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Final published version

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Citation (APA)

Kharbeet, G., Khodaei, H., Ortt, R., & Scholten, V. (2026). Triggers of sustainable business model innovation in technology-based startups: An empirical investigation. *Journal of Innovation and Knowledge*, 16, Article 101021. <https://doi.org/10.1016/j.jik.2026.101021>

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Triggers of sustainable business model innovation in technology-based startups: An empirical investigation

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ARTICLE INFO

JEL classification:

L26
O31
M13
Q01

Keywords:

Business model innovation
Sustainable business models
Triggers
Technology-based startups

ABSTRACT

This study examines what technology-based startups treat as external triggers for initiating sustainable business model innovation (SBMI) through an interview-centered, comparative qualitative study of 31 sustainability-oriented startups in the Netherlands. The 46 semi-structured interviews conducted during 2023–2025 were complemented by archival material to develop a multilevel framework of external triggers. The analysis identifies seven trigger domains across two distinct levels. At the value network level, startups report customer and user adoption expectations for greener solutions, ecosystem gatekeeper and competitive pressures, impact-oriented finance and public funding conditions, and digital trust, traceability, and transparency requirements in procurement and inter-organizational exchange. At the institutional level, startups report clean-tech trajectories and socio-technical infrastructures, rules, standards, and compliance regimes, and societal climate and circularity norms shaping legitimacy climates and solution spaces. The findings show that SBMI initiation is not prompted by an undifferentiated set of generic environmental factors, but by structured multilevel triggers that impact startups through distinct ecosystem channels and prompt reconsideration of value creation, value delivery, and value capture.

Introduction

Sustainability challenges such as climate change, biodiversity loss, and social inequality have become central concerns in management and innovation research (Markard et al., 2012; Dzhunushalieva & Teuber, 2024). The United Nations Sustainable Development Goals (SDGs) intensify expectations that firms contribute simultaneously to environmental protection, social inclusion, and economic resilience, and recent work has increasingly examined how innovation and knowledge activities support or hinder progress on these goals (Raman et al., 2024). In parallel, digital technologies such as artificial intelligence (AI), big data analytics, blockchain, and the Internet of Things (IoT) are reshaping how organizations coordinate, monitor, and optimize activities, with important implications for sustainable development (Nishant et al., 2020; Vinuesa et al., 2020; Wang et al., 2023). However, evidence also suggests that digital transformation and sustainability strategies are not automatically aligned, and that organizations often struggle to translate digital capabilities into sustainability outcomes in practice (Guandalini, 2022; Quttainah & Ayadi, 2024; Pricopoaia et al., 2025).

Business model research offers a useful lens to examine how firms

respond to the combined demands of sustainability and digitalization. Business models describe how organizations structure value creation, value delivery, and value capture for customers and other stakeholders (Teece, 2010; Demil & Lecocq, 2010; Massa et al., 2017). Business model innovation (BMI) refers to the deliberate, non-trivial changes in these value processes that alter how firms generate and appropriate value (Foss & Saebi, 2017; Ghezzi & Cavallo, 2020; Cavallo et al., 2024). Related work on dynamic business models also emphasizes the importance of examining business model change under changing internal and external conditions, rather than treating business models as static representations (Khodaei & Ortt, 2019). A growing stream of BMI research focuses on the triggers, including technological developments, regulatory change, crises, and shifts in customer expectations, that prompt firms to initiate and direct business model change (Bocken & Geradts, 2020; Ammirato et al., 2021; Vittori et al., 2022). Digital technologies feature prominently in this literature because they can both reshape the conditions that firms face (e.g., competitive dynamics and industry architectures) and influence how triggers translate into changes in value creation, value delivery, and value capture. Recent work shows that digital technologies can transform innovation drivers, underscoring

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what this implies for value mechanism innovation. This reinforces the need to treat digitalization not merely as context but as a force that reshapes the trigger landscape itself (Mancuso et al., 2025a).

Building on BMI, sustainable business model innovation (SBMI) focuses on business model change that embeds environmental and social objectives alongside economic viability into value creation, value delivery, and value capture (Boons & Lüdeke-Freund, 2013; Evans et al., 2017; Geissdoerfer et al., 2018). Although the SBMI literature offers substantial conceptual guidance, firms often struggle to translate sustainability-oriented designs into viable and scalable business model change (Boons & Lüdeke-Freund, 2013; Baldassarre et al., 2020; Atkova et al., 2025). This challenge becomes more complex in digitally intensive settings, where digital technologies can support sustainability outcomes while also introducing ethical risks, rebound effects, and other forms of value destruction (Vinueza et al., 2020; Mancuso et al., 2025b).

Despite these advances, relatively little is known about the triggers of SBMI in practice, especially in entrepreneurial contexts. Studies elaborate on policy initiatives and sustainability regulation, impact-oriented finance, and changing stakeholder expectations as relevant background conditions (Yip & Bocken, 2018; Bocken & Geradts, 2020; Hellemans et al., 2022; Pan et al., 2022; Dhir et al., 2023; Pricopoaia et al., 2025), but typically stop short of examining them as specific triggers that founders recognize as salient and respond to through concrete reconfigurations of value creation, value delivery, and value capture. Reviews and conceptual work repeatedly call for stronger empirical evidence on the conditions that trigger SBMI, and on how external conditions initiate sustainability-oriented business model change over time (Shakeel et al., 2020; Minatogawa et al., 2022). Similar studies on sustainable business models in Small and Medium Enterprises (SMEs) indicate that the adoption of innovation practices depends on identifiable enabling factors, reinforcing the need to unpack concrete initiating conditions rather than treating sustainability as a generic orientation (Troise et al., 2024). Additionally, empirical studies that examine business model adaptation triggers often focus on incumbent firms, leaving the early-stage entrepreneurial setting under-examined (Saebi et al., 2017; Atkova et al., 2025).

Technology-based startups with an explicit sustainability orientation offer a relevant context to address these gaps. These startups aim to solve environmental or social problems through novel technologies while operating under resource scarcity, liability of newness, and legitimacy deficits (Andries et al., 2013; Sinkovics et al., 2021). Compared with incumbents, they typically lack slack resources, established customer bases, and stable institutional legitimacy, which makes sustainability-oriented business model change less straightforward in their case. Therefore, it is important to understand what triggers the founders of startups to initiate and prioritize SBMI despite uncertain survival prospects. Startups also operate in fast-moving technological and institutional environments and often rely on experimentation and business model adaptation to navigate uncertain markets and evolving policy regimes (McDonald & Eisenhardt, 2020; Xu et al., 2022; Vittori et al., 2022). Evidence from adjacent research suggests that external stakeholders such as customers can be influential learning sources shaping whether and how young firms change their business models under high uncertainty (Denoo et al., 2022). There is no systematic empirical evidence, however, on the sustainability-related external triggers perceived by founders as salient in early stages, and how they link these triggers to changes in value creation, value delivery, and value capture while startups attempt to maintain their sustainability commitments.

This study investigates the sustainability-related external triggers of SBMI initiation in technology-based startups that explicitly pursue environmental or social objectives. Drawing on multiple case studies of 31 startups in the Netherlands, and based on 46 semi-structured interviews conducted between 2023 and 2025 and extensive archival material, we identify seven recurring trigger domains and organize them in a multilevel structure that distinguishes triggers anchored at the

institutional (macro) level from those arising within the surrounding value network (meso) (Markoff-Legrand et al., 2024). At the value network level, startups report (1) customer and user adoption expectations for greener solutions, (2) ecosystem gatekeeper and competitive pressures, (3) impact-oriented finance and public funding conditions, and (4) digital trust, traceability, and transparency expectations. At the institutional level, startups report (5) clean-tech trajectories and socio-technical infrastructures, (6) rules, standards, and compliance regimes, and (7) societal climate and circularity norms. We then examine how founders describe these triggers as prompting them to reconsider value creation, value delivery, and value capture choices in early startup development.

Our contribution is to provide a startup-grounded mapping of how sustainability-related external triggers are structured across levels and transmitted through ecosystems to initiate SBMI. Rather than treating triggers as abstract background factors, we specify which external conditions founders recognize as triggering and how these triggers reach startups through institutional and value network environments. The key research question guiding the study is: What external sustainability-related triggers do technology-based startups recognize as initiating SBMI?

The remainder of this paper is organized as follows. Section 2 reviews the theoretical background, Section 3 outlines the research methodology, Section 4 presents the empirical findings, Section 5 discusses the findings and presents the framework, and Section 6 concludes with theoretical and practical implications, limitations, and directions for future research.

Theoretical background

BMI and its triggers

Business models describe how firms organize value creation, value delivery, and value capture for customers and other stakeholders (Teece, 2010; Demil & Lecocq, 2010). As these value processes are shaped by changing technologies, markets, and institutions, business models are not fixed templates but evolve constantly (Zott & Amit, 2010; Massa et al., 2017; Foss & Saebi, 2017). BMI refers to the deliberate, non-trivial changes to value creation, value delivery, and/or value capture, and to the logic linking these elements (Foss & Saebi, 2017; Ghezzi & Cavallo, 2020; Cavallo et al., 2024). It is therefore distinct from product or technological innovation because it alters how the firm creates and appropriates value, not only what it offers (Chesbrough, 2010; Amit & Zott, 2020).

Implementing BMI involves overcoming some challenges. Firms face cognitive barriers linked to dominant mental models and established assumptions about how value should be created and captured (Massa & Tucci, 2013; Schneider & Spieth, 2013). They also encounter structural barriers related to routines, resource commitments, and stakeholder expectations, which can generate inertia and resistance to business model change (Casadesus-Masanell & Zhu, 2013; Heidenreich et al., 2022). It is thus important to understand the concept of BMI, as well as how it is initiated and the conditions under which firms begin to change their business models.

Several studies examine the triggers of BMI, defined as the internal or external conditions that prompt firms to initiate business model change (Foss & Saebi, 2017; Bocken & Geradts, 2020; Ammirato et al., 2021). The external drivers include technological developments, market shifts, regulatory change, crises, competitive pressure, and investor expectations, and the internal drivers include leadership, governance, and organizational capabilities (Foss & Saebi, 2017; Ammirato et al., 2021). As they are different in nature and may operate at different levels and time horizons, an exploration of BMI must indicate those triggers perceived as salient and how they translate into changes in business model elements over time (Foss & Saebi, 2017; Bocken & Geradts, 2020).

Digital technologies are central to this perspective. First, digitalization can act as a trigger by reshaping customer expectations, competitive dynamics, and industry architectures, thereby pushing firms to reconsider value creation, delivery, and capture (Volberda et al., 2021; Vittori et al., 2022). Second, digital technologies can enable firms to translate drivers into business model change by improving data availability, accelerating experimentation, and supporting coordination across activities and channels (Bhatti et al., 2021; Volberda et al., 2021). Recent longitudinal research illustrates this logic by demonstrating the processes by which innovation drivers trigger distinct phases of BMI and digital technologies support the transformation of drivers into changes in firms' value processes over time (Mancuso et al., 2025a). Evidence from digital markets further shows that shifts in customer reasoning and willingness-to-pay can trigger changes in monetization logics such as subscription plans, with direct implications for value capture and customer relationships (Tani et al., 2022). Overall, triggers are the key forces that help explain when and why business model change is initiated, and how firms respond to evolving external conditions.

SBMI and sustainability-related triggers

SBMI extends BMI by integrating environmental and social objectives into the logic of value creation, value delivery, and value capture alongside economic viability (Stubbs & Cocklin, 2008; Boons & Lüdeke-Freund, 2013; Evans et al., 2017; Geissdoerfer et al., 2018). Beyond definitional work, the SBMI literature has developed archetypes, taxonomies, and design tools that specify alternative pathways for organizing sustainable value creation, including circularity, sufficiency, sharing, and inclusion (Bocken et al., 2014; Joyce & Paquin, 2016; Lüdeke-Freund et al., 2018, 2019, 2024; Shakeel et al., 2020; Snihur & Bocken, 2022). At the same time, this literature points to a persistent design-implementation gap: conceptual guidance is relatively mature, while empirical understanding remains limited regarding how sustainability-oriented business model change is initiated and enacted in practice, especially under entrepreneurial constraints (Boons & Lüdeke-Freund, 2013; Baldassarre et al., 2020; Minatogawa et al., 2022).

