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Proof-Based Green Marketing for Scaling Circular Business Models in Water-Scarce Emerging Economies: An Exploratory Corpus Analysis of Pedagogical Case Narratives from Tunisia

Lotfi Mazhoudi[1*]

Abstract

Green entrepreneurship is often positioned as a pathway to circular transitions in water-scarce emerging economies, yet evidence on how ventures translate environmental claims into market acceptance remains limited. Drawing on a corpus-based cross-case analysis of eight pedagogical case narratives from Tunisia (143 coded meaning units), we develop proof-based green marketing capability (PB-GMC)—an offer-level capability for generating, validating, and translating environmental performance data into credible market signals. The corpus emphasizes three recurring scaling bottlenecks—energy costs, logistics friction, and quality assurance—and frames proof as a market asset used to secure customers, partners, and finance. Water scarcity appears to raise the evidentiary bar for "water saved" claims, motivating baselines, monitoring routines, and (where feasible) third-party validation. We triangulate three cases with publicly available sources to confirm descriptive facts and illustrate proof artefacts rather than validate impact magnitudes. We contribute a capability-based framework and a Minimum Viable Proof System to support scaling of circular business models under resource constraints, and outline measurement directions for future confirmatory research.

Keywords: *green entrepreneurship; circular economy; circular business models; proof-based green marketing; legitimacy; resource efficiency; water scarcity; sustainable finance; ESG metrics; Tunisia; emerging economies*

Introduction

Resource constraints, climate risks, and widening sustainability expectations are reshaping how firms create and justify value. Across sectors, stakeholders increasingly demand that environmental and social impacts be considered alongside conventional financial performance, a logic often framed as the triple bottom line (Elkington, 1997) and operationalized through sustainability reporting and ESG metrics (Global Reporting Initiative [GRI], 2021). In this context, entrepreneurship is frequently positioned as a critical mechanism for experimenting with new technologies, value propositions, and organizational forms that can accelerate system transitions (Dean & McMullen, 2007; Cohen & Winn, 2007). However, the scaling of green ventures remains uneven, and failure rates are high despite strong societal narratives about "green growth" and "win–win" solutions.

Two overlapping transition discourses are particularly influential. The green economy emphasizes improving human well-being and social equity while reducing environmental risks and ecological scarcities (United Nations Environment Programme [UNEP], 2011). The circular economy focuses on keeping products, components, and materials at their highest utility and value for as long as possible, distinguishing between biological and technical cycles (Ellen

[1] RED Laboratory (LR23ES10), Higher Institute of Management, University of Gabes, Gabes 6029, Tunisia; Email: lotfimazhoudi68@gmail.com

MacArthur Foundation, 2013; Stahel, 2016). While definitions vary, a common thread is the ambition to reduce waste and decouple value creation from virgin resource extraction by prioritizing value retention options such as refuse, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover (Kirchherr, Reike, & Hekkert, 2017; Reike, Vermeulen, & Witjes, 2018).

For entrepreneurs, these discourses translate into concrete design challenges: how to build circular loops that are economically viable; how to compete against linear incumbents with lower short-term costs; and how to convince customers, regulators, and financiers that claimed environmental benefits are real. The credibility challenge is central because sustainability-related attributes are often difficult for buyers to observe directly; they frequently resemble "credence qualities" where information asymmetries invite opportunistic behavior and raise concerns about greenwashing (Akerlof, 1970; Delmas & Burbano, 2011). As a result, the marketing of green offerings cannot rely solely on aspirational narratives; it must be connected to verifiable proof that withstands stakeholder scrutiny (Dangelico & Vocalelli, 2017; Peattie & Crane, 2005).

This article concentrates on a setting where these challenges are intensified: water-scarce emerging economies. Tunisia offers an illustrative context because water scarcity is recognized as a major economic constraint affecting agriculture, tourism, and urban services (World Bank, 2023). Water losses in distribution networks have also been reported to increase over time, indicating governance and infrastructure challenges that compound climatic pressures (World Bank, 2023). In parallel, circular approaches to organic waste, plastics, and resource recovery are increasingly discussed as potential sources of jobs, local value creation, and climate mitigation (GIZ & ANGED, 2023; World Bank, 2024).

