability of sectors such as fisheries, aquaculture, and tourism (Kyvelou and Ierapetritis 2019). However, unsustainable exploitation of marine resources, habitat destruction, and rising ocean temperatures continue to undermine these sectors (United Nations 2020).

Economically, sustainable business models aim to achieve profitability without degrading marine resources (Garlock et al. 2024; Adams et al. 2016). Financial instruments such as blue bonds, government subsidies, and impact investment funds illustrate how capital structures are being reshaped to support SOI (Sarangi 2023; Thompson 2022; Cappelletto et al. 2018).

Social sustainability emphasizes inclusive development through fair labor practices, protection of small-scale fisheries and indigenous knowledge, and efforts to reduce social inequality (Soma et al. 2018; Dziura and Cernota 2015). Social impact refers to the measurable effects of business activity, such as improved livelihoods and community resilience, but these benefits are often unequally distributed. Marginalized groups frequently face exclusion from decision-making, technological gaps, and displacement by industrial maritime operations (Jennings et al. 2024). This imbalance highlights a theoretical gap: while the TBL treats social, environmental, and economic pillars symmetrically, empirical evidence suggests persistent asymmetry, with the social

dimension systematically weaker. This study addresses that gap by explicitly examining why the social pathway lags in BE firms.

Sustainable innovation involves developing and implementing new ideas, products, or processes that simultaneously generate economic, environmental, and social value (Kennedy and Bocken 2020; Adams et al. 2016). A subset of this, social innovation, focuses on meeting social needs through novel strategies and organizational models that foster empowerment and enhance well-being (Cisneros-Montemayor et al. 2021).

In BE, hybridity has become a strategic necessity, as firms reconcile commercial viability with environmental and social missions, operating under competing institutional logics that create trade-offs between profit and public value (Moizer and Tracey 2010; Stubbs and Cocklin 2008).

2.2 | Innovation as a Driver of Sustainability

Innovation refers to the application of novel processes, products, or practices that create value and competitive advantage (Schumpeter 1934). In the BE, innovation spans technological, governance, and business model advancements that enhance operational efficiency, reduce environmental impact, and build resilience (Elston et al. 2024). Drawing on Schumpeter's concept of the entrepreneur as an agent of change, firms apply these innovations, whether in products, processes, or organizational models.

SOI has emerged as a critical framework integrating environmental, social, and economic considerations into long-term business strategy. It emphasizes value creation that aligns with sustainability goals (Breuer et al. 2018; Adams et al. 2016). In the BE, SOI manifests in eco-friendly maritime technologies, circular economy adoption, and digital solutions for marine conservation.

Innovation in the BE manifests in multiple forms, incremental improvements, such as optimized fishing gear or energy-efficient propulsion systems (Shi et al. 2020), to radical disruptions, such as hydrogen-powered transport or offshore floating solar farms (Valdez-Juárez and Castillo-Vergara 2021; Rupo et al. 2018). Firms also engage in exploitative strategies that refine existing practices (e.g., logistics optimization, digital monitoring) (Behnam and Cagliano 2017) and explorative strategies that experiment with new knowledge (e.g., biomimicry, AI-based oceanographic research) (Adams et al. 2016; Benner and Tushman, 2003). This diversity of innovation forms highlights a strategic challenge: firms must choose between incremental efficiency and more transformative trajectories, often under conditions of financial and regulatory uncertainty.

The relationship between SOI and the TBL framework provides a foundation for assessing the impact of sustainability-driven innovation on business performance (Llorca-Ponce et al. 2021; Bossle et al. 2016; Nidumolu et al. 2013). Real-world applications in the BE, such as bio-based shipbuilding, smart aquaculture, and block chain-enabled supply chains, illustrate how innovation can reinforce sustainability objectives (Garlock et al. 2024; Choudhary et al. 2021; Cisneros-Montemayor et al. 2021).

However, most prior studies emphasize best practices without analyzing how institutional pressures condition which innovations are viable. This study contributes by examining SOI as a mediating mechanism that links sustainability orientation with actual performance outcomes.

Despite these advancements, the transition to sustainability-oriented business models requires systemic support from policymakers, investors, and industry stakeholders (Martínez-Vázquez et al. 2021). Understanding these dynamics is essential for analyzing the barriers and pathways to sustainable transformation, as explored in the next section.

2.3 | Barriers for a Sustainable and Innovative BE

Despite growing momentum, numerous barriers continue to hinder the widespread implementation of sustainability in the BE. These challenges are multifaceted, spanning regulatory, financial, technological, and knowledge-related constraints that limit the ability of firms to fully integrate SOI and TBL into their operations and strategies (Elston et al. 2024; Martínez-Vázquez et al. 2021).

Regulatory fragmentation and overlapping jurisdictions create uncertainty, delay decision-making, and deter investment in sustainable innovations (Almeida et al. 2024; OECD 2024). Financial constraints are particularly acute for SMEs, given the substantial upfront investments of renewable energy infrastructure, circular economy initiatives, and low-carbon technologies especially in the absence of strong incentives or subsidies (World Bank and UN DESA 2017; European Investment Bank 2021). Technological immaturity further limits adoption, as many marine innovations remain commercially unviable without sustained R&D support (Almeida et al. 2024). Lengthy bureaucratic processes further delay the deployment of innovative technologies and the adoption of sustainable business models (Benzaken et al. 2022; Penca 2019).

Organizational inertia, entrenched norms, and risk-averse cultures also hinder willingness to change (Porter and Kramer 2011). Additionally, market reluctance reinforces this dynamic, as investors and customers often prioritize short-term cost savings over long-term sustainability (Garcia et al. 2007). Finally, knowledge and skills gaps persist, as firms lack training, technical expertise, and absorptive capacity (OECD 2019; Kyvelou and Ierapetritis 2019).

Collaboration is increasingly recognized as a critical enabler of SOI, particularly where firms face resource and capability constraints. Cross-sector cooperation helps overcome financial limitations and regulatory inefficiencies by pooling knowledge and capabilities. Arroyave et al. (2025) demonstrate that frequent cooperation with stakeholders amplifies the relationship between environmental orientation and circular economy adoption, showing that collaboration functions as a structural mechanism for translating sustainability commitments into concrete innovation practices.

Overcoming these barriers requires coordinated stakeholder engagement, institutional reform, and regulatory adaptation (Van

Sumeren et al. 2021). Nonetheless, many efforts remain fragmented and underresourced, meaning even the most innovative solutions struggle to scale. This reveals a theoretical gap: prior studies often describe barriers as static constraints, but rarely examine how firms adapt, resist, or strategically negotiate them. This study addresses that gap by analyzing barriers as part of the dynamic interplay between institutional pressures and firm-level responses.

To guide the empirical analysis, this study adopts a conceptual framework (Figure 1) that synthesizes key theoretical and contextual insights. Grounded in institutional theory, RBV, and the TBL, the framework anticipates the research question by positioning SOI as a mediating mechanism that links institutional pressures and firm resources to uneven sustainability outcomes. It highlights the asymmetry between stronger environmental/economic pathways and a weaker social pathway, revealing a systemic feedback loop that shapes the pace of sustainability transitions in the Portuguese BE.