From a triggers perspective, SBMI implies a more complex external trigger landscape than conventional BMI. Sustainability-oriented ventures must navigate not only market and technological change but also policy programs, accountability requirements, impact-oriented finance, and broader societal expectations regarding transparency and measurable outcomes (Yip & Bocken, 2018; Bocken & Geradts, 2020; Hellemans et al., 2022; Reinecke et al., 2023; Pan et al., 2022; Dhir et al., 2023). Existing empirical evidence remains fragmented and does not yet provide a clear account of which sustainability-related external conditions founders recognize as triggering, how these conditions vary in proximity to the startup, or how they initiate business model change over time (Shakeel et al., 2020; Bashir et al., 2022; Minatogawa et al., 2022). Complementary evidence from SME research suggests that sustainable business model adoption depends on identifiable enabling conditions, reinforcing the need to unpack specific initiating conditions rather than treating sustainability as a general orientation (Troise et al., 2024). These gaps motivate a trigger-focused, startup-grounded approach that specifies what founders treat as triggering and how those triggers are structured in the environment they operate within.

Digital technologies are central to the BMI-SBMI connection because they can both enable and complicate sustainable value creation. On the enabling side, technologies such as blockchain, IoT, and AI can improve monitoring, traceability, and measurement, thereby strengthening accountability and the feasibility of sustainability-oriented value creation (Saunila and Ukko, 2019; Saberi et al., 2019; Wamba & Queiroz, 2020; Hellemans et al., 2022). At the same time, digitalization can introduce sustainability trade-offs and unintended consequences, including energy and resource burdens, ethical risks, and rebound effects (Nishant et al., 2020; Vinuesa et al., 2020; Guandalini, 2022). Recent work on AI-related innovation highlights this duality by showing

how sustainability-oriented value creation can coexist with risks of sustainable value destruction depending on objectives, stakeholder interests, and lifecycle choices (Mancuso et al., 2025b). For SBMI, this implies that digitalization is not merely contextual; it also forms part of the external trigger landscape through which sustainability concerns become relevant to business model change.

Theoretical lens: a multilevel triggers perspective

Building on the concepts of drivers and triggers in the BMI literature, we examine SBMI initiation in technology-based startups through the theoretical lens of the triggers perspective. We define triggers as identifiable external conditions that founders recognize as salient and that prompt reconsideration of business model choices, rather than as actions undertaken during SBMI implementation (Foss & Saebi, 2017; Bocken & Geradts, 2020; Ammirato et al., 2021). We focus on mapping the external triggers that initiate SBMI, rather than on theorizing internal response mechanisms or a causal process model.

We conceptualize external triggers as multilevel to address the critique that trigger frameworks can resemble generic environmental scans. Drawing on neo-institutional and ecosystem-oriented reasoning, we distinguish triggers anchored at the institutional (macro) level from triggers arising within the surrounding value network (meso) (Markoff-Legrand et al., 2024). Institutional triggers reflect rule systems, societal norms, and socio-technical infrastructures that shape what is permissible, desirable, and verifiable. Value network triggers arise through proximate actors and infrastructures that structure exchange and access, such as customers and users, incumbents and gatekeepers, investors and intermediaries, and digital and technical infrastructures that condition market participation.

We use the value creation-delivery-capture structure as an interpretive mapping device to specify where external triggers expose business model assumptions, rather than as a coding structure or a sequence of responses (Teece, 2010; Demil & Lecocq, 2010). Digital technologies are critical in this context as they can function as triggers in their own right and reshape the external trigger landscape by changing what information becomes visible, which standards are enforceable, and which actors can influence adoption and legitimacy in sustainability-related markets (Volberda et al., 2021; Mancuso et al., 2025a; Mancuso et al., 2025b).

Methods

Sampling and research setting

Given the limited understanding of how technology-based startups perceive and experience external triggers for SBMI, we adopt an inductive, comparative qualitative research design including multiple startups. The study is interview-centered, using founders' accounts to identify external trigger episodes and drawing on cross-case comparisons to build a structured classification of trigger domains (Eisenhardt, 1989; Eisenhardt & Graebner, 2007). As our unit of analysis is trigger exposure as described by informants, we do not develop a process model of SBMI but map the external conditions founders associate with initiating or reconsidering sustainability-oriented business model change. Our empirical setting focuses on technology-based startups in the Netherlands, particularly those addressing sustainability challenges through novel hardware or integrated technology-based solutions. Restricting the sample to a relatively homogenous business environment allows us to isolate the triggers for business model change more effectively, while minimizing confounding variables such as sociopolitical context (Zott & Huy, 2007).

Our study is grounded in the specific challenges of sustainable entrepreneurship through focus on the early stages of development in technology-based startups. According to Vohora et al. (2004), these startups move through five development phases: research, opportunity

framing, pre-organization, re-orientation, and sustainable returns. Each phase is separated by a critical juncture that must be overcome: opportunity recognition, entrepreneurial commitment, credibility, and sustainability. Many of the startups in our sample are positioned at the credibility juncture or beyond, where firms seek to establish legitimacy with customers and investors, move from pilots toward scaling, and consolidate stable market relations (Vohora et al., 2004; Van Geenhuizen & Soetanto, 2009). We classify startups by their position in Vohora's development framework and by their sustainability orientation, represented through alignment with the United Nations SDGs (Table 1). Entrepreneurs in these phases often need to adapt and experiment with their business models under conditions of ambiguity, uncertainty, and resource scarcity (Andries et al., 2013; McDonald & Eisenhardt, 2020). These challenges are especially pronounced for sustainability-oriented startups, which must balance economic viability with social and environmental goals (Davies & Chambers, 2018; Pache & Santos, 2013; Hoogendoorn et al., 2019; Esau et al., 2025).

We first approached Yes!Delft, a Dutch incubator known for supporting sustainability-oriented tech startups. Such facilitators offer a well-defined sampling frame for identifying early-stage startups (Clough et al., 2019). We then used purposeful, snowball, and network-based sampling methods to recruit additional startups. All firms explicitly positioned themselves as sustainability-oriented; as shown in Table 1, this was captured through SDG alignment and corroborated through mission statements and interview accounts. The inclusion of cases was not based merely on sustainability orientation but required the informants to describe at least one sustainability-related business model change (i.e., a change in value creation, value delivery, and/or value capture beyond routine execution) and link it to a concrete external trigger episode.

Data collection

In total, we conducted 46 semi-structured interviews with internal actors such as founders, co-founders, executives, engineers, and product leads from 31 startups. Table 2 summarizes the interview corpus (firms, interview timing, number of interviews, and informant roles). The primary focus of these interviews was to identify and document founder-reported trigger episodes and the sustainability-oriented business model changes founders associated with those episodes. While the majority of cases involved a single retrospective interview, where informants reflected on their journey to date, a subset of startups was tracked longitudinally to capture real-time triggers. Startup C participated in two interviews conducted over a one-year period (2023–2024), while startup E was engaged at six-month intervals, resulting in four interviews between 2023 and 2024. Startup M was interviewed twice in 2023 and once in 2024, and startup Y three times over the course of 2023. Startup R was interviewed at three points across 2023, 2024, and 2025, and startup V took part in two interviews in 2024 and 2025. Startups L and K each participated in two interviews in 2024, spaced six months apart. These repeat interviews allowed us to time-anchor trigger episodes more precisely, complementing the predominantly retrospective accounts in the broader sample.

The first wave of interviews, conducted between March and May 2023, focused on identifying retrospective triggers by exploring the strategic history and key inflection points of each startup. These interviews elicited founders' accounts of concrete external trigger episodes and how these were associated with initiating or reconsidering SBMI. Subsequent data collection occurred during October–November 2023, March–May 2024, October–November 2024, and March–May 2025, and involved follow-up interviews with selected cases as well as new interviews with additional startups. Across the waves, each interview ranged from 30 to 90 minutes.

First-time interviews explored foundational elements of the business model, such as the startup's value proposition, customer segments, revenue logic, and early strategic decisions. These conversations also

included questions tailored to uncover past trigger events, for example: "What triggered a change in your offering or delivery model?" and "How did market, technological, or regulatory changes affect your direction?" Follow-up interviews, by contrast, focused on the inter-interview changes, allowing us to track ongoing adjustments and emerging triggers as they occurred. Ethical rigor was ensured through confidentiality measures, and participants were assured that informant and firm names would be anonymized, while preserving contextual richness and relevance.

To support factual case context and corroborate the timing of major events referenced in interviews, we also consulted publicly available materials (e.g., startup websites, pitch decks, media items, and public posts).

Data analysis

Our analysis focused on identifying and classifying the triggers of SBMI in technology-based startups. We adopted a structured, inductive approach informed by the Gioia methodology (Gioia et al., 2013), staying grounded in the empirical language of informants while building theoretical insight.

The analysis proceeded in three stages. First, all interviews were transcribed and reviewed to identify statements in which respondents described external triggers such as concrete events, constraints, or contextual shifts that they linked to changes in the startups' business models. These passages were coded into first-order categories using the respondents' own terms. Second, through iterative comparison and axial coding, related first-order categories were grouped into second-order themes that captured broader, sustainability-oriented patterns in the external triggers of SBMI. Third, second-order themes were consolidated into seven trigger domains organized across two levels. Institutional-level domains captured (1) rules, standards, and compliance regimes, (2) societal climate and circularity norms, and (3) clean-tech trajectories and socio-technical infrastructures. Value network domains captured (4) customer and user adoption expectations for greener solutions, (5) ecosystem gatekeeper and competitive pressures, (6) impact-oriented finance and public funding conditions, and (7) Digital trust, traceability, and transparency requirements. In line with the Gioia approach, the data structure represents increasing conceptual abstraction rather than temporal sequence or causality.

We present an illustration from our coding structure to elucidate this process. A co-founder of Startup Q recalled, "We started out focused just on energy cost savings, but as climate goals became urgent, we reframed our mission around helping clients decarbonize their operations." This quotation was first coded as "climate agendas prompting explicit climate-aligned missions" (first-order category). Through iterative comparison, it was grouped into the second-order theme "normative pressure for circular and climate-aligned design," which is located within the aggregate dimension of "societal climate and circularity norms." A similar procedure was applied to all interviews, ensuring that first-order categories remained grounded in the respondents' terms, while second-order themes and aggregate dimensions reflected increasing conceptual abstraction (Gioia et al., 2013).

We conducted the following credibility checks to enhance the analytical rigor. First, the repeat interviews at six-month intervals in the subset of cases aided in the temporal anchoring of the trigger episodes and reduced reliance on retrospective reconstruction (Huber & Power, 1985). Where only one interview was possible, we reconstructed trigger episodes through detailed retrospective narratives. Second, we used secondary materials to corroborate the timelines of major events referenced in the interviews and to provide factual context for the startups.

Coding was undertaken iteratively by the authors. Initial first-order coding was performed on a subset of interviews to align the coding logic and develop a shared codebook and structured coding log. The first author then coded the full dataset manually using this codebook, and emerging codes were iteratively compared across interviews and cases.

Table 1
Characteristics and sustainability orientation of sample startups.