This framework illustrates how sustainability transitions unfold through SOI shaped by institutional theory and innovation logic and constrained by governance gaps and systemic imbalances across the TBL framework. It emphasizes the relative weakness of social sustainability outcomes and underscores the feedback loop between institutional legitimacy, innovation mechanisms, and performance.

3 | Methodology

This study explores how firms in Portugal's BE integrate SOI into their business strategies. It builds on prior quantitative research involving 40 firms,¹ which employed PLS-SEM to examine the drivers of sustainability and innovation (Elston et al. 2026).

That analysis found a strong positive relationship between sustainability and innovation ($\beta=0.686, p<0.01$). Innovation had significant positive effects on economic ($\beta=0.427, p<0.05$) and environmental outcomes ($\beta=0.341, p<0.05$), while the effect on social outcomes was nonsignificant ($\beta=-0.222, p=0.391$). These findings revealed an asymmetry across the TBL and highlighted the need to further investigate why social outcomes lag. In addition, survey responses indicated perceived barriers related to finance, regulation, and stakeholders (Elston et al. 2026). These insights directly informed the design of the qualitative stage, motivating the case selection and the interview themes.

The current research deepens these findings through semistructured interviews,² with five firms. Firms were selected using purposive sampling, targeting those with the highest composite scores in sustainability and innovation, based on the prior survey results. While not statistically generalizable, these information-rich cases have strong theoretical and empirical relevance (Bell et al. 2019; Yin 2018). This case-study design (Yin 2018) enables in-depth exploration of organizational strategies, contextual factors, and sustainability transitions (Gerring 2006). By focusing on firms that excel in both innovation and sustainability, the study seeks to identify replicable models to inform policy and practice.

A qualitative approach was adopted to examine the drivers, barriers, and strategic responses that shape SOI within firms. The following research questions guided the analysis: (1) How do firms in the Portuguese BE operationalize sustainability and innovation in their business practices? (2) What are the key enablers and barriers influencing sustainability-oriented innovation in these firms? and (3) How can sustainability and innovation strategies BE effectively scale and replicate across sectors?

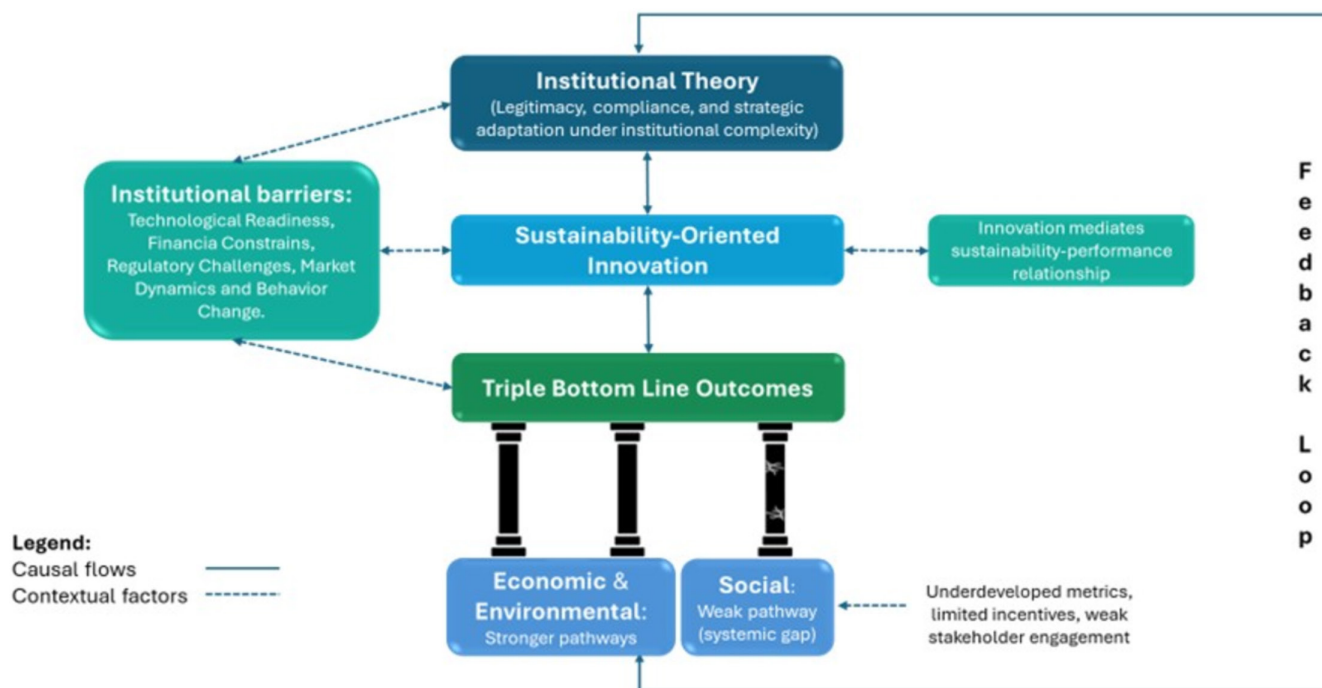


FIGURE 1 | Conceptual Framework—navigating sustainability in the Portuguese BE. Source: Own elaboration.

Semistructured interviews were conducted using a discussion guide (Cachia and Millward 2011), the interview guide was structured around six thematic categories (Table 1), derived from the literature review (Elston et al. 2024) and prior survey findings. Although participants were not provided with the full question list in advance, they were informed of the thematic areas, enabling spontaneous and candid responses. Questions were open-ended with structured prompts to encourage depth and consistency across cases (Blandford 2013). Interviews were conducted via Zoom, recorded with consent, and transcribed for analysis. Although online interviews have limitations (Bell et al. 2019), they allowed flexible scheduling and greater accessibility.

In total, five interviews were conducted (one executive per firm, typically the CEO, founder, or equivalent). This reflects the small size and centralized governance of Portuguese BE firms, where strategic decision-making is concentrated in top management.

Thematic analysis was performed using NVivo (QSR International v15), combining directed content analysis (based on prior literature) and open coding (Hsieh and Shannon 2005). The coding process followed five steps: (i) transcripts were imported into NVivo; (ii) initial deductive coding applied the six predefined categories; (iii) inductive open coding captured emergent themes; (iv) codes were consolidated into higher-order categories; and (v) cross-case comparisons were conducted using hierarchy charts and category ranking maps. These results were treated as exploratory, acknowledging that frequency may reflect repetition rather than importance (Namey et al. 2007; Wong and Li Ping 2008; Vaismoradi et al. 2016).

To enhance methodological rigor, an audit trail was maintained, documenting all stages from participant selection and interview design to coding decisions and data analysis (Bryman 2012). This transparency strengthens the reliability and credibility of the findings. Data triangulation enhanced validity by combining:

- Primary data: Semistructured interviews with company representatives.
- Secondary data: Institutional websites, publicly available information (mission, values, products, and services).
- Comparative analysis: Interview themes were cross-referenced with prior survey data³ to identify consistencies and validate findings across sources.