Firm	Type of Innovation	Development Stage	Team Size	Founder Experience	Sustainability Orientation
A	Product/process – vessel motion forecasting software	Credibility juncture (pilots-to-market scaling)	Small (~10–15)	Technical founders in marine engineering	Reduces fuel waste and emissions in offshore operations through motion forecasting; SDG 13 (Climate Action)
B	Product/process – AI-based CirCleaner system	Credibility juncture (pilots-to-scaling)	Small (~10)	Technical founders with accelerator experience	Intercepts plastic in waterways upstream with fish-friendly systems; SDG 14 (Life Below Water)
C	Product and business model – modular solar kits	Re-orientation stage (scaling proven tech)	Large (~200)	Entrepreneurial background in off-grid solar	Expands affordable clean energy access in off-grid Africa with PAYGO solar; SDG 7 (Clean Energy)
D	Product/process – barriers and interceptor vessels	Re-orientation stage (scaling proven tech)	Large (~200)	Entrepreneurial background in engineering	Removes floating plastic from oceans and rivers at scale (90% target by 2040); SDG 14 (Life Below Water)
E	Product/process – modular, disassemblable panels	Credibility juncture (pilots-to-scaling)	Small–Medium (~20–30)	Technical founders in solar and circular design	Develops circular, fair-trade solar panels designed for full recyclability; SDG 7 (Clean Energy) and SDG 12 (Responsible Consumption)
F	Product and business model – modular solar hatches/decks	Credibility juncture (pilots-to-scaling)	Small–Medium (~20–30)	Technical founders in solar engineering	Cuts shipping emissions by integrating solar into vessels (SolarHatch, SolarDeck); SDG 7 (Clean Energy)
G	Product and business model – solar thermal Haas systems	Credibility juncture (pilots-to-commercial)	Small (~2–10)	Technical founders in solar and energy systems	Replaces gas boilers in industry/agriculture with solar thermal systems; SDG 7 (Clean Energy) and SDG 13 (Climate Action)
H	Product and business model – unbox-and-plug panels	Credibility juncture (market validation)	Small–Medium (~20–30)	Technical founders in consumer cleantech	Democratizes household access to solar with plug-and-play panels for renters; SDG 7 (Clean Energy)
I	Product/process – polymer-based recyclable panels	Credibility juncture (pilots-to-scaling)	Small–Medium (~40–50)	Technical founders with solar R&D expertise	Produces lightweight, per- and polyfluoroalkyl substance (PFAS)-free, recyclable solar panels for circular energy systems; SDG 7 (Clean Energy) and SDG 12 (Responsible Consumption)
J	Product/process – printed colored façade panels	Credibility juncture (pilots-to-commercial)	Small–Medium (~20–30)	Technical spin-off in architecture and tech	Integrates solar into building facades without compromising aesthetics; SDG 11 (Sustainable Cities) and SDG 7 (Clean Energy)
K	Product/process – non-toxic thrusters and spaceplane	Re-orientation stage (scaling proven tech)	Medium (~120)	Technical founders in space propulsion	Develops reusable spaceplanes and non-toxic thrusters to reduce space emissions; SDG 9 (Innovation) and SDG 13 (Climate Action)
L	Product/process – noise-free vibratory pile driving	Credibility juncture (pilots-to-scaling)	Small (~10)	Technical founders from Delft University of Technology (TU Delft)	Minimizes underwater noise and enables pile re-use in offshore wind foundations; SDG 14 (Life Below Water) and SDG 9 (Innovation)
M	Software – blockchain-based digital product passports	Credibility juncture (pilots-to-commercial)	Small–Medium (~30–40)	Founders with recycling and data privacy expertise	Increases supply chain transparency for recycling with blockchain product passports; SDG 12 (Responsible Consumption) and SDG 9 (Innovation)
N	Product – wireless force- and vibrotactile gloves	Credibility juncture (pilots-to-adoption)	Small–Medium (~30–50)	Technical founders in haptics	Enables sustainable Virtual Reality (VR) training and prototyping, reducing physical resource use; SDG 9 (Innovation)
O	Product/software – AI glasses and app	Credibility juncture (commercial adoption)	Small–Medium (~30–40)	Founders with AI and engineering expertise	Enhances independence of visually impaired with AI glasses; SDG 10 (Reduced Inequalities) and SDG 9 (Innovation)
P	Software – privacy- by-design patient data platform	Credibility juncture (pilots-to-commercial)	Small–Medium (~11–50)	Founders with AI and privacy expertise	Improves equitable access to clinical trials with privacy-preserving AI tools; SDG 3 (Health) and SDG 9 (Innovation)
Q	Product/process – kite-based mobile wind systems	Credibility juncture (pilots-to-scaling)	Small–Medium (~35)	TU Delft spin-off (aerospace and energy)	Provides low-cost wind energy with reduced material use vs turbines; SDG 7 (Clean Energy) and SDG 13 (Climate Action)
R	Product/process – active noise-cancelling glass	Credibility juncture (pilots-to-commercial)	Small (~6–8)	Technical founders in acoustics engineering	Reduces traffic and aircraft noise exposure in urban homes; SDG 3 (Health) and SDG 11 (Sustainable Cities)
S	Product/process – AI detection and drone interception	Credibility juncture (pilots-to-commercial)	Small (~10–15)	Technical founders in aerospace and AI	Cuts pesticide use in greenhouse farming with autonomous pest control drones; SDG 12 (Responsible Consumption) and SDG 2 (Zero Hunger)
T	Product/process – mycelium and hemp-based “living” coffins	Credibility juncture (pilots-to-scaling)	Small (~10–20)	Founder with biodesign and architecture expertise	Creates biodegradable coffins and urns that regenerate soil ecosystems; SDG 12 (Responsible Consumption) and SDG 15 (Life on Land)
U	Product/process – wearable speckle- based sensor	Credibility juncture (pilots-to-commercial)	Small (~14)	Founders with med-tech and sensor R&D expertise	Enables accurate remote health monitoring with wearable sensors; SDG 3 (Good Health)
V	Product/process – passive ergonomic support suits	Credibility juncture (pilots-to-scaling)	Small (~5–10)	Technical founders with TU Delft ergonomics	Improves worker safety and reduces injuries with ergonomic exoskeletons; SDG 3 (Health) and SDG 8 (Decent Work)
W	Software – hardware-free Digital Twin fleet monitoring	Credibility juncture (pilots-to-revenue)	Small (~10)	Founders from TNO maritime analytics	Reduces ship CO ₂ emissions with digital twin fuel monitoring; SDG 13 (Climate Action)
X	Product/process – curved photovoltaic (PV) modules and smart controls	Credibility juncture (pilots-to-scaling)	Small–Medium (~21–50)	Founders in solar R&D and architecture	Integrates solar seamlessly into urban infrastructure and smart lighting; SDG 7 (Clean Energy) and SDG 11 (Sustainable Cities)
Y	Software – AI/Geographic Information System (GIS) tools and citizen science training	Credibility juncture (pilots-to-scaling)	Small (~10–20)	Founders with AI and marine expertise	Protects coral reefs with AI mapping and citizen science training; SDG 14 (Life Below Water)
Z	Product/process – microwave-based food sensors	Credibility juncture (pilots-to-scaling)	Small (~2–10)	Founders with microwave sensing expertise	Reduces food waste with non-invasive fruit quality sensing; SDG 12 (Responsible Consumption) and SDG 2 (Zero Hunger)

(continued on next page)

Table 1 (continued)

Firm	Type of Innovation	Development Stage	Team Size	Founder Experience	Sustainability Orientation
AA	Software – AI-driven purchase order management platform	Credibility juncture (commercial rollout)	Small–Medium (~20)	Founders in supply chain tech	Streamlines supply chains to cut errors and resource waste; SDG 9 (Innovation) and SDG 12 (Responsible Consumption)
AB	Product/process – swappable renewable power stations	Credibility juncture (pilots-to-commercial)	Small (~2–10)	Founders in industrial design and engineering	Eliminates CO ₂ and noise from construction sites with swappable battery stations; SDG 7 (Clean Energy) and SDG 13 (Climate Action)
AC	Product/process – flexible superconducting Input/Output (I/O) cables	Credibility juncture (commercial scaling)	Small–Medium (~40)	Founders with quantum hardware engineering	Enables scaling of quantum computers, which support breakthroughs in climate modeling, energy materials, and sustainability research; SDG 9 (Innovation and Infrastructure)
AD	Product – breathing robot for sleep aid	Credibility juncture (market growth)	Small (~22)	Founders with robotics and sleep-tech expertise	Promotes non-pharmaceutical sleep health with AI-driven sleep robots; SDG 3 (Good Health)
AE	Product/process – renewable Reverse Osmosis desalination systems	Credibility juncture (pilots-to-rollout)	Small (~2–10)	Founders in sustainable water and energy tech	Provides affordable fresh water using renewable-powered desalination; SDG 6 (Clean Water) and SDG 7 (Clean Energy)

Table 2

Startup data descriptives.

Firm	Year Founded	Industry	Data Collection Period	Number of Interviews	Interviewees
A	2018	Maritime technology (vessel motion forecasting)	2023 May	1	Founder and Managing Director
B	2016	Environmental technology (plastic interception in waterways)	2023 May	1	Founder
C	2011	Solar energy (off-grid PAYGO systems)	2023 May 2024 May	2	Chief Operating Officer (COO)
D	2013	Environmental technology (ocean and river plastic removal)	2023 May	1	Business Development Director
E	2020	Solar energy (circular, disassemblable panels)	2023 May 2024 December 2023 November	2 1	Co-founder and Finance Lead Co-founder and Product Development Lead
F	2017	Renewable energy (maritime solar hatches and decks)	2024 Mar	1	Co-founder and Technical Lead
G	2017	Renewable energy (solar thermal heating and cooling)	2023 April	1	COO and Operations Lead Co-founder and Chief Executive Officer (CEO)
H	2017	Solar energy (plug-and-play consumer panels)	2023 April	1	Managing Director and Co-founder
I	2018	Solar energy (lightweight recyclable panels)	2023 April	1	Co-founder and CEO
J	2018	Solar energy and design (building-integrated facades)	2023 May	1	Co-founder and CEO
K	2016	Aerospace technology (green propulsion and reusable spaceplanes)	2024 Sep 2025 Mar	2	Co-founder and Chief Revenue Officer (CRO)
L	2022	Energy and sustainability (noise-free pile driving for wind foundations)	2024 Sep 2025 Mar	2	Co-founder and CEO
M	2016	Supply chain and blockchain (digital product passports)	2023 May 2023 Nov 2024 May	3	Co-founder and CEO
N	2015	Virtual reality (haptic feedback gloves)	2024 May	1	Creative lead
O	2017	Assistive technology (AI-powered glasses for visually impaired)	2024 May	1	Founder
P	2021	Health technology (AI patient-screening software)	2024 Nov 2025 Mar	1 1	Founder Co-founder
Q	2016	Renewable energy (airborne wind systems)	2024 May 2025 May	1 1	Co-founder and Academic Research Lead
R	2018	Smart building tech (noise-cancelling windows)	2023 Nov 2024 May 2025 Mar	3	Founder and CEO
S	2019	Agriculture tech (autonomous pest-control drones)	2024 Nov	1	Founder
T	2020	Biotech (mycelium-based coffins and urns)	2023 May 2023 Nov	1 1	Product Engineer Strategic Sales and Marketing Lead
U	2018	Health technology (wearable remote monitoring)	2023 Nov	1	Co-founder and CEO
V	2013	Manufacturing and ergonomics (industrial exoskeletons)	2023 Nov 2025 Mar	2	Co-founder
W	2016	Marine analytics software (digital twin fuel monitoring)	2023 Nov	1	Founder
X	2012	Solar energy technology (curved PV modules and smart controls)	2023 Nov	1	Founder and CEO
Y	2020	Marine conservation technology (AI/GIS reef monitoring)	2023 May	3	Co-founder and CEO
Z	2017	Radio frequency (RF) and microwave sensing (fruit quality testing)	2023 Mar	1	Co-founder and CEO
AA	2013	Information and Communication Technology, software and cloud (supply chain collaboration)	2023 Mar	1	Co-founder and Chief Technology Officer (CTO)
AB	2022	Portable renewable energy (swappable battery stations)	2023 Mar	1	Founder and CEO
AC	2017	Electronics and quantum hardware (cryogenic I/O systems)	2023 Mar	1	Co-founder
AD	2016	Health technology (AI-driven sleep robot)	2023 Mar	1	Co-founder and CEO
AE	2012	CleanTech / water management (solar desalination)	2023 Mar	1	Founder
Total:				46	

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The codebook was refined through repeated comparison and discussed in regular author meetings until agreement was reached on the second-order themes and the final seven-domain structure. The analysis of the additional interviews was used to check whether new trigger domains emerged; once the seven-domain structure stabilized, subsequent interviews were used to refine domain boundaries and clarify distinctions rather than to expand the set. Two independent academic researchers with qualitative-methods expertise reviewed the coding logic and domain definitions, and provided feedback on clarity, consistency, and conceptual fit.

The semi-structured interview protocol that guided data collection, including the key questions used to elicit accounts of business model changes and their triggers, is provided in [Appendix A](#), while the follow-up interview guide is presented in [Appendix B](#). The resultant coding structure is presented and elaborated in Section 4.

Empirical findings

This section presents the empirical findings derived from interviews with technology-based startups. [Table 3](#) presents the frequency of triggers per firm. The counts reflect the number of coded trigger references in the interview corpus for each firm; since the interview volume varies across cases, these frequencies are descriptive indicators of salience within our data rather than comparable measures of “trigger intensity” across firms. The most frequently observed domain concerns ecosystem gatekeeper and competitive pressures, followed by impact-oriented finance and public funding conditions. Rules, standards, and compliance regimes are also highly prevalent, indicating that institutional compliance requirements repeatedly shaped what could be developed, sold, and scaled. Adoption expectations for greener solutions, societal climate and circularity norms, and digital trust expectations also appear prominently across cases, while clean-tech trajectories and socio-

technical infrastructures are somewhat less frequent but still recurrent.

To strengthen transparency and show how each trigger domain is grounded in informant language, [Appendix C \(Table C1\)](#) provides representative quotes for each second-order theme.

Building on this overview, [Figure 1](#) presents the data structure and coding process, showing how each trigger domain is grounded in second-order themes and first-order categories. Following the order of the aggregate dimensions in the data structure (i.e., the seven trigger domains), we describe each domain and illustrate how it shaped SBMI across the cases.

Customer and user adoption expectations for greener solutions

Founders did not describe “demand” as a generic pull toward greener offerings. Instead, they framed adoption as a set of external acceptance conditions that determine whether a sustainability-oriented solution can be used, trusted, and implemented. Two second-order themes capture these adoption expectations and constraints: (1) user acceptability, cultural fit, and dignity constraints, and (2) usability and simplicity requirements for adoption.