Theoretical triangulation was also employed, interpreting the findings through multiple conceptual lenses: institutional theory, RVB, and the TBL, to strengthen robustness and avoid reliance on a single explanatory approach (Bell et al. 2019; Gerring 2006).

Additionally, a qualitative comparative analysis (QCA) was used to explore causal pathways linking SOI outcomes with specific strategies, enablers, and barriers (Hanckel et al. 2021). Given the small-N sample, this was treated as a pattern recognition tool rather than for formal calibration. For example, firms that combined access to external funding with strong stakeholder collaboration consistently reported more successful scaling of SOI practices, while firms facing simultaneous financial and regulatory barriers struggled to translate innovation into measurable outcomes.

TABLE 1 | Thematic categories and subcategories used in NVivo coding.

Main category/theme	Subcategories
1. Contextual information and company identity	1.1. History and organizational context 1.2. Description products and services 1.3. Core values
2. Sustainability strategy and implementation	2.1. Environmental, economic, and social sustainability 2.2. Integration of sustainability into business strategy 2.3. Innovation as a means to achieve sustainability 2.4. Navigating sustainability trade-offs
3. Innovation practices	3.1. Innovation processes and strategies 3.2. Impact of innovation on business performance
4. External collaborations and stakeholder engagement	4.1. Partnerships with universities and R&D centers 4.2. Industry and institutional collaborations 4.3. Collaboration with communities 4.4. Sustainability communication and literacy
5. Challenges and barriers	5.1. Financial resources 5.2. Expertise and human resources 5.3. Bureaucratic and regulatory barriers 5.4. Market and cultural resistance
6. Opportunities and incentives	6.1. External funding and policy incentives 6.2. Regulatory changes supporting sustainability 6.3. Emerging market, tips, and business opportunities

Source: Own elaboration.

Ethical procedures followed standard guidelines for qualitative research. Informed consent was obtained for all interviews, and participants were briefed on objectives prior to recording (Bell et al. 2019). Identities were anonymized in reporting. Ethics approval was granted by the University of Algarve's Research Ethics Committee. This methodological approach provides a rigorous basis for understanding how Portuguese BE firms integrate sustainability and innovation. The following section presents findings, highlighting strategic patterns, enabling conditions, and persistent barriers.

4 | Integrating Sustainability: Empirical Findings and Theoretical Discussion

This section presents findings from five case studies and interprets them through multiple theoretical lenses. Drawing on triangulated methods, it integrates qualitative and quantitative insights to explore how firms operationalize SOI. This dual approach allows both descriptive richness and analytical depth, reinforcing credibility.

4.1 | Case-Study Description

To preserve confidentiality and respect the anonymity requested by participants, the five case-study firms are referred to as B1 through B5 throughout this analysis. These

designations, while coded, correspond to distinct organizational profiles within the Portuguese BE. Each firm was selected based on high scores in sustainability and innovation from the initial survey dataset, and their characteristics are summarized early in Table 2 to guide the reader. Company-specific data, such as sector, size, and turnover, derive from survey responses, while mission statements are sourced from institutional websites. This provides a structured overview that situates the case analysis.

The first case, B1, pursues incremental innovation in electro-solar vessels, aligning with Porter's (1985) differentiation strategy, where environmental innovation differentiates both product and brand. B2 applies biomimicry to water treatment and floating wetland systems, exemplifying nature-based solutions (Pathak 2019). Its emphasis on ecological design underscores environmental stewardship as a strategic pillar.

B3 develops compact wind energy solutions for off-grid contexts, reflecting ecological modernization theory (Mol and Sonnenfeld 2013), where technological progress reconciles growth and sustainability. B4, an aquaculture company, employs closed-loop systems and sustainable feed strategies aligned with circular economy principles (Magalhães et al. 2024; Geissdoerfer et al. 2017), aiming for both efficiency and sectoral leadership. Finally, B5, a state-owned enterprise managing ports and fish auctions, integrates digital traceability and sustainable logistics, consistent with industrial ecology (Graedel and Allenby 1995).

TABLE 2 | Case-study characteristics and mission.

Stakeholder	Industry sector	No. of employees	Company turnover	Mission
B1	Shipbuilding and repair; maritime transport	11–50	Up to 2 million	Develop energy-autonomous vessels for multiple markets; integrate sustainability into design and brand identity.
B2	Blue bioeconomy and biotechnology	11–50	Up to 2 million	Use biomimicry to create eco-friendly water and air treatment systems; prioritize ecological impact and cost-efficiency.
B3	Renewable energy	≤10	Up to 2 million	Democratize wind energy through compact turbines for off-grid use, supporting decentralization and energy resilience.
B4	Aquaculture	51–250	10–43 million	Produce healthy seafood through sustainable aquaculture to reduce Europe's import dependence; promote animal welfare, resource efficiency, and high sustainability standards while supporting biodiversity, food safety, and skilled rural employment.
B5	Fishing; port activities	>250	10–43 million	Modernize ports and fish auctions with a focus on traceability, compliance, and sustainability as a public sector mandate.

Source: Own elaboration, company size, sector, and turnover based on survey responses; mission statements retrieved from company websites.

Table 2 summarizes each company's core attributes, including sector, size, turnover, and mission. This table functions as the main comparative reference, replacing detailed narrative repetition. Figure 2 presents a word cloud generated from the firms' public value statements, offering a visual synthesis of the values driving sustainability across cases.

The word cloud illustrates how firms frame sustainability through recurring public values. Common terms, such as innovation, responsibility, transparency, and equity, reflect an orientation toward ethical, inclusive, and eco-conscious practices. These values align with social capital theory (Dodd et al. 2015), which emphasizes trust and collaboration in stakeholder engagement. This framing also supports the RVB (Barney 1991), suggesting that competitive differentiation arises from unique internal capabilities. However, in the dynamic BE, such capabilities must be continuously adapted, consistent with the dynamic capabilities theory (Teece et al. 1997). The novelty here is that sustainability is not presented as reactive compliance but as a proactive, value-driven identity, positioning firms to lead rather than follow sectoral change.

4.2 | Overview of Sustainability and Innovation Strategy

In the firms studied, sustainability emerges primarily not as a response to external pressure, but as a core and enduring organizational principle. NVivo coding revealed strong convergence between leader narratives, public mission statements, and strategic sustainability actions. Interviews consistently emphasized that sustainability is driven by leadership conviction rather than compliance or trends. This reinforces the internalization of sustainability as a long-term value rather than a reactive obligation.

The owner of B2 remarked, "Sustainability is not an optional goal, it is embedded into every stage of our product development ... It has always been my dream to close the water cycle." The CEO of B1 similarly explained "... I don't know, out of conviction or maybe even DNA, I have always placed great importance on the theme of sustainability."

These statements exemplify how senior leaders' values shape strategic direction, aligning with upper echelons theory (Hambrick and Mason 1984), which posits that executive beliefs



FIGURE 2 | Word cloud of the core values of the case studies. Source: Own elaboration, NVivo output.

influence organizational outcomes. Leadership commitment here drives sustainability integration not for compliance or market advantage, but as a foundational and identity-defining principle (Bennett et al. 2018).

Across the five cases, different innovation pathways emerged (see Section 4.1), each aligning directly with sustainability priorities. Firms employed incremental improvements (e.g., optimizing existing technologies), explorative experimentation (biomimicry and novel biological solutions), radical disruptions (compact wind turbines), and exploitative refinements (digital traceability and closed-loop aquaculture).

This diversity illustrates that innovation in the BE is not an isolated function but a continuous, integrated process. Technological advancement, resource efficiency, and resilience converge to build sustainable business models that extend beyond compliance and position firms as proactive sectoral leaders (Geissdoerfer et al. 2018; Porter and Kramer 2011).

4.2.1 | Environmental Sustainability

Environmental sustainability is a shared strategic priority across the five case-study firms, reflected in their strategic priorities and aligned with global frameworks such as the Paris Agreement (UNFCCC 2015) and the EU Green Deal (European Commission et al. 2024). Emphasis is placed on low-impact production, circular economy principles, and decarbonization as key enablers of environmental performance. This strategic emphasis is corroborated by survey findings: 87% of firms rated environmental sustainability as "important" or "very important," mirroring the priority expressed in interviews.

Decarbonization and renewable energy integration is one of the most significant strategies. For example, B4's solar-powered infrastructure reduces carbon emissions by 35%, while B5 has modernized port management with renewable energy and efficiency measures. As B5's executive explained, "We are committed to transparency, fish traceability, and supporting the conservation of marine resources, aligning with national and European sustainability policies." Digital traceability systems help support sustainable fisheries management by preventing overfishing and ensuring compliance (FAO 2020).

Some firms also explore negative-emission technologies and closed-loop systems. B2 developed photobioreactors capable of CO₂ capture, reflecting a nature-based, innovation-driven approach to climate mitigation (Pathak 2019). B4's land-based aquaculture model prevents fish escapes and recycles seawater, reducing risks of genetic contamination and habitat degradation.

Survey findings reinforce these patterns: 60% of firms reported adopting green technologies and 45% use renewable energy systems. Overall, environmental sustainability is not pursued as compliance, but as a strategic orientation toward innovation, competitiveness, and ecological stewardship. By integrating renewable energy, carbon sequestration, and circular economy practices, these firms are reshaping sectoral benchmarks and contributing to broader transitions in the blue economy.

4.2.2 | Economic Sustainability

In the BE, economic sustainability is underpinned by innovation, resource efficiency, diversification, and financial resilience. Both interview data and survey results affirm that sustainability and profitability are closely linked (An and Li 2020). Through cost reduction, new revenue streams, and differentiation via environmental leadership, it is shown that sustainability-oriented strategies can generate tangible value (Geissdoerfer et al. 2018; Flores et al. 2008).

Cost efficiency emerged as a recurring strategy. B2's cork-based water systems, requiring only annual maintenance, reduce operational costs. B4 scaled revenues from €15 million to €40 million by leveraging efficiency gains and advanced technologies. B5's campaigns promoting undervalued fish species simultaneously enhanced product value and supported local fishing communities. These cases illustrate how economic returns sometimes can also reinforce social returns.

Beyond growth, sustainability initiatives mitigate risk. Firms investing in renewable energy and circular models are more resilient to volatile energy prices and regulatory shifts. As B1 explained, "Our electro-solar vessels ensure long-term financial stability in a future where fossil fuel dependency is no longer viable." B4's CEO similarly emphasized long-term positioning through continuous R&D investment, blending competitiveness with sustainability.

Survey evidence supports this emphasis: Over 70% of firms identified reduced operational costs as a key SOI outcome. These findings suggest that economic sustainability is not limited to cost control but involves forward-looking investments that enhance profitability and resilience. By embedding sustainability into business models and strategic planning, these firms are positioning themselves for long-term advantage.

4.2.3 | Social Sustainability

Social responsibility is a critical dimension of sustainability, encompassing community well-being, ethical conduct, and inclusive development. Across cases, social engagement emerged through three main patterns: (i) community partnerships, (ii) employee-centered initiatives, and (iii) business models embedding social value. This was supported by interview data, coded values from public communications, and survey responses on perceived social impact.

B5's weekly fish donations and support programs for small-scale fishers exemplify community benefit linked to business operations. B2's floating cork islands combine environmental stewardship with basic sanitation solutions in underserved areas, illustrating eco-innovation with social outcomes. B4's internal programs, including inclusive hiring and employee health services, reflect a progressive CSR model that connects workforce well-being to organizational performance. Beyond these examples, several firms move beyond conventional CSR by embedding social problem-solving into their core innovation strategies (de Souza Barbosa et al. 2023; Ismail 2021).

Survey data reinforces these insights: 63% of firms reported positive impacts on quality of life, while a similar proportion highlighted benefits in environmental education and awareness. Nevertheless, the findings also reveal a systemic gap: 38% rated their impact on education and awareness as weak or neutral (scores 2–3). This indicates that communication and outreach remain underdeveloped, despite broader sustainability commitments.

Figure 3 (NVivo hierarchy chart) illustrates this imbalance: environmental references dominated (48% of total interview codes, $n = 32$), while economic and social codes accounted for only ~26% each ($n = 17$). This asymmetry supports prior literature noting that the social pillar of the TBL is persistently weaker than environmental and economic dimensions (Kennedy and Bocken 2020; Maier et al. 2020). The novelty here lies in showing how this imbalance persists even among high-performing firms, where leadership conviction drives sustainability. While firms generate indirect social benefits, systematic metrics for equity, inclusivity, and labor remain limited, making social outcomes harder to capture, communicate, and scale.

Recent evidence suggests that this persistent weakness of the social pillar can be addressed through the deliberate cultivation of ethical culture within organizations. Ruiz-Palomino et al. (2025) show that structured ethics-training programs and leadership-driven ethical cultures translate moral values into concrete practices that strengthen fairness, trust, and employee engagement. Such initiatives operationalize social sustainability by embedding ethical behavior into daily decision-making, thereby linking leadership conviction with measurable improvements in organizational well-being and stakeholder relations. Integrating this ethical-culture perspective provides a pathway for firms to reinforce the social dimension of sustainability and reduce the imbalance across the TBL.

4.2.4 | Trade-Off Between Economic, Environmental and Social Sustainability

Balancing environmental, economic, and social goals remains a key challenge for firms in the BE. This imbalance, already evident in the PLS-SEM analysis, highlights how environmental and economic benefits are more immediately captured than social outcomes. Although sustainability initiatives offer long-term strategic advantages, they often involve significant upfront investments. Interviewees consistently emphasized that sustainability is perceived as a short-term cost but a long-term asset.

Firms acknowledged that investing in renewable energy, waste reduction, and sustainable supply chains entails high initial costs, but also yields long-term efficiency, savings, and competitive positioning. As B4's CEO noted, "I have to convince shareholders, but in most cases, the most sustainable option is also the most economical one in the long run." Similarly, B1 emphasized that high sustainability standards are "strategic and nonnegotiable" for financial optimization and customer satisfaction.