User acceptability, cultural fit, and dignity constraints

User acceptability was conditioned by the social meaning attached to use contexts, including where a solution is deployed, how it is framed, and what it signals in terms of dignity, identity, and appropriateness. These conditions shaped the terms of acceptance, particularly in culturally sensitive or image-sensitive settings where ecological performance alone did not confer legitimacy. Startup T’s strategic sales and marketing lead captured this clearly: “In funerals, you also have to be careful how you present new ideas... we frame things gently to help people accept ecological alternatives,” showing that cultural norms define what counts as “appropriate” sustainability innovation.

Table 3
Triggers frequency per firm.

Firm	Customer and user adoption expectations for greener solutions	Ecosystem gatekeeper and competitive pressures	Impact-oriented finance and public funding conditions	Clean-tech trajectories and socio-technical infrastructures	Digital trust, traceability, and transparency requirements	Rules, standards, and compliance regimes	Societal climate and circularity norms
A	4	5	3	2	2	4	2
B	2	4	4	1	2	2	1
C	4	10	8	1	2	4	2
D	1	1	2	1	1	3	2
E	1	4	3	2	2	1	2
F	2	5	3	1	1	2	3
G	2	4	2	2	2	2	2
H	3	6	3	2	1	4	1
I	2	5	2	2	1	6	4
J	1	4	3	1	3	2	1
K	2	6	1	1	1	2	3
L	1	2	3	1	1	5	2
M	2	5	3	3	3	6	1
N	2	4	1	2	1	2	1
O	1	4	1	1	1	2	2
P	1	5	2	2	2	3	1
Q	1	1	1	1	1	1	2
R	2	3	5	3	4	2	2
S	1	2	1	1	1	2	1
T	3	4	4	2	2	2	4
U	2	4	1	2	1	2	1
V	2	6	1	1	2	1	1
W	2	3	1	1	1	1	1
X	2	3	1	1	1	1	1
Y	2	6	1	1	3	1	2
Z	1	5	1	1	1	1	1
AA	3	3	5	1	1	1	1
AB	2	4	5	1	2	1	3
AC	1	2	1	3	2	1	1
AD	1	3	3	1	1	1	1
AE	1	2	3	2	2	2	1
Total	57	125	78	47	51	70	53

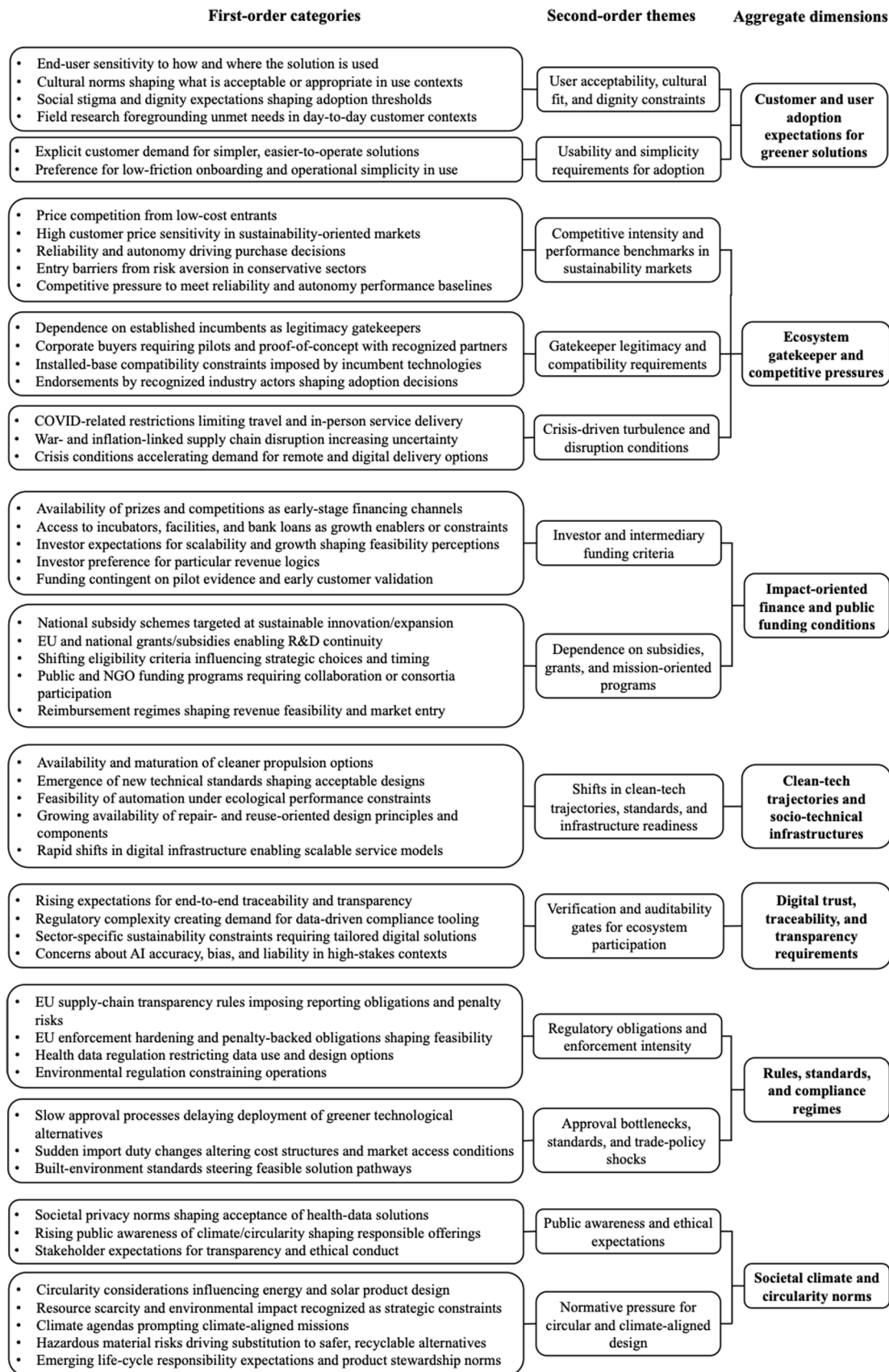


Figure 1. Data structure and coding process.

Acceptability also extended to stigma and reputational concerns in public-facing sectors. Startup F's COO observed that "avoiding being seen as polluting ships... improves their image," suggesting that adoption can hinge on whether the solution protects the buyer's social standing. In health-data contexts, ventures likewise could not claim legitimacy without privacy safeguards, clear data handling, and user control. These were baseline trust conditions, not optional design choices. Startup P's founder emphasized: "For patients, the focus is on building trust through a user-friendly app that allows them to control their health data."

Finally, a mismatch between sustainability ambition and daily realities surfaced as barriers in the field. Startup C's COO explained, "We started with field research in Madagascar, asking people what they wanted, then prototyping a solar lamp based on their needs," and Startup AE's founder stated, "If you do not adjust the design to places with no infrastructure or high water stress, people simply will not use it." Across cases, adoption expectations became external triggers of SBMI because diffusion depended on meeting legitimacy in real use settings.

Usability and simplicity requirements for adoption

Founders consistently framed low-friction operation as a prerequisite for uptake rather than a desirable feature. In multiple cases, customers were described as unwilling to tolerate complexity, extra steps, or high coordination effort, especially in resource- and time-constrained settings. Startup H's co-founder emphasized that their plug-and-play solar panel was "designed to be easy to set up, even for renters, people with low income, or cautious buyers," illustrating how usability expectations can define who is able to and willing to adopt a sustainability-oriented offering in practice.

The same logic applied to in agri-tech and industrial contexts, where simplicity was treated as a market condition. Startup S stated that they want their solution to be "so hassle free that it is essentially a no-brainer" for greenhouse customers, signaling that adoption depends on reducing operational burden to near zero. Startup N referred to the need for a similar threshold in another context, noting, "Our product is not a big exoskeleton, it is small and easy to set up, even for those who are not daily VR users," indicating that for effective diffusion, sustainability-oriented solutions must be operable even by those who are not expert or highly motivated users. Collectively, these accounts indicate that usability and operational simplicity were critical triggers by exposing the misfits between delivery setups and the practical demands of adoption at scale, making ease-of-use non-negotiable in offering and delivery design.

Ecosystem gatekeeper and competitive pressures

This trigger domain operated through the startup's surrounding ecosystem, where diffusion was shaped by competitive intensity, performance baselines, gatekeeping actors, and episodic turbulence. Startups did not compete in a neutral market; they encountered externally imposed conditions that structured whether their solutions could enter established sectors, be taken seriously, and scale. Three themes were salient within this domain: (1) competitive intensity and performance benchmarks in sustainability markets, (2) gatekeeper legitimacy and compatibility requirements, and (3) crisis-driven turbulence and disruption conditions.

Competitive intensity and performance benchmarks in sustainability markets

Competitive dynamics emerged as triggers as viability benchmarks tightened for sustainability-oriented offerings. Solutions had to remain affordable while meeting performance requirements that enable substitution. Price competition was repeatedly framed as an external constraint on what could be offered and at what margin. Startup C's COO explained, "Chinese competition offered similar products at much lower prices, forcing us to pivot away from low-cost items," while

Startup H's co-founder added, "payback times for solar dropped from seven or eight years to just two or three... you need to redesign continuously to make solar work at scale." These accounts show how high customer price sensitivity in sustainability markets can operate as a selection environment, where ecological ambition must be reconciled with shortened payback horizons.

Performance requirements simultaneously functioned as purchase conditions. Startup S's founder warned that "if the drones do not perform consistently, no one will replace traditional pesticide application methods with them," indicating that reliability and autonomy are not internal optimization goals but the entry bar for greener substitutes. Competitive pressure also created differentiation opportunities where incumbents underperformed on circularity or other sustainability-related attributes. Startup E's co-founder and finance lead stressed, "Most panels could not be repaired or recycled at all. We saw that gap and thought if we make ours circular, that is how we will stand out," and Startup K's co-founder emphasized that early adoption of green propulsion created "a real competitive advantage." Finally, conservative sectors imposed additional entry barriers through institutional risk aversion. As Startup U's co-founder noted, "Hospitals are very conservative... we had to prove ourselves step by step before they were willing to test our system." In combination, price ceilings, performance baselines, and sector conservatism triggered SBMI by defining whether sustainable alternatives could compete, substitute, and scale under externally imposed market conditions.

Gatekeeper legitimacy and compatibility requirements

Founders described market access as mediated by gatekeepers that set legitimacy and compatibility requirements, making credibility something that had to be conferred rather than claimed. Partnerships with established actors provided validation in incumbent-dominated markets. Startup R's founder explained, "Collaborations with a major international airport and the glass manufacturers made a big difference in helping us validate and refine our technology," and Startup N's creative lead recalled that showing a working prototype to automotive stakeholders "gave us early validation." Some ecosystems also required endorsement by recognized industry actors: Startup A's founder noted, "We worked with a leading international energy company and got our technology written into their guidelines. That opened doors to new projects."

The requirement to pilot the technology was important as it opened up pathways to provide the requisite proof-of-concept, which conditioned the market willingness to engage with the technology. Startup M's co-founder reflected that "those first pilots gave us credibility. They proved the technology worked, and after that clients started coming to us instead of us chasing them." Compatibility constraints were especially salient in installed-base environments where stand-alone alternatives are hard to adopt. Startup F's COO explained: "We work with an incumbent component supplier to integrate solar panels, making it easier for customers," indicating that adoption depended on aligning with incumbent architecture.

Legitimacy signals also interacted with intellectual property (IP) and reputational anchors. Startup E's co-founder and finance lead stressed, "After we applied for the patent in 2024, we noticed people took us more seriously and our credibility in the industry grew," while Startup K highlighted European Space Agency support as a reputational anchor. Even in culturally sensitive markets, intermediaries shaped diffusion pathways, as Startup T's strategic sales and marketing lead explained, "We also collaborate with funeral companies... People working in funeral organizations are then presented with the option of environmentally friendly burials." These requirements showed that market access was mediated rather than direct. Partnerships, pilots, endorsements, and installed-base fit became prerequisites for entry and scaling, making gatekeeping a recurring external trigger of SBMI.

Crisis-driven turbulence and disruption conditions

Abrupt shocks destabilized assumptions about supply chains, revenue models, and operational continuity by shifting the feasibility of delivery and exchange. Founders described COVID-related disruption as constraining travel, testing, and in-person delivery while forcing operational workarounds. Startup X's founder explained, "After Covid, there was a shortage of chips... That is why we decided to buy our own machine and make our own products," and Startup I's co-founder added that multiple shocks "forced us to rethink supply chains and localize production."