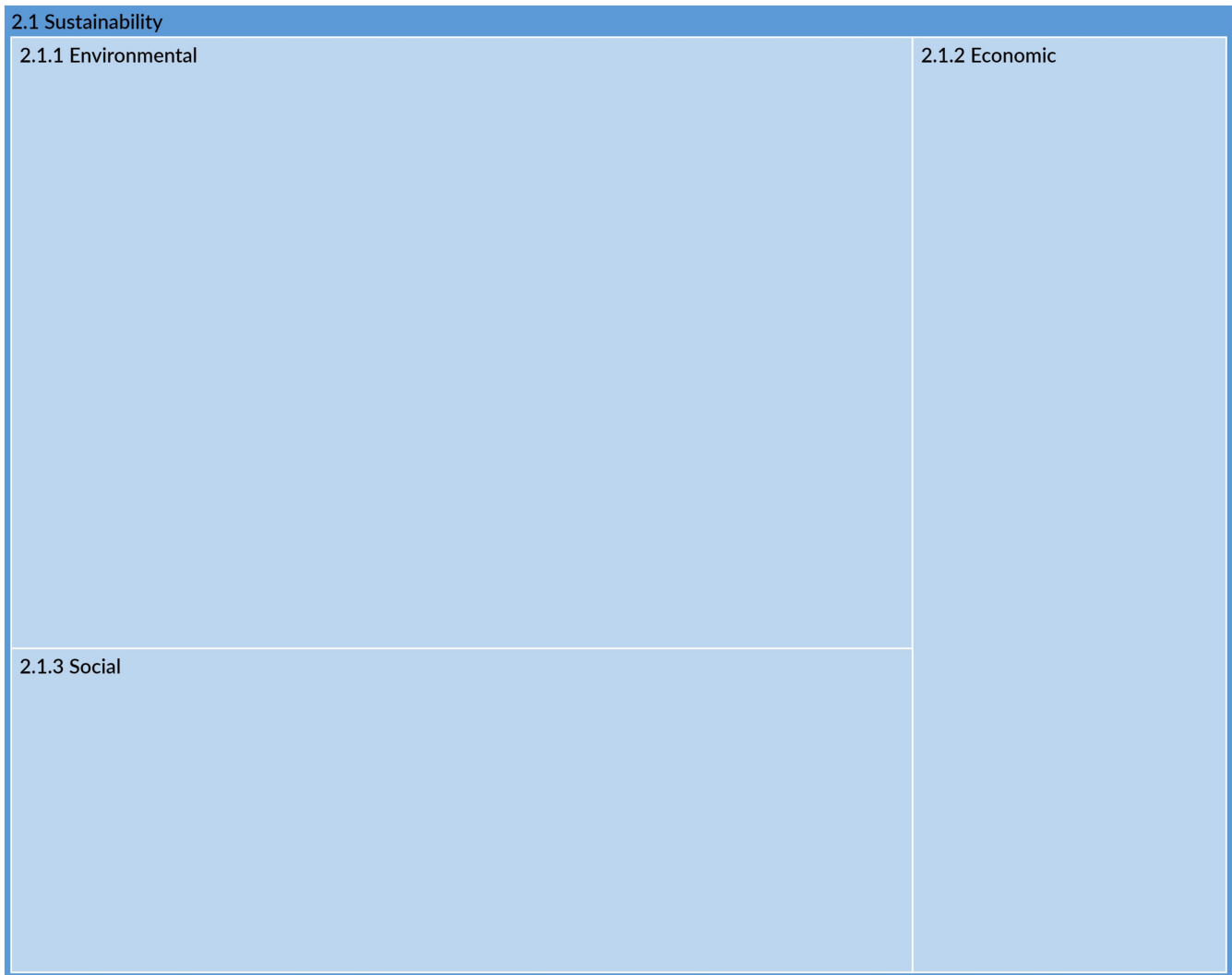


FIGURE 3 | Hierarchy chart of sustainability dimensions coded in interviews. *Source:* Own elaboration, NVivo output.

Survey data reinforces these qualitative findings as over 65% of firms rated economic sustainability practices, such as cost-saving innovation or diversification, as “important” or “very important,” and more than 70% agreed that environmental investments improved their long-term market position. These perceptions are consistent with the PLS-SEM results, which showed that innovation significantly enhanced economic ($\beta=0.427, p<0.05$) and moderately enhanced the environmental outcomes ($\beta=0.341, p<0.05$), while the effect on social outcomes was nonsignificant ($\beta=-0.222, p=0.391$). This asymmetry suggests that trade-offs are not viewed as zero-sum, but as phased transformations in which economic and environmental benefits are more readily quantified and communicated, whereas social benefits remain harder to capture and justify in shareholder terms.

For SMEs, sustainable practices often require large upfront investments. This creates tension between short-term strain and long-term gain. As noted by Matzembacher et al. (2020), stakeholder buy-in is not always immediate. Nevertheless, firms in this study consistently view sustainability as a pathway to innovation, efficiency, and revenue growth, not simply as a cost. While firms actively frame these trade-offs as strategic

opportunities, their success is also contingent on broader systemic conditions. The next section explores the organizational, financial, and regulatory barriers that shape the ability of firms to implement SOI at scale.

4.3 | Stakeholder Engagement

4.3.1 | Supplier Partnerships for Sustainable Sourcing

Supplier sustainability emerged as a strategic priority across all five case studies. Firms proactively encouraged environmental accountability among suppliers, particularly in reducing carbon footprints, improving sourcing practices, and minimizing waste. As B4 shared, “Suppliers weren’t measuring their carbon footprint ... I told them I wouldn’t buy from them anymore if they didn’t report it.”

Because of capacity limitations and the novelty of many of their technologies, several companies rely heavily on external partners to develop sustainable solutions. These collaborations provide access to green materials and advanced components without requiring full internalization. As B2 explained: “Our

supplier network is crucial, they provide high-quality, eco-friendly materials that align with our sustainability principles.”

This type of engagement reflects Schaltegger and Wagner (2017) notion of collaborative networks driving sustainable innovation. NVivo coding under Node 4.1.2 (Figure 4) confirms this with 11 references across cases. Survey evidence is consistent, with over 50% of respondents citing supplier collaboration as having a moderate or high impact on their sustainability strategies.

4.3.2 | Community Partnerships and Social Impact

Beyond operational sustainability, firms invest in community partnerships that foster environmental awareness and social inclusion. These initiatives extend corporate impact beyond business operations into broader regional development.

B5 has implemented education and training programs with fishing communities, promoting selective fishing and waste reduction. B4 sponsors local sustainability projects, while B3 engages in public awareness campaigns on renewable energy. These activities represent not only goodwill but also a strategic embedding of social responsibility.

NVivo coding confirms this pattern: “Collaboration with Communities” (Node 4.1.3, Figure 4) was less frequently referenced ($n=3$) than supplier or academic collaborations. This indicates that while present, community partnerships remain secondary in strategic weight. Survey data aligns with the fact that community engagement was positively perceived but not systematically integrated into firm strategies.

4.3.3 | Collaboration With Universities and R&D Facilities

Partnerships with universities and research institutions emerged as the strongest and most consistent form of external collaboration. All five firms reported collaborations providing access to academic expertise, interns, and applied research.