Turbulence also undermined value capture through payment instability. Startup C's COO noted, "The cyclone destroyed half our portfolio, then Covid came. Pay-as-you-go collapsed when customers stopped paying, so we shifted to cash sales." War- and inflation-linked shocks were described as producing immediate demand freezes and cost escalation. Startup X's founder recalled, "When the war in Ukraine started, a lot of purchases stopped directly because everyone wanted to save money. Even the governments did not want to do anything," and added that "the raw materials have been getting more expensive with the Covid and war crises, posing a challenge." Crises also interacted with local contestation and delays that extended timelines and costs, with Startup L's co-founder recalling, "In a northern region of the Netherlands, the public did not want us to do the test because of soil shaking... concerns about breeding birds delayed things and caused us to go over budget."

Under these conditions, demand for remote or digitally supported delivery options became more salient, and some startups experimented with alternative delivery arrangements. Startup Y's co-founder explained, "Paying for AI is quite unfeasible, so in the end we have to pair that with a volunteer program," while others redirected attention to markets with more favorable institutional conditions, such as Startup H's decision to expand in France after resistance in the Netherlands. The findings thus broadly indicate that turbulence acts as a trigger when volatility undermines the feasibility of existing delivery and revenue logics, making previously workable configurations untenable.

Impact-oriented finance and public funding conditions

Financial conditions were described as external triggers because they influenced which sustainability-oriented business model trajectories were feasible, fundable, and scalable. Funding was rarely portrayed as a neutral input; founders framed it as governed by allocation rules and due-diligence screens that affected whether SBMI could be initiated, sustained, and expanded. Two second-order themes capture this trigger domain: (1) investor and intermediary funding criteria and (2) dependence on subsidies, grants, and mission-oriented programs.

Investor and intermediary funding criteria

Investor and intermediary funding screens informed whether and which sustainability-oriented business models could move from concept to viability. In multiple cases, prizes and competitions provided early-stage financing while also signaling legitimacy, shaping later access to partners and capital. As Startup Z's co-founder recalled, "Winning that first prize did not just give us money for a prototype, it signaled to others that our idea was worth backing," showing how external validation created momentum alongside funding.

Access to incubators, facilities, and bank loans worked in a similar way, acting as growth enablers or constraints depending on whether or not startups could secure them. Startup O's founder noted, "Rabobank was the only one willing to back us. That loan gave us room to build the first version of the glasses and prove that it could really help people," indicating that formal credit availability could impact the ability of startups to escape concept-stage limitations. As startups sought larger capital injections, investor expectations for scalability and growth further shaped feasibility perceptions and nudged startups toward particular business model logics. Startup V's co-founder emphasized, "Getting our first investment meant we could finally hire engineers full-

time. Before that, it was just us, part-time, and everything moved slowly," while Startup AA's co-founder admitted, "investors did not like our one-off deals. They pushed us to switch to subscriptions, so we adapted the model." Funding was also typically contingent on pilot evidence and early customer validation, making proof a precondition for releasing resources. Startup B's founder explained, "We built a really basic prototype just to land a pilot. That pilot was enough to convince clients and unlock bigger contracts." The case material shows that finance was rarely neutral: fundability criteria served as external triggers of SBMI by making certain sustainability-oriented trajectories, capability-building paths, and value capture configurations more fundable than others.

Dependence on subsidies, grants, and mission-oriented programs

Subsidies, grants, and mission-oriented programs often determined whether sustainability-oriented innovation could be sustained through uncertainty and long development horizons. National subsidy schemes targeted at sustainable innovation and expansion were repeatedly described as important for the feasibility of early experimentation, especially when commercial traction was delayed. Startup X's founder recalled, "Our first subsidies were tiny, but they kept the lights on long enough to finish a prototype. Later, the bigger RVO schemes finally gave us a real runway," referring to subsidy programs of the Netherlands Enterprise Agency (RVO).

For research-intensive startups, the European Union (EU) and national programs were especially decisive in determining whether technologies could progress beyond lab-stage constraints. Such dependence was also evident in smaller, targeted schemes that sustained teams through uncertain periods; according to Startup B's founder, "Those MIT grants we got over the years really kept us afloat. Without them we would not have been able to keep the development team together." Startup AC's co-founder explained, "Deep-tech is expensive. Without European and Dutch subsidies, superconducting circuits like ours would have stayed in the lab."

Importantly, founders also described shifting eligibility criteria as a trigger in its own right, because program conditions determined what could be developed, strategic choices, and timing. Startup Y's co-founder noted, "Every scheme comes with its own conditions. More than once we had to reshape our project just to qualify. Sometimes the subsidy design drives the project more than we do," highlighting how policy design can redirect startups' trajectories. Public and NGO funding programs also frequently required collaboration or consortium participation, turning partnership formation into a condition for resource access rather than a purely strategic preference. Startup D's business development director emphasized: "Working with public agencies gave us both the grants and the credibility to enter new countries. Without that, scaling globally would have been impossible." Policy also shaped feasibility through reimbursement regimes rather than grants alone, with Startup O's founder noting, "Insurance reimbursement rules shift from one country to another. In Europe, coverage meant growth opportunities. In the US, without reimbursement, we had to rethink our whole entry strategy." Across the sample, public funding was not an add-on but a structural trigger of SBMI: it enabled high-risk innovation to continue, embedded societal priorities into development pathways, and shaped the timing, scope, and partnerships through which sustainability-oriented business models could be built and scaled.

Clean-tech trajectories and socio-technical infrastructures

Startups described this trigger domain as a set of external constraints that shaped which sustainability-oriented business model configurations were feasible and credible. Shifting technology frontiers, evolving design and certification criteria, and infrastructure readiness influenced what could be built, validated, automated, and scaled. This trigger domain is captured in a single second-order theme: shifts in clean-tech trajectories, standards, and infrastructure readiness.

Shifts in clean-tech trajectories, standards, and infrastructure readiness

Clean-tech trajectories formed a moving frontier that defined what qualified as a viable and legitimate sustainability pathway. In some sectors, the maturation of cleaner propulsion options was tightly linked to sector-level performance expectations, influencing what a “credible” transition even looked like. As Startup K’s co-founder stated, “Our main focus now is advancing R&D for the spaceplane. The idea is to fly frequently, because that is how the market will really grow.”

In parallel, evolving technical standards shaped what counted as an acceptable design, narrowing the solution space and making sustainability requirements integral to core design decisions. Startup I’s co-founder illustrated this as a hard constraint tied to end-of-life feasibility: “If you put PFAS in panels, you can forget about recycling them. We decided to leave it out, even if it makes life harder, because at least our panels can be reused.” Acceptability was not only technical but also architectural and aesthetic in built-environment settings. Startup J emphasized the need to reconcile visual requirements with performance: “We developed color-printing techniques for solar panels to minimize efficiency loss and maximize visual appeal.”

Scaling bottlenecks also surfaced through the feasibility of automation and the maturity of digital infrastructure. Startup A’s founder described how delivery at scale became realistic only once the underlying infrastructure was stable enough: “At first we built everything in MATLAB, but it kept crashing. By 2021 we had rebuilt it as a web platform, and finally it was able to handle more clients.” Lastly, repair and upgrade pathways were increasingly treated as the minimum standard, not a bonus feature. Startup E’s co-founder and technical lead put it simply: “If you want these panels to stay in use, people need to be able to repair and upgrade them. Otherwise, they just get replaced.” These dynamics thus shaped SBMI since what counted as feasible and acceptable shifted outside the startup, realigning which sustainability-oriented configurations could be credibly built and scaled.

Digital trust, traceability, and transparency requirements

Rising ecosystem expectations for digital trust, traceability, and transparency formed a distinct trigger domain, captured in one second-order theme: verification and auditability gates for ecosystem participation. In these value networks, sustainability claims had to be supported with traceable, auditable data that could be shared across organizational boundaries.

Verification and auditability gates for ecosystem participation

As gatekeeping expectations around verification and auditability intensified, sustainability performance increasingly needed to be verifiable and auditable to partners, customers, and regulators within the value network, making data practices and reporting interfaces part of the adoption and participation conditions. Startup M’s co-founder framed end-to-end transparency as a precondition for making circular practices workable at all: “We realized pretty quickly that without transparency in supply chains, recycling just does not work. Blockchain gave us a way to share data securely while still protecting trade secrets.” The same demand surfaced as reluctance to share commercially sensitive information, with Startup M’s co-founder stressing, “No one wanted to share their supply chain data, it was too sensitive. We had to design the system with trust built in from the beginning.”

Regulatory complexity further intensified these demands by translating compliance into a design constraint for digital systems, particularly in high-stakes domains. In healthcare data, Startup P’s founder contrasted institutional environments: “In the US you can move faster, but in Europe you simply cannot launch unless you meet GDPR and MedMij. That has shaped the whole platform,” referring to the EU’s General Data Protection Regulation (GDPR) and the Dutch national health IT standard for secure patient data exchange (MedMij). These demands also intersected with sector-specific sustainability constraints and the evidentiary basis expected before action. Startup B’s founder

captured this clearly: “Clients wanted proof before they would act. So we started with mapping and monitoring first, otherwise they would not commit to removal projects.”

Finally, while AI was sometimes positioned as helpful for documentation and compliance burdens, founders also highlighted risk concerns that constrain deployment in high-stakes contexts. As Startup M’s co-founder cautioned: “AI can make mistakes or even invent information, so we use it with a lot of caution.” In this context, traceability, transparency, and digital trust triggered SBMI when verification and auditability became participation gates for legitimacy, partnership formation, and scaling.

Rules, standards, and compliance regimes

Rules, standards, and compliance regimes introduced non-negotiable requirements for market participation. These requirements shaped whether sustainability-oriented solutions could be launched and scaled, often demanding documentation, verification, and alignment with formal standards before adoption became feasible. Two second-order themes capture this trigger domain: (1) regulatory obligations and enforcement intensity and (2) approval bottlenecks, standards, and trade-policy shocks.

Regulatory obligations and enforcement intensity

Stricter regulation and enforcement reset the entry bar for market participation and credibility. In health, credibility hinged on demonstrable compliance with data governance and integration with national health IT infrastructure. Startup U’s co-founder explained: “Before hospitals would even talk to us, we had to show proof we were GDPR-compliant and connected to national health IT. Without that, we simply were not in the game.”

Similar dynamics appeared in regulated operational environments, where rule strictness determined what could be tested and deployed. Startup R’s founder recalled how “working with airports like Schiphol means you deal with very strict rules on noise and building standards. That shaped how we designed and tested our product,” indicating that regulatory constraints enter early as design and deployment boundaries rather than ex post checks. Regulation also operated as a demand-side trigger when tightening rules made previously ignored solutions salient. Startup V’s co-founder highlighted how new safety requirements “finally made companies pay attention to our exoskeleton,” effectively shifting adoption from optional to necessary for some buyers.

EU enforcement intensity was described as having hardened over time, turning guidance into penalty-backed obligations. Startup M’s co-founder described how supply chain transparency rules “changed everything... suddenly, if you did not comply, you risked massive fines. That forced us to redesign our system to make transparency part of daily operations.” What matters here is not the firm’s choice to prioritize transparency, but the external shift toward enforceable reporting with credible penalty risk.

Environmental regulation also constrained feasible operating space while reshaping value propositions. Startup L’s co-founder explained: “Tightening underwater noise rules made our silent pile-driving technology highly attractive, but getting the official certifications is still a huge challenge and slows us down.” Across these accounts, regulation becomes consequential when it raises the minimum bar for participation, and thereby narrows which sustainability-oriented configurations remain viable under the prevailing compliance regime.

Approval bottlenecks, standards, and trade-policy shocks

This trigger domain centers on timing frictions and abrupt shifts in market access and economic conditions, including approval delays, standards, and trade-policy shocks. Founders noted that greener technological alternatives can be technically available but remain effectively blocked by approval timelines and certification sequences. Startup K’s frustration that green propulsion alternatives “take forever to get

approved” illustrates how clearance regimes delay substitution and prolong reliance on less sustainable incumbents.

By setting compliance benchmarks, built-environment rules shaped which solutions could become commercially viable. Startup I’s co-founder emphasized that “BENG and MPG rules mean buildings must meet energy performance standards. That gave us a steady market for lightweight panels even when customers were not yet asking for them,” referring to the Dutch Bijna EnergieNeutraal Gebouw (BENG, Nearly Energy-Neutral Building) and MilieuPrestatie Gebouwen (MPG, Environmental Performance of Buildings) standards. In this case, BENG and MPG did not merely constrain; they structured demand by embedding sustainability into compliance targets.

Finally, sudden trade-policy shifts disrupted feasibility through immediate cost and exchange shocks. Startup C’s COO recalled how sudden import duties in Mozambique “hit our margins straight away. We had to rethink pricing on the spot.” In these cases, the trigger is the external change in approvals, standards, or trade policy that alters the timing, cost structure, or market access conditions under which a sustainability-oriented business model can plausibly scale.

Societal climate and circularity norms

Norms around climate responsibility and circularity impacted what stakeholders considered acceptable sustainability conduct and credible innovation. Founders did not frame these norms as vague background sentiment; instead, they experienced them as concrete expectations that affected trust, partner willingness, and the acceptance of sustainability claims. Two second-order themes capture this trigger domain: (1) public awareness and ethical expectations and (2) normative pressure for circular and climate-aligned design.

Public awareness and ethical expectations

Public awareness and ethical expectations linked the adoption of sustainability-oriented solutions to social legitimacy. In sensitive settings, legitimacy was anchored in societal privacy norms alongside formal regulation. Startup P’s founder stressed that “Patients expect full control over their data. In Europe especially, privacy is not just a regulation, it is something people care about deeply. If we had not built the system around that, no one would have trusted us,” indicating that acceptance depended on meeting an external baseline for admissible data practice.

Related acceptance constraints also appeared in the healthcare adoption dynamic, where Startup U’s co-founder recalled that doctors refused to trial solutions unless they were immediately usable and understandable for patients. In consumer-facing sustainability markets, rising public awareness of circularity likewise impacted what counted as a “responsible” offering. Startup E’s co-founder and product development lead noted, “People kept asking us, ‘Can these panels be recycled?’ and that made us put circularity right at the heart of the design,” indicating that ecological credibility had to be built into the offering rather than added as a feature.

In cases where impacts were difficult for outsiders to confirm, startups had to make the claims visible and checkable through transparency and verification. Startup Y’s co-founder explained: “Communities wanted to see proof of what was happening with the reefs... we involved volunteers to help collect and share the data so people could trust the results.” Similar boundary-setting appeared in wellbeing domains: Startup AD’s co-founder reflected that a sleep robot was initially met with skepticism, but became more acceptable as stress and wellbeing entered public debate and it was framed as an alternative to medication. The data show that privacy norms, transparency demands, and scrutiny of circularity raised the bar for acceptance: as adoption depended on social legitimacy, startups aligned governance, communication, and offering design with externally defined responsibility standards.

Normative pressure for circular and climate-aligned design

Normative expectations around circular and climate-aligned design redefined what counted as an acceptable sustainability pathway and narrowed the design space by making life-cycle responsibility central. As climate agendas intensified, startups had to reposition what they stood for and how they framed their purpose. Startup Q’s co-founder recalled, “We started out focused just on energy cost savings, but as climate goals became urgent, we reframed our mission around helping clients decarbonize their operations,” illustrating how climate alignment became a legitimacy requirement rather than a branding choice.

In energy and solar contexts, founders described increasing expectations to design for circularity and stewardship. Startup E’s co-founder and finance lead emphasized, “We design panels to be repaired and upgraded. Standardization makes it easier to keep them in use, instead of throwing them away,” reflecting a growing emphasis on life-cycle responsibility through repair, reuse, and product stewardship. Material choices were similarly constrained by the need to avoid hazardous inputs when they undermine end-of-life feasibility. Startup I’s co-founder explained their decision to eliminate PFAS despite added complexity: “Leaving PFAS out was a tough choice, but we did it because recyclability mattered more in the long run,” reflecting expectations to substitute harmful materials with safer, recyclable alternatives.

Beyond circularity, environmental impact and resource constraints were treated as legitimate performance criteria. Startup F’s COO described how their hatches “save fuel, cut emissions, and are simply a cleaner way to power vessels,” while Startup W’s founder noted that shipping clients increasingly expected solutions that reduce emissions and costs simultaneously. Even in culturally sensitive markets, ecological integrity was described as a non-negotiable boundary. Startup T’s sales and marketing lead stated: “It is not just about growth, it is about staying true to the mission.” Overall, societal climate and circularity norms allowed for circular design, safer materials, and climate-aligned baseline requirements, shaping which sustainability-oriented business models were regarded as legitimate and scalable.

Discussion

This study set out to examine what technology-based startups themselves treat as external triggers of SBMI initiation. The data show that founders did not describe triggers as a unilateral set of contextual factors. Instead, they described a patterned environment in which triggering forces differ in distance, origin, and how they are encountered in practice. Building on this insight, we develop a multilevel framework distinguishing between triggers anchored at an institutional (macro) level and those arising within the value network (meso) surrounding the startup (Figure 2). The framework is deliberately not a process model. Rather, it maps triggering conditions that founders associate with revisiting value creation, value delivery, and value capture (Teece, 2010; Foss & Saebi, 2017; Geissdoerfer et al., 2018). The dashed arrow is intended to signal SBMI initiation or reconsideration, not a staged sequence of responses.

Our multilevel framing draws adapts the neo-institutional approaches that distinguish broad institutional pressures from ecosystem-embedded tensions arising through interdependent value networks (Markoff-Legrand et al., 2024) to a startup context. It treats these forces not as a response model, but as external triggers that founders associate with SBMI initiation. The framework clarifies where triggers originate and how they reach startups. Institutional-level triggers reflect rule systems, societal norms, and socio-technical infrastructures that shape the boundaries of permissible and desirable business conduct. Value-network triggers arise through proximate actors and infrastructures that govern day-to-day exchange, such as customers and users, competitors, incumbents and gatekeepers, investors and intermediaries, and the digital and technical infrastructures that increasingly condition market participation (Perotti et al., 2025; Quttainah & Ayadi, 2024). The analytical gain is that “the environment” is no longer

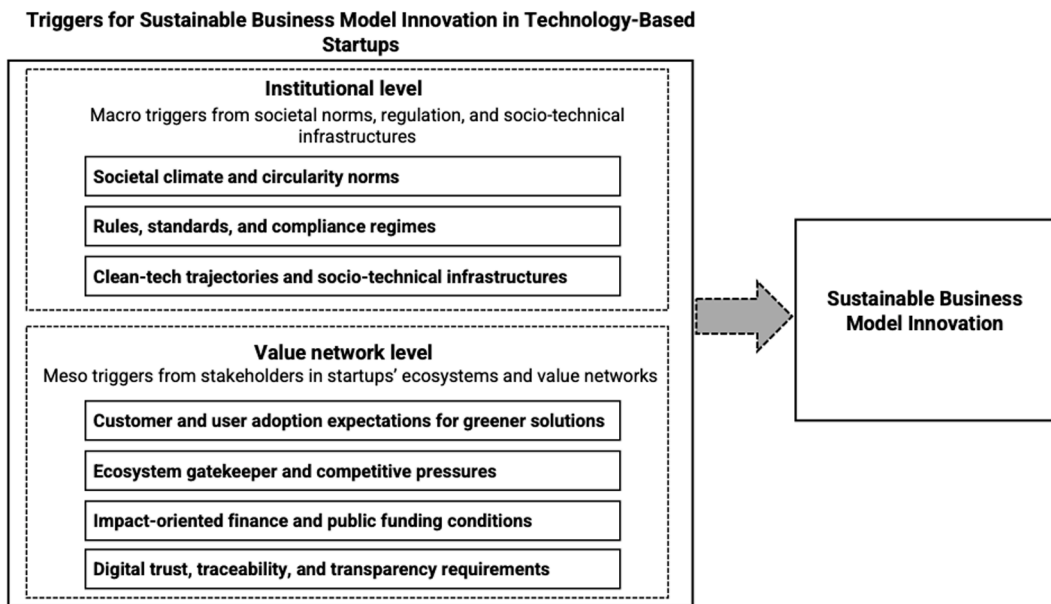


Figure 2. Multilevel framework of external triggers for SBMI initiation in technology-based startups.

Note: Triggers may co-occur across levels and do not imply temporal ordering or causality.

treated as a single undifferentiated layer, as the framework specifies how triggering conditions are structured and transmitted to startups operating under resource constraints and legitimacy liabilities (Dzhunushalieva & Teuber, 2024; Reinecke et al., 2023).

At the institutional level, three trigger domains are particularly salient. First, rules, standards, and compliance regimes operate as boundary conditions that can simultaneously constrain and catalyze sustainability-oriented BMI. Founders described how enforcement intensity, approval bottlenecks, data governance requirements, and shifts in duties and standards alter what can be offered, to whom, and with what evidence. These patterns align with evidence that shows that digitalization and sustainability are not automatically aligned in practice, because governance requirements and accountability expectations reshape feasible pathways and impose “translation” costs from technological potential to sustainability outcomes (Guandalini, 2022; Grybauskas et al., 2022; Kar et al., 2022; Wei et al., 2023). Second, societal climate and circularity norms appear as a legitimacy climate rather than as demands from one identifiable stakeholder. The relevant expectations here pertain to various elements of responsible conduct including climate responsibility, circular design, life-cycle stewardship, transparency, and ethical expectations. Startups experience these as market-shaping forces because they determine reputational risk, adoption viability, and the credibility needed to operate as a sustainability-oriented startup (Reinecke et al., 2023; Dzhunushalieva & Teuber, 2024). Third, clean-tech trajectories and socio-technical infrastructures capture shifts in field-level technologies, enabling systems, and design expectations that shape what is feasible or required. These include maturation of cleaner technological options, emergence of technical standards that define “acceptable” designs, and evolving design principles and components that enable repair, reuse, and ecological performance. Rather than being background noise, these shifts delineate the solution space within which SBMI can plausibly occur.

A central finding, however, is that institutional triggers rarely confront startups in a purely abstract form. They are translated into concrete constraints and opportunities through the value network level. This is where founders reported the most pressing day-to-day requirements and constraints: adoption conditions, gatekeeping, competition, and funding criteria. Two value network trigger domains emerged consistently from the data. Customer and user adoption expectations for

greener solutions do not function as simple “demand signals.” They are sustainability-laden and culturally conditioned: acceptability, dignity, stigma, and usability requirements shape whether adoption is even possible. In parallel, ecosystem gatekeeper and competitive pressures reflect the reality that diffusion in many sustainability-relevant sectors is intermediated. Incumbents, certification regimes, and influential partners function as legitimacy filters. Pilots, endorsements, and compatibility with installed bases are often described as structural conditions for market entry rather than optional add-ons, particularly in conservative or high-stakes contexts (Perotti et al., 2025; Quttainah & Ayadi, 2024; Zhang et al., 2025). This helps refine the meaning and implications of “market trigger” in SBMI: it is not a loose category but an actor-configured network in which gatekeepers can determine what counts as credible sustainability innovation.

The remaining value network trigger domains highlight how resources and infrastructures mediate SBMI initiation. Impact-oriented finance and public funding conditions capture the role of investors, incubators, competitions, subsidies, and mission-oriented programs as allocation and governance mechanisms. Startups repeatedly described that access to finance is not neutral: it is channeled through criteria that encompass assumptions about growth, scalability, acceptable revenue logics, and evidence thresholds, often tied to impact narratives and sustainability commitments. This aligns with studies emphasizing how funding logics and knowledge infrastructures condition sustainable digital transformation (Lim & Hwang, 2024; Riaz et al., 2024; Cabrilo et al., 2024). Finally, digital trust, traceability, and transparency requirements emerge as a distinct meso trigger domain, even when amplified by institutional regulation. What makes this a trigger at the “value network level” is how it is experienced, not as a distant societal expectation, but as an adoption and participation requirement imposed by buyers, hospitals, incumbents, and supply-chain partners through procurement rules, integration demands, and verification practices. The trigger is therefore carried by the ecosystem, even when its content is shaped by institutional architectures such as privacy and data governance regimes. This finding sits squarely in current debates about digital technologies (AI, blockchain, IoT, analytics) as double-edged enablers: while they can support sustainability via monitoring, transparency, and resource optimization, they also introduce new liabilities, governance requirements, and concerns around accuracy, bias, and accountability (Nishant et al., 2020; Vinuesa et al., 2020; Hellems et al., 2022;

Perotti et al., 2024; Meinhold et al., 2025).

This multilevel structure clarifies where triggers are anchored and how they operate combinatorially. Institutional triggers shape the rules of the game and the legitimacy climate. Value network triggers reach startups through day-to-day exchange, gatekeeping, funding channels, and participation rules tied to key infrastructures. This is not a one-way relationship as institutional triggers often gain practical force only when they are translated through value network mechanisms such as procurement standards, incumbent compatibility demands, investor evidence screens, or traceability infrastructures. Startups operating under similar institutional backdrops report different trigger profiles precisely because it matters how broader expectations are filtered through the specific ecosystems in which startups are embedded (Markoff-Legrand et al., 2024; Perotti et al., 2025; Quttainah & Ayadi, 2024).