B4 highlighted mutual benefits: “We work with universities to bring students into real-world sustainability projects, students gain experience, and we benefit from fresh ideas.” Similarly, B1 and B2 stressed that academic partnerships keep them at the cutting edge of sustainability innovation. As B2 noted: “We collaborate with research institutions because sustainability is an evolving field. If we want to stay ahead, we need to be constantly learning and developing new solutions with academic experts.”

This finding aligns with broader evidence that stakeholder cooperation amplifies firms’ capacity to translate sustainability orientation into actionable practices, as frequent collaboration with stakeholders strengthens the pathway between environmental orientation and circular economy adoption, a pattern also reflected in the partnerships observed among the firms studied (Arroyave et al. 2025).

These collaborations generated tangible innovations, from photobioreactors (B2) to sustainable aquaculture systems (B4), reinforcing the value of public–private research exchange. NVivo analysis confirms this prominence: academic collaboration received 13 references (Node 4.1.1), the highest among all nodes in Figure 4. Survey data corroborates this: 73% of firms rated university collaboration as significant (scores 4–5), although 28%



FIGURE 4 | NVivo hierarchy chart: external collaborations and stakeholder engagement. *Source:* Own elaboration, NVivo output.

reported minimal or no collaboration, revealing an untapped opportunity to deepen partnerships.

4.4 | Barriers Toward Sustainable Innovation

4.4.1 | Financial Constraints: The Cost of Sustainability

Financial limitations emerged as one of the most consistently cited barriers to SOI. While participants acknowledged the long-term value of sustainability, they emphasized that the upfront costs of clean technologies, renewable energy integration, and sustainable supply chains often impose significant financial strain, particularly on SMEs.

B4 highlighted the need to “convince shareholders” of the long-term returns on sustainability investments, while B2 remarked that “banks and investors still see sustainable technologies as risky”, making financing difficult to secure. Public funding programs frequently require firms to co-finance a portion of the investment, creating additional strain. As B1 explained, “Most funding programs cover around 75% of costs. For small companies, finding the remaining 25% can be impossible.” B3 reinforced this point, noting that for startups, even partial self-financing can be “a deal-breaker.”

This paradox, publicly incentivizing sustainability while restricting access through liquidity barriers, was a recurring theme across cases. In capital-intensive sectors, it often forced firms to rely on incremental innovation or external partnerships rather than scaling disruptive solutions.

NVivo analysis confirms the salience of this theme, with *Financial Resources*, one of the most frequently coded nodes under *Barriers* (node 5.1, Figure 5). Survey results corroborate this: 62.5% of respondents identified limited financial resources as a primary obstacle, rising to 70% among SMEs (< 50 employees). These findings echo Boons and Lüdeke-Freund (2013), who argue that high upfront costs continue to deter investment in green innovation (Verdolini et al. 2021). Addressing this barrier requires more inclusive financing

mechanisms that prioritize long-term sustainability over short-term capital returns.

4.4.2 | Lack of Human Resources and Skilled Workforce

A second major challenge is the shortage of skilled professionals in SOI. Firms consistently reported that expertise in this area is both scarce and costly to attract. As B3 noted, “Every company is looking for sustainability experts, but there aren’t enough of them. The few who are available are often recruited by large corporations that can afford and offer higher salaries.”

This talent scarcity spans engineers, scientists, and researchers, slowing the pace of innovation. For smaller firms, financial constraints exacerbate the challenge, making it impossible to match the salaries offered by large corporations. As a result, firms often resort to internal training and capacity building, which increases both costs and time to implementation (Pace et al. 2023).

NVivo coding confirms *Expertise and Human Resources* as a significant barrier across all five case-study firms (node 5.2, Figure 5). Taken together, qualitative and quantitative findings highlight talent scarcity as a systemic bottleneck that limits the pace at which firms can internalize and scale sustainability capabilities.

4.4.3 | Lack of Government Support and Policy Incentives

Although sustainability is a stated government priority, firms in the BE face persistent challenges with funding mechanisms, procurement policies, and bureaucratic inefficiencies. These institutional obstacles often delay projects and impose financial strain, particularly for SMEs that depend on public programs to scale sustainable technologies.

A major source of frustration was the *Fundo Azul* program, which requires firms to advance capital and endure long waits, sometimes over a year, for reimbursement. As B1 explained, “The reimbursement process takes so long that we’ve had to find alternative financing ... we’re still waiting on payments over a year later.” B4 described how shifting regulations generated costly delays: “We waited two years for approval due to changing mandates on environmental impact studies, wasting time, money, and resources.”

Public procurement was another critical issue. B1 noted that even patented domestic innovations were overlooked: “The last boat purchased for a sustainable project was Spanish, failing the required specifications, but chosen for its lower price.” Such decisions undermine both innovation incentives and the competitiveness of national firms.

As a result, firms frequently resort to private financing, delay projects, or scale down ambitions. Unpredictable shifts in regulatory requirements and enforcement cycles further create uncertainty, financial losses, and stagnation, particularly for SMEs seeking to commercialize patented innovations.



FIGURE 5 | NVivo hierarchy chart: challenges and barriers. Source: Own elaboration, NVivo output.

NVivo analysis underscores the prominence of this theme: *Bureaucracy and Government Inefficiencies* was the most frequently coded barrier (node 5.3, Figure 5). These findings echo Kemp et al. (2007), who stress that regulatory stability, consistent enforcement, and timely institutional support are preconditions for effective sustainability transitions.

4.4.4 | Market Challenges and Consumer Misunderstanding of Sustainable Products

Market dynamics that prioritize price over environmental value are also a burden to firms. Despite offering greener alternatives, many firms in the BE find that customers remain focused on short-term affordability. As B4 remarked, “At the end of the day, the price of the fish is what matters most... The EU survey positioned price, with 55%, as the most important factor for consumers, with sustainability last.”

This price sensitivity constrains the ability to charge a premium for sustainable products and reduces incentives to innovate. Firms are often forced to educate consumers about lifecycle savings. As B1 explained: “We constantly explain that our boats pay for themselves through fuel savings in six years.”

B2 observed that radical innovations often face skepticism, largely due to unfamiliarity. As Claudy et al. (2015) argue, adoption depends on perceived risks and benefits, while Davies and Chambers (2018) note that high upfront costs remain a deterrent to consumers choosing sustainable alternatives.

NVivo coding highlights commercialization challenges ($n=10$) as a significant manifestation of these market obstacles (node 5.4, Figure 5). These findings suggest that sustainable business models cannot succeed through internal innovation alone. Shifting consumer perceptions, building trust, and communicating long-term value are critical to overcoming adoption barriers.

As shown in Figure 5, the most frequently cited barriers were bureaucratic inefficiencies ($n=21$), financial constraints ($n=10$), commercialization challenges ($n=10$), and shortages of qualified workforce ($n=8$). Taken together, these findings reveal a system marked by both structural and perceptual obstacles. Overcoming them requires coordinated policy action to reduce regulatory friction, broaden financial access, and foster greater consumer awareness.

4.5 | Opportunities and Incentives for Sustainable Innovation

4.5.1 | External Incentives and Financing

Despite financial constraints, sustainable financing opportunities are growing, particularly through EU grants, green funds, and impact investment. Firms aligned with TBL principles become more attractive to sustainability-focused investors. EU initiatives like the Green Deal and Horizon Europe support innovation in renewable energy, water conservation, and circular economy models. Carbon markets and certifications allow firms

to monetize sustainability, often by charging a premium for certified products.