A final point concerns how these triggers initiate SBMI without collapsing the discussion into an “actions” account. In this paper, value creation, value delivery, and value capture are used as interpretive lenses to specify where business models are exposed to external triggers, rather than as a coding structure or a sequence of responses (Teece, 2010; Foss & Saebi, 2017). Customer and user adoption expectations tend to destabilize value creation and value delivery by redefining what “sustainable value” means in use and what adoption requires under cultural fit, dignity, and usability constraints. Gatekeeper legitimacy and compatibility requirements primarily expose value delivery assumptions because they govern access routes, diffusion channels, and ecosystem acceptance. Competitive intensity often surfaces as value capture exposure because it imposes viability ceilings through pricing constraints and performance benchmarks. Funding gatekeepers likewise concentrate exposure in value capture by conditioning revenue assumptions, scaling trajectories, and evidence requirements for resource access. Clean-tech trajectories and socio-technical infrastructures reshape value creation by defining the feasible solution space for sustainable technologies (e.g., technology maturation, infrastructural readiness, and field-level design expectations), while digital trust expectations reshape value delivery by making transparency, traceability, and data-governance participation requirements in the ecosystem (Nishant et al., 2020; Vinuesa et al., 2020; Guandalini, 2022; Hellemans et al., 2022; Perotti et al., 2024). Using the value lens in this manner preserves the unit of analysis as triggers while explaining why certain external conditions are experienced as initiating business model reconsideration.

Overall, the framework positions SBMI initiation in technology-based startups as an outcome of multilevel trigger exposures that are structured and transmitted through institutions and ecosystems rather than arriving as isolated “factors.” This is critical for the broader conversation on sustainability and digitalization because our evidence shows that digital technologies are not mere tools that startups may leverage. As carriers of external expectations, they operationalize societal and regulatory demands into concrete ecosystem requirements for accountability and transparency. Whether digitalization becomes an enabler of sustainable outcomes therefore depends on the surrounding governance, funding logics, and knowledge and data infrastructures through which startups must operate (Guandalini, 2022; Hellemans et al., 2022; Lim & Hwang, 2024; Riaz et al., 2024; Perotti et al., 2025). By focusing on triggers and locating them at the appropriate level of analysis, the discussion presents clearly the process through which sustainability-oriented expectations and requirements reach startups and how they trigger SBMI in practice (Raman et al., 2024; Dzhunushalieva & Teuber, 2024).

Conclusion

Theoretical implications

This study advances theory on SBMI by clarifying how technology-based startups conceptualize external triggers of SBMI initiation and

demonstrating that these triggers are structured across levels, rather than experienced as a single undifferentiated environment. Despite some trigger labels resembling broad environmental categories (e.g., regulation, market, technology), our contribution is not to point out their existence in the abstract, but more a startup-grounded account of where they are anchored and how they are transmitted through ecosystems in ways that founders experience as triggering.

First, we finetune the construct of SBMI triggers by specifying what makes a condition “triggering” in founder accounts, and by separating these from subsequent actions. We conceptualize triggers as external conditions that make sustainability-oriented business model choices harder to pursue or sustain, thereby prompting founders to reconsider value creation, value delivery, and value capture (Teece, 2010; Foss & Saebi, 2017; Geissdoerfer et al., 2018). In our framework, triggers are therefore analytically distinct from implementation activities. Actions are treated as responses that may follow exposure, whereas triggers remain the external conditions founders describe as destabilizing prior assumptions or opening viable pathways (Bocken & Geradts, 2020; Reinecke et al., 2023). This distinction matters in SBMI because initiation is often shaped by shifts in what becomes workable, credible, and financeable under contested expectations and evolving infrastructures, rather than by a planned internal decision sequence (Boons & Lüdeke-Freund, 2013; Minatogawa et al., 2022).

Second, we extend theorizing on SBMI triggers by introducing a multilevel taxonomy that moves beyond inventories organized around political, economic, social, technological, environmental, and legal factors and clarifies how triggers reach startups. Building on the idea that external triggers operate at different distances from the startup (Markoff-Legrand et al., 2024), our evidence differentiates between triggers at the institution level and those at the value network level. Institutional triggers (societal climate and circularity norms; rules, standards, and compliance regimes; clean-tech trajectories and socio-technical infrastructures) shape boundary conditions and the legitimacy climate. Value network triggers (customer and user adoption expectations for greener solutions; ecosystem gatekeeper and competitive pressures; impact-oriented finance and public funding conditions; digital trust, traceability, and transparency requirements) are conveyed through proximate actors and infrastructures that govern exchange and ecosystem participation. The theoretical contribution of this framework is that “the environment” is not treated as a single layer of contextual factors. It specifies where triggers are anchored and through which channels they become venture-relevant for startups operating under resource scarcity and legitimacy liabilities (Dzhunushalieva & Teuber, 2024; Reinecke et al., 2023). Our findings thus provide a structured classification of external SBMI triggers that supports analytical granularity and cross-study comparability (Bocken & Geradts, 2020; Markoff-Legrand et al., 2024).

Third, we refine the implications of “market” and “technology” for SBMI by showing that sustainability changes the content of these triggers and by identifying digital trust as a distinct trigger domain. In the value network, market-related triggers did not operate primarily as generic demand; instead, adoption hinged on cultural fit, dignity expectations, stigma, and usability, while diffusion was mediated by gatekeepers, installed-base compatibility, pilots, and endorsements. This reframes demand-side triggers as legitimacy-laden and actor-configured, extending work on stakeholder pressures (Konietzko et al., 2020; Reinecke et al., 2023) by showing that adoption conditions and gatekeeping operate as distinct modes of external selection in sustainability contexts. Digital trust, traceability, and transparency requirements are likewise experienced at the value network level even when amplified by institutional regulation. Ecosystem actors translate regulatory complexity and sustainability accountability into concrete participation criteria (e.g., verification, data governance, auditability). This reinforces the view of digitalization as a double-edged force in sustainable innovation, enabling accountability while creating new liabilities and value destruction risks (Nishant et al., 2020; Vinuesa et al.,

2020; Mancuso et al., 2025b). It also aligns with arguments that knowledge infrastructures and funding logics condition sustainable digital transformation trajectories (Di Vaio et al., 2021; Perotti et al., 2025).

These implications reposition SBMI initiation in technology-based startups as an outcome of multilevel trigger exposure structured by institutions and transmitted through ecosystems, rather than as a simple response to generic environmental factors. By preserving the unit of analysis (external triggers) while clarifying anchoring levels and transmission channels, the study strengthens conceptual rigor and improves cross-study comparability in SBMI trigger research (Bocken & Geradts, 2020; Markoff-Legrand et al., 2024).

Practical implications

Our findings point to three practical implications for founders and ecosystem stakeholders involved in SBMI in technology-based startups. First, external triggers should be treated as strategic design constraints rather than background noise. Founders experienced external triggers as patterned and multilevel, with some anchored in the institutional setting (e.g., socio-technical infrastructures and clean-tech trajectories, compliance regimes, and broader circularity norms), and others encountered through the value network (e.g., adoption expectations, gatekeeping and competition, funding conditions, and verification and transparency expectations). Using the framework as a diagnostic map would help startups anticipate trigger exposure events and the resultant reconsideration of business model assumptions, particularly when triggers co-occur rather than appearing one at a time (Bocken & Geradts, 2020; Reinecke et al., 2023; Markoff-Legrand et al., 2024).

Second, SBMI is shaped not only by customer demand but also by intermediation and resource access that depends on proof. Entrepreneurs should plan explicitly for gatekeeping dynamics as pilots, endorsements, installed-base compatibility, procurement rules, and verification practices often determine whether market access is possible at all (Perotti et al., 2025; Quttainah & Ayadi, 2024). Financing similarly operates as a selection environment. Public funding, prizes, and mission-oriented programs can enable early experimentation, but they also channel startups toward specific impact narratives, scaling logics, and reporting obligations. Treating finance and gatekeepers as part of the same value network environment encourages founders to build credible evidence packages early (impact claims, compliance readiness, and operational proof) instead of postponing them to later-stage milestones (Lim & Hwang, 2024; Riaz et al., 2024).

Third, digital technologies should be approached as participation infrastructure, not merely as efficiency tools. Across cases, demands for digital trust, traceability, and transparency were frequently experienced as ecosystem entry requirements carried through buyers, incumbents, and supply-chain partners, even when amplified by regulation. Practically, this means investing early in data governance, auditability, interoperability, and verification routines because these increasingly condition adoption and legitimacy in sustainability-relevant markets (Nishant et al., 2020; Vinuesa et al., 2020; Hellemans et al., 2022). For policymakers and intermediaries, the implication is to reduce unnecessary bottlenecks and ambiguity in standards and reporting expectations, and to support shared infrastructures that lower verification and compliance costs for young startups without weakening accountability (Guandalini, 2022; Perotti et al., 2025).

Limitations and future research avenues

While this study contributes to the growing empirical literature on SBMI, the following limitations should be considered when interpreting

the findings and identifying directions for future research.

First, our analysis focuses on how founders in technology-based startups describe external triggers associated with SBMI initiation, and we organize these triggers into seven domains structured across institutional and value network levels. This is not an exhaustive set of triggers as the environments in which startups operate are open-ended, and new or unexpected triggers can emerge as technologies, infrastructures, and governance arrangements evolve. Future research could extend our trigger map by examining additional contexts, sectors, and institutional settings, and by testing the recurrence of these trigger domains in addition to the salience of new ones.

Relatedly, our framework does not theorize the mechanisms through which trigger exposure translates into specific business model reconfigurations. This allows for future work to examine how external trigger exposure is interpreted and acted upon by the startup, for example through experimentation routines, cross-functional coordination, boundary-spanning search, and learning processes. In line with recent calls on sustainable digital transformation and accountability infrastructures (Hellemans et al., 2022; Lim & Hwang, 2024), future studies could investigate how knowledge management practices (e.g., data governance, learning from digital platforms, shared repositories) shape founders' recognition and prioritization of, and response to trigger exposure (Di Vaio et al., 2021; Wang et al., 2023). Such work could explicitly connect trigger exposure to changes in value creation, value delivery, and value capture, and clarify when it results in incremental adaptation vis-à-vis more fundamental SBMI.

Second, our qualitative design raises generalizability considerations. The study focuses on technology-based startups located in the Netherlands. While this setting supports theory building by reducing institutional heterogeneity (Davidsson & Gruenhagen, 2020; Zott & Huy, 2007), it remains unclear whether the same multilevel trigger structure and trigger salience would hold in contexts with different policy regimes, market infrastructures, and cultural expectations. Comparative studies across countries and regions, as well as across sustainability-relevant sectors with different gatekeeping structures, could test the boundary conditions of our framework.

Third, while our findings emphasize that triggers often co-occur across levels, our qualitative evidence is not designed to model interactions systematically. Future research could examine configurations and interactions between triggers, including how institutional triggers become venture-relevant through value network mechanisms (e.g., procurement, verification infrastructures, and investor proof requirements) and how digital infrastructures amplify, dampen, or reshape the effects of regulation, market access, and funding conditions (Nishant et al., 2020; Meinhold et al., 2025; Raman et al., 2024). Longitudinal designs could further capture how trigger exposure shifts over startup development, including whether the same triggers persist, intensify, or decline as startups scale, enter new markets, or move into later growth phases (Cavallo et al., 2024; Ghezzi & Cavallo, 2020). Mixed-method approaches, including real-time process data and archival or digital trace evidence, could also help reduce retrospective bias and strengthen causal inference about when trigger exposure precedes business model change.

CRedit authorship contribution statement

Ghassan Kharbeet: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hanieh Khodaei:** Writing – review & editing, Supervision. **Roland Ortt:** Writing – review & editing, Supervision. **Victor Scholten:** Writing – review & editing, Supervision.

Appendix A. Interview guide

Company: _____

Date: _ / _ / ____

Interviewee Name and Role: _____

Interviewer: _____

Introduction (to explain at the start)

- Thank participant for their time.
- Explain the purpose: We are studying how startups adapt their business models in response to different events or conditions, with a special focus on sustainability. The goal is to understand how business models evolve, what triggers these changes, and how ventures balance commercial and sustainability goals.
- Confirm confidentiality: names and company identifiers will be anonymized.
- Request permission to record (if applicable).

1. Founding and early development

- Can you describe the early stages of your company's development and its business model?
- To what extent was sustainability part of your business model in this phase?
- What events or circumstances influenced your early business model decisions?
- Did you make any changes to your business model during this early stage?
- Can you describe your current growth stage and what your business model looks like now?

Probe (if needed): Some startups highlight technology breakthroughs, sustainability challenges, or early funding opportunities. Did any of these influence your early business model?

2. Moving forward and commitment

- At what point did you decide to fully commit resources and time to the venture?
- What events or milestones shaped your business model at this stage?
- Were sustainability-related goals, pressures, or opportunities part of this decision-making?
- Did you need to adjust your business model as you committed to growth?

Probe (if needed): Early customer interest, investor signals, partnerships, or technology developments often influence this stage. Did any of these matter for your business model?

3. Building credibility and scaling

- How did you work to build credibility with customers, partners, or investors?
- Did demonstrating sustainability play a role in gaining credibility?
- Were there events or conditions that influenced your business model while establishing credibility?
- What kinds of changes did you make in order to grow or gain legitimacy?

Probe (if needed): Some companies mention customer feedback, competition, regulation, or partnerships. Did any of these shape your business model from a sustainability perspective?

4. Sustaining and refining the business

- As your company matured, what changes did you make to strengthen or sustain your business model?
- What role did sustainability play in these changes?
- How do you balance commercial needs with your sustainability goals when making business model decisions?
- What kinds of events or external conditions prompted these changes?
- What challenges did you face in embedding sustainability into your business model for the long term?

Probe (if needed): Competitive pressure, policy shifts, funding dynamics, technological advances, or societal expectations are often mentioned. Did any of these affect your business model?

5. Reflection across the journey

- Looking across your journey, what have been the most important events or triggers that shaped your business model?
- Which elements of your business model were most affected, and why?
- How has sustainability influenced your business model over time, and how do you see it shaping your future?

Probe (if needed): Were particular factors such as sustainability-oriented market demand, sustainability finance, sustainability-driven technology, sustainability regulation and policy pressures, or societal and sustainability expectations especially decisive?

Closing

- Is there anything else you think is important for us to understand?
- Thank participant, explain anonymization, and note possible follow-up.

Appendix B. Follow-up interview guide

Company: _____
Date: _ / _ / ____
Interviewee Name and Role: _____
Interviewer: _____
Introduction

- Thank participant for their continued time.
- Explain purpose: We are following up to understand what has changed since the last interview in terms of your business model, especially regarding sustainability, and the conditions that influenced those changes.
- Confirm confidentiality and recording (if applicable).

1. Since the last interview

- What has changed in your business model—including sustainability aspects—since we last spoke?
- What triggered those changes?

Probe (if needed): Some founders mention customer reactions, funding dynamics, partnerships, regulations, technological developments, or sustainability expectations as important in this period. Did any of these affect your business model?

2. Current challenges and adaptations

- What are the biggest challenges you are facing right now?
- Have these challenges led to adjustments in your business model?
- How are you balancing commercial needs with your sustainability goals at this stage?

3. Looking ahead

- What upcoming events, sustainability expectations, milestones, or external conditions do you expect will shape your business model in the near future?
- How are you preparing for these possible changes?

Closing

- Is there anything else important that we should capture about your journey since our last conversation?
- Thank participant, explain anonymization, and note possible future follow-ups.

Appendix C. Representative quotes by trigger domain

Table C1
 Representative quotes.

Aggregate dimension	Second-order theme	First-order category	Quotes
Customer and user adoption expectations for greener solutions	User acceptability, cultural fit, and dignity constraints	End-user sensitivity to how and where the solution is used	“We pay a lot of attention to the context people associate with it. If it feels awkward in the real setting, people just will not use it.” Startup T
		Cultural norms shaping what is acceptable or appropriate in use contexts	“In some countries, burial is so regulated and tradition-bound that it is not really an individual choice anymore.” Startup T
	Usability and simplicity requirements for adoption	Social stigma and dignity expectations shaping adoption thresholds	“People do not want something that makes them feel singled out in public. If the glasses look awkward or draw attention, they will simply not wear them, even if the tech is good.” Startup O
		Field research foregrounding unmet needs in day-to-day customer contexts	“Once we started talking to users every day and seeing how things work in real life, we realized our assumptions were off. That feedback changed what we focused on first.” Startup AD
Ecosystem gatekeeper and competitive pressures	Competitive intensity and performance benchmarks in sustainability	Explicit customer demand for simpler, easier-to-operate solutions	“People want solar without the technical headache. If it feels complicated, they postpone it forever.” Startup H
		Preference for low-friction onboarding and operational simplicity in use	“We try to make it effortless. We take the responsibility so customers do not have to babysit the solution.” Startup S
		Price competition from low-cost entrants	“Cheaper imports forced us to stop playing the small-product game and redesign what we offered and how we delivered it.” Startup C
		High customer price sensitivity in sustainability-oriented markets	“We can build something great, but if we land at around €1000 per square meter and clients hesitate, that sets the ceiling for what we can sell.” Startup X

(continued on next page)

Table C1 (continued)

Aggregate dimension	Second-order theme	First-order category	Quotes
Impact-oriented finance and public funding conditions	Gatekeeper legitimacy and compatibility requirements	Reliability and autonomy driving purchase decisions	"To sell commercially you need proof it is reliable and safe, otherwise customers will not trust it in their operations." Startup S
		Entry barriers from risk aversion in conservative sectors	"In conservative sectors, people want references first. Without proof and familiar channels, they hesitate even if they like the idea." Startup AB
	Crisis-driven turbulence and disruption conditions	Competitive pressure to meet reliability and autonomy performance baselines	"We got a lot of feedback like, 'this is too big' or 'this is too complicated.' That is when it clicked: if it is not easy to use and reliable, it will not scale." Startup N
		Dependence on established incumbents as legitimacy gatekeepers	"Big players and their guidelines shape what is considered acceptable. Getting included there changes everything." Startup A
Impact-oriented finance and public funding conditions	Investor and intermediary funding criteria	Corporate buyers requiring pilots and proof-of-concept with recognized partners	"With the bigger customers, it always starts with a pilot. They want to see it working in their context, and having the right partners involved makes that conversation much easier." Startup Q
		Installed-base compatibility constraints imposed by incumbent technologies	"Our customers want something they can drop into their existing setup. So, we built it as a fully assembled module: they plug it in, screw it in, and it just works. If it needs a whole redesign on their side, they will not adopt it." Startup AC
		Endorsements by recognized industry actors shaping adoption decisions	"Once you have reference customers or formal validation, the conversation shifts from 'why' to 'how fast'." Startup A
	Dependence on subsidies, grants, and mission-oriented programs	COVID-related restrictions limiting travel and in-person service delivery	"Covid removed the ability to visit customers and demonstrate in person, and that slowed adoption and sales momentum." Startup W
		War- and inflation-linked supply chain disruption increasing uncertainty	"Since Covid and the war, raw materials have got a lot more expensive. It has been a real challenge for us." Startup X
		Crisis conditions accelerating demand for remote and digital delivery options	"When things got unstable, anything we could do remotely suddenly mattered more, because it cut down delays and hassle." Startup AA
Clean-tech trajectories and socio-technical infrastructures	Investor and intermediary funding criteria	Availability of prizes and competitions as early-stage financing channels	"In the early days, EU funding and startup prizes were what made development possible. It gave us runway and helped us get momentum before we had serious investors." Startup G
		Access to incubators, facilities, and bank loans as growth enablers or constraints	"Support programs and incubators helped fill gaps in skills and access, and that changed how fast we could move." Startup AB
		Investor expectations for scalability and growth shaping feasibility perceptions	"Once funding came, the pressure shifted to scaling production and building a more professional setup." Startup T
	Shifts in clean-tech trajectories, standards, and infrastructure readiness	Investor preference for particular revenue logics	"One-off sales were limiting. A subscription logic made the model work better for scaling and adoption." Startup AD
		Funding contingent on pilot evidence and early customer validation	"Validation from pilots and early commitments is what unlocks the next funding step. Without evidence, it is stalled." Startup R
		National subsidy schemes targeted at sustainable innovation and expansion	"Subsidies let us test and develop things we could not finance from operations alone." Startup G
Digital trust, traceability, and transparency requirements	Verification and auditability gates for ecosystem participation	EU and national grants or subsidies enabling R&D continuity	"That ESA subsidy is what made the R&D collaboration financially possible. Without it, we could not have done that work." Startup K
		Shifting eligibility criteria influencing strategic choices and timing	"We time development around funded projects, because major development steps depend on that availability." Startup J
		Public and NGO funding programs requiring collaboration or consortia participation	"Being part of programs often means working in consortia, which shapes pace, coordination, and costs." Startup L
		Reimbursement regimes shaping revenue feasibility and market entry	"It really depends on whether insurance covers it. That changes who can adopt it and how we price it, because it shifts the risk for the user" Startup V
Clean-tech trajectories and socio-technical infrastructures	Shifts in clean-tech trajectories, standards, and infrastructure readiness	Availability and maturation of cleaner propulsion options	"We found a real need for in-space propulsion, and nitrous oxide turned out to be a good fit. It is available, it works, and it is also a cleaner option." Startup K
		Emergence of new technical standards shaping acceptable designs	"Standards basically set the bar for what is acceptable. We had to design around that, because otherwise you do not even get through the door." Startup AC
		Feasibility of automation under ecological performance constraints	"Automation helps, but some quality checks still need hands-on work. Scaling is not just software, it is engineering and operations." Startup X
Digital trust, traceability, and transparency requirements	Verification and auditability gates for ecosystem participation	Growing availability of repair- and reuse-oriented design principles and components	"We push durability and recyclability through material choices and design, because lifetime and end of life matter to the model." Startup AE
		Rapid shifts in digital infrastructure enabling scalable service models	"Moving to modern platforms and adding AI capabilities changed what we could deliver and how scalable it became." Startup P
		Rising expectations for end-to-end traceability and transparency	"People simply do not see what is happening across the chain, and they do not trust the data they get. Without that, circularity falls apart." Startup M
Digital trust, traceability, and transparency requirements	Verification and auditability gates for ecosystem participation	Regulatory complexity creating demand for data-driven compliance tooling	"Compliance is getting too heavy to manage in spreadsheets. Companies want something that turns the rules into day-to-day routines, or they risk fines." Startup B
		Sector-specific sustainability constraints requiring tailored digital solutions	"Traceability only works if enough players join the same network, so we picked one sector first instead of scattering pilots everywhere." Startup J

(continued on next page)

Table C1 (continued)

Aggregate dimension	Second-order theme	First-order category	Quotes
Rules, standards, and compliance regimes	Regulatory obligations and enforcement intensity	Concerns about AI accuracy, bias, and liability in high-stakes contexts	"AI can help, but in compliance, you cannot afford mistakes. One wrong output and you lose trust fast." Startup M
		EU supply-chain transparency rules imposing reporting obligations and penalty risks	"In the EU, it is no longer advice. If you fail transparency requirements, penalties can be serious, so companies take action." Startup M
		EU enforcement hardening and penalty-backed obligations shaping feasibility	"The tone changed. It is not box-ticking anymore, it affects how companies actually run their operations." Startup F
		Health-data regulation restricting data use and design options	"In medtech you cannot just launch something half-finished. The regulations basically force you to have a complete, compliant product from day one, and that really shapes what you can build and how you design it." Startup U
Societal climate and circularity norms	Approval bottlenecks, standards, and trade-policy shocks	Environmental regulation constraining operations	"Policy basically sets the rules for where and how we are allowed to operate. It shapes the whole way we run the project." Startup B
		Slow approval processes delaying deployment of greener technological alternatives	"The approval and certification process takes time, and you cannot shortcut it. It slowed down deployment, even when we felt the technology itself was ready." Startup U
	Public awareness and ethical expectations	Sudden import duty changes altering cost structures and market access conditions	"Our unit costs jumped, and suddenly margins only worked at scale." Startup H
		Built-environment standards steering feasible solution pathways	"Once the EU sets a standard, it becomes the reference point. Even companies outside Europe start designing to meet it, because otherwise you lock yourself out of the market." Startup M
Normative pressure for circular and climate-aligned design	Public awareness and ethical expectations	Societal privacy norms shaping acceptance of health-data solutions	"People will only engage if they feel in control of their data. Trust is not optional in health." Startup P
		Rising public awareness of climate and circularity shaping responsible offerings	"Awareness is rising, and it changes what people see as responsible choices, even if adoption still needs proof and convenience." Startup D
		Stakeholder expectations for transparency and ethical conduct	"We earn trust by being open about what we do. We run tests with the consortium partners and we communicate regularly with stakeholders." Startup L
		Circularity considerations influencing energy and solar product design	"We kept coming back to repairability, recyclability, and safer materials because the current solar model is not circular." Startup E
Resource scarcity and environmental impact recognized as strategic constraints	Normative pressure for circular and climate-aligned design	Resource scarcity and environmental impact recognized as strategic constraints	"We realized pretty quickly that materials and resource use are not just a cost issue. If you waste resources, you pay twice: financially and environmentally, so we had to design with efficiency in mind." Startup G
		Climate agendas prompting climate-aligned missions	"The mission is directly tied to emissions and pollution realities we saw, and that is what the company is built around." Startup W
		Hazardous material risks driving substitution to safer, recyclable alternatives	"Removing problematic substances and designing for recycling is not a nice-to-have. It is where the future is heading." Startup I
		Emerging life-cycle responsibility expectations and product stewardship norms	"A lease or service model also gives you control over what happens after use, so the product does not disappear into waste." Startup AB

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