B4 emphasized: “We secured EU funding to implement energy-efficient systems in our aquaculture facilities. Over the past four years, about €3 million has been invested in R&D through approved projects.”

NVivo coding and survey data confirm the importance of external funding: 62.5% of firms accessed national or EU support. These findings demonstrate that while funding gaps remain, targeted financial mechanisms can act as catalysts for eco-innovation scaling.

4.5.2 | Political and Regulatory Changes

As climate concerns gain political momentum, firms identify regulatory improvement as a crucial enabler of SOI. While existing policy frameworks broadly align with environmental goals, they are often experienced as overly bureaucratic, opaque, and resource-intensive, particularly for SMEs.

Interviewees described funding applications, such as those for the Fundo Azul program, as administratively complex, requiring dense documentation and often unclear eligibility guidelines. For many SMEs, the absence of internal capacity makes it difficult to navigate these processes. As one firm noted, “We sometimes need external consultants just to understand the application requirements.”

Firms called for simplified access, faster reimbursements, and greater transparency in public incentive schemes. B3 explained: “If access to incentives were more transparent and faster, we'd be able to adopt sustainable technologies without hesitation.” Participants emphasized that these changes would not only improve access but also speed up implementation and de-risk innovation investment.

Public procurement also emerged as a major opportunity. Several firms argued that prioritizing domestic sustainable products in procurement decisions would strengthen national innovation and generate positive economic spillovers.

In short, firms are not only identifying bottlenecks but also proposing concrete reforms: capacity-building for SMEs, simplified procedures, and procurement policies that better reflect sustainability goals. Survey evidence reinforces this: over 60% of respondents cited regulatory complexity as a barrier, but many also recognized that streamlined administration and targeted incentives could meaningfully enhance innovation capacity.

4.5.3 | Recommendations for Companies Pursuing Sustainability

The five case-study firms offer valuable insights into how SOI can be pursued amid financial, regulatory, and market constraints. Rather than generic best practices, the lessons below reflect context-specific strategies tailored to the BE:

- **Start with incremental innovation as a practical entry point:** For resource-constrained firms, incremental innovation offers a low-risk strategy (Anderson and Turshman, 1990). B1's vessel improvements and B4's aquaculture optimizations illustrate how stepwise changes build legitimacy and reduce resistance, creating the foundation for larger transitions.
- **Leverage existing technologies through smart integration:** B1 and B3 show that adapting mature technologies can be as transformative as inventing new ones. By integrating electro-solar propulsion or decentralized wind into novel systems, firms reduce R&D risk and accelerate time-to-market.
- **Strengthen financial resilience beyond grant reliance:** While public funding catalyzes change, long-term viability depends on creating value. As B2 noted: "Public funds are a bonus, not the foundation." Successful firms combined grants with efficiency gains, niche positioning, and stakeholder trust.
- **Stay flexible and iterate strategically:** Uncertainty is inherent in sustainability transitions. B2's strategy of pursuing multiple innovation tracks demonstrates how agility allows firms to pivot, learn, and scale what works.
- **Use partnerships to accelerate learning and scale:** Collaborations with universities (B4), suppliers (B2), and public bodies (B5) helped firms fill capability gaps, reduce costs, and legitimize solutions, particularly important for SMEs.
- **Educate consumers and shape demand:** Technological solutions require cultural acceptance. B2 and B5 emphasized the importance of communicating lifecycle benefits and sustainability value, underscoring education as a critical enabler of demand creation.
- **Diversify funding and align with SDG targets:** Firms accessing EU funds, carbon markets, or impact investors scaled more effectively and retained autonomy. Aligning strategies with SDG metrics enhanced credibility and broadened funding eligibility.

Taken together, these cases show that SOI is not a one-size-fits-all model but a strategic negotiation between innovation, resilience, and systemic alignment. Firms adapt within constraints, leveraging partnerships, policy shifts, and internal capacity to drive transformation. Table 3 synthesizes the five firms' sustainability and innovation strategies, outlining how each navigates unique barriers and enablers to implement SOI under real-world conditions.

While Table 3 highlights firm-specific pathways, Figure 6 consolidates these findings into a cross-case framework, emphasizing how internal capabilities and external structures jointly shape the potential of SOI. The matrix illustrates how leadership conviction, SME flexibility, and partnerships act as critical enablers, while structural challenges such as bureaucratic inefficiencies, talent scarcity, and market risk aversion continue to constrain scalability. The matrix underscores that sustainable innovation emerges from the interplay of firm-level capabilities and systemic conditions, reinforcing the need for multilevel policy and institutional support.

TABLE 3 | Strategic synthesis of the five case-study firms.

Firm	Innovation type	Sustainability focus	Key enablers	Main barriers	Strategic takeaway
B1	Incremental	Renewable marine transport	Technology recombination; visionary leadership	Bureaucratic delays; co-financing requirements	Use mature tech in niche markets to reduce risk and build legitimacy gradually
B2	Explorative	Biomimicry-based water and air systems	R&D collaboration; mission-driven values	Consumer skepticism; scaling radical tech	Combine experimental innovation with education and staged rollout
B3	Radical	Decentralized wind energy	Product differentiation; lean structure	Talent scarcity; limited capital	Balance bold ideas with financial discipline and agile adaptation
B4	Exploitative	Closed-loop aquaculture	Public funding; CSR embeddedness; operational scale	Regulatory complexity; shareholder resistance	Build trust through small wins and use public funding to scale incrementally
B5	Exploitative	Port decarbonization; digital traceability	Public mandate; stakeholder trust	Procurement bias; institutional rigidity	Leverage public legitimacy to shape procurement and policy environments

Source: Own elaboration.

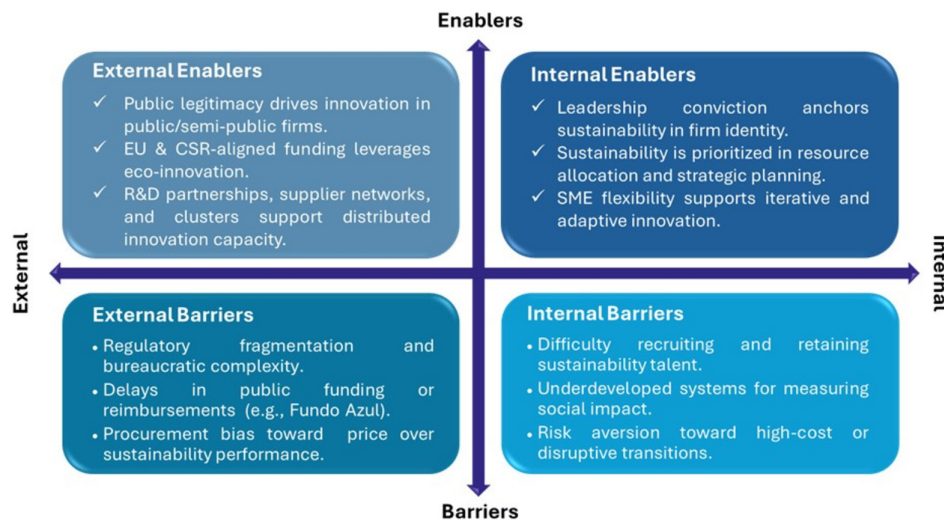


FIGURE 6 | Enablers and barriers matrix: cross-case analytical synthesis. *Source:* Own elaboration.

5 | Conclusion

Sustainable innovation lies at the core of how firms evolve and create value across the blue economy. This article explored how five Portuguese BE firms implement SOI in practice, drawing on triangulated data from semistructured interviews, company materials, and previous survey results. It examined how sustainability becomes embedded in strategic and operational decisions, the barriers firms face, and the conditions that support scalable transitions. It demonstrated how firms that integrate sustainability into their core strategy exhibit greater resilience.

This study contributes theoretically by clarifying persistent asymmetries across the TBL. Consistent with the PLS-SEM findings, economic and environmental outcomes were more readily measurable and communicable, whereas social sustainability remained the weakest pillar, even among high-performing firms. Social outcomes, such as equity, labor inclusivity, and community well-being, were often indirect or peripheral (e.g., donations, awareness campaigns), confirming earlier observations that the social pillar is persistently underdeveloped (Kennedy and Bocken 2020; Maier et al. 2020).

These findings align with wider debates in hybrid organization research, where firms struggle to balance commercial and mission-driven priorities (Moizer and Tracey 2010; Stubbs and Cocklin 2008). The complexity of value capture in balancing multiple goals remains a systemic challenge (Wilson and Post 2013).

To explain these dynamics, the study integrates institutional theory (Scott 2008) to demonstrate how fragmented governance and regulatory volatility compound these issues, the RVB and dynamic capabilities (Teece et al. 1997) to demonstrate how adaptive strategies build resilience, and diffusion theory (Rogers et al. 2019) to highlight how firm size, legitimacy, and absorptive capacity shape uptake. Social Capital Theory (Dodd et al. 2015) helps explain further how inclusive governance and trust-based networks support resilience in coastal communities. Social capital theory (Dodd et al. 2015) further clarifies how inclusive

governance and trust-based networks support resilience in coastal communities.

This analysis also underscores the role of ethical culture in translating sustainability values into practice, consistent with Ruiz-Palomino et al. (2025), who demonstrate that leadership-driven ethics initiatives help institutionalize the social dimension of sustainability. Consistent with these perspectives, evidence also indicates that frequent stakeholder cooperation strengthens firms' capacity to translate environmental orientation into circular innovation, reinforcing collaboration as a structural enabler of sustainability transitions (Arroyave et al. 2025). Together, these frameworks advance understanding of institutional and organizational asymmetries shaping sustainability outcomes in ocean-based industries.

Empirically, the cases reveal promising practices, including closed-loop aquaculture, CO₂ sequestration, and biomimicry-based treatment systems, but also structural barriers that limit scalability. These findings carry clear policy implications, pointing to four key policy priorities. First, shift from reimbursement to upfront financing to reduce liquidity barriers, especially for SMEs, which prevent access to EU and national funds. Second, reform public procurement to prioritize certified domestic sustainable solutions over low-cost imports, reinforcing innovation incentives and national competitiveness. Third, streamline regulatory and licensing procedures, ensuring stability and predictability while cutting delays that undermine investor confidence. Lastly, strengthen the social dimension of policy instruments, explicitly valuing labor equity, inclusivity, and community well-being alongside environmental performance.

These recommendations are closely tied to the empirical findings: delayed reimbursements (B1, B4), procurement bias (B1, B5), regulatory inefficiencies (B4), and limited social performance metrics (survey results and section 4.2.3). Comparatively, Portuguese BE firms face similar obstacles to other regions. Nordic aquaculture also struggles with regulatory bottlenecks (Luthman et al. 2022), renewable energy projects in Latin America face financing and governance gaps (Bicalho

et al. 2024), and OECD reports highlight fragmented global ocean governance as a systemic inhibitor of scaling sustainable innovation (OECD 2024). Placing Portuguese experiences in this comparative lens underscores both shared challenges and the country's potential leadership in piloting socially inclusive, innovation-driven BE strategies.

Methodologically, this study demonstrates the value of triangulating interviews, surveys, and company data to capture how sustainability is articulated and practiced. This approach addresses a recurring gap in BE research, where reliance on secondary statistics often obscures organizational processes. The multisource framework offers a replicable model for future research into sustainability transitions in context-sensitive and sector-specific domains.

While offering context-rich insights, this research is bounded by the scope of five Portuguese cases, which, although diverse, are not statistically representative. Future studies should expand across geographies and subsectors, with particular attention to the social dimension of sustainability, which is currently under-explored. Comparative analyses across international contexts will be essential to understand how global markets, trade dynamics, and governance networks influence firms' strategies. Only through cumulative, cross-sectoral evidence can the BE evolve from isolated good practices to systemic transformation aligned with the SDGs and global climate goals.

This research reinforces the importance of revisiting assumptions in sustainability theory, especially around scalability, equity, and replicability. It highlights how context-specific, triangulated methods are crucial to understanding how sustainability transitions unfold in practice. While the cases provide encouraging insights, they also reveal structural limits beyond firms' direct control.

SOI in the BE emerges not as symbolic but as strategic and necessity-driven. Firms adapt creatively to institutional fragmentation, resource scarcity, and financing constraints, showing that successful innovation often stems from necessity rather than abundance. Practices such as electro-solar vessels, CO₂ sequestration, and sustainable aquaculture reveal the transformative potential of ocean-based industries if supported by coherent ecosystems of finance, regulation, and partnerships. In the cases studied, trust-based partnerships, with universities, communities, and suppliers, enhanced both innovation and legitimacy, reinforcing the role of stakeholder engagement in building competitive advantage (Markard et al. 2012; Freeman and McVea 2005; Elkington 1998).

At a broader level, the blue economy must be recognized as more than a maritime sector. It is a critical arena for the global sustainable transition, where ecological stewardship, technological innovation, and social inclusion intersect. Anchored in the SDGs, the EU Green Deal, and the Paris Agreement, the BE has the potential to operationalize sustainability transitions in ways that are both globally significant and locally grounded. With the right support, BE firms can become pioneers of just and resilient transitions, bridging planetary boundaries with socio-economic development (Elkington 1998; Markard et al. 2012).

Ultimately, this study underscores that advancing SOI in the BE requires both firm-level ingenuity and systemic reform. By linking organizational resilience with institutional coordination, the BE can serve not only as a testing ground but also as a global exemplar for sustainability transitions, showing that ocean-based industries can be at the forefront of a just, inclusive, and low-carbon global transition.

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Endnotes

- ¹ Full PLS-SEM model structure is included in Appendix A, for contextual reference.
- ² The semistructured interviews were guided by a predefined set of themes and questions. The full interview guide is available in Appendix B.
- ³ For transparency and to support the triangulation of findings, the key summary statistics of the survey data are included in Appendix D, although the PLS-SEM analysis may be found in Appendix A.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** Supplementary Information.