Water scarcity is not a generic backdrop in Tunisia. FAO's AQUASTAT-linked estimates place renewable water availability at about 390 m^3 per capita per year (2020), and national water stress has been reported at around 96% (2019), with agriculture accounting for roughly 80% of withdrawals. Such conditions translate into heightened scrutiny of water-related claims and, at times, policy responses such as drought-related tariff adjustments. In this context, "water saved" becomes an economically salient and contested value proposition, especially for irrigation technologies and water-efficient agri-food supply chains (Food and Agriculture Organization of the United Nations [FAO], n.d.; Reuters, 2024; World Bank, 2023).

Tunisia also illustrates a broader pattern: when public infrastructure for waste segregation, reverse logistics, renewable energy, and quality certification is limited, the "missing middle" between innovation and scale becomes costly. Entrepreneurs must solve not only technical and market problems but also coordination problems typically handled by institutions or established intermediaries. In management literature, such environments are sometimes described as characterized by institutional voids—gaps in product, labor, and capital market institutions that raise transaction costs for firms (Khanna & Palepu, 2010).

At the same time, emerging economies are not merely constrained settings; they can be fertile grounds for frugal, inclusive, and locally embedded sustainability innovations. Circular ventures that valorize organic waste, agro-industrial residues, or underused biomass can connect environmental problem-solving with income generation, local employment, and export positioning. Yet success depends on whether circularity is translated into "buyable value": cost savings, risk reduction, quality, reliability, or reputational benefits that matter to targeted customers and partners.

A key practical observation—often acknowledged in both practice and scholarship—is that circular business models fail rarely because the core idea is environmentally wrong; they fail because the economics of the loop are poorly constructed. Energy, logistics, and quality assurance costs can dominate unit economics in resource recovery, while compliance requirements can delay operations and absorb scarce managerial attention. Consequently, marketing and finance decisions are inseparable from operations and regulatory strategy, especially for ventures that handle waste streams or claim measurable environmental benefits.

We therefore propose that scaling circular ventures requires a capability that sits at the intersection of operations, measurement, and market communication: proof-based green marketing capability (PB-GMC). PB-GMC refers to an organization's ability to (i) define impact-relevant claims that are material for stakeholders; (ii) generate evidence through measurement, traceability, and assurance; and (iii) translate this evidence into credible market signals that reduce perceived risk and facilitate adoption. This conceptualization draws on signaling theory (Spence, 1973) and on the green marketing literature's emphasis on transparency, authenticity, and the avoidance of "false marketing" practices (Peattie & Crane, 2005).

The article addresses three research questions (RQs):

RQ1: How do circular ventures in a water-scarce emerging economy construct the economics of circular loops, and which cost drivers most strongly shape scalability?

RQ2: What forms of "proof" are used to support green marketing claims, and how does proof influence go-to-market choices (e.g., B2B vs. B2C, export vs. domestic)?

RQ3: How do regulatory strategy and investability interact with proof-based marketing in shaping scaling pathways?

To explore these questions, we conduct an exploratory secondary-case corpus analysis of pedagogical case narratives from Tunisia's green entrepreneurship training materials. The aim is theory building about how proof expectations, loop economics, and compliance constraints are framed and linked to scaling pathways, rather than confirmatory testing of venture performance. We complement the corpus with contextual policy sources and light public triangulation for selected ventures.

The article contributes in three ways. First, it develops PB-GMC as a bridging concept connecting circular business model innovation (CBMI) with market adoption under credibility constraints. Second, it provides cross-case insights on how the operational economics of circular loops (energy–logistics–quality) translate into marketing and financing choices in an emerging economy. Third, it highlights regulatory strategy as a design dimension of circular business models, arguing that "designing for compliance" can be reframed from a bureaucratic burden into a strategic asset for B2B contracting and green finance access.

Literature Review and Theoretical Background

This section reviews research streams relevant to the study's objectives and develops an integrative lens. We focus on (i) sustainable or green entrepreneurship; (ii) circular economy and circular business models; (iii) green marketing, credibility, and evidence; and (iv) the role of regulatory and finance ecosystems in emerging economies. We then synthesize these insights into a conceptual framework and a set of propositions guiding the empirical exploration.

Sustainable and Green Entrepreneurship

Sustainable entrepreneurship research examines how entrepreneurial action can reduce environmental degradation and contribute to socio-economic development while remaining economically viable. Seminal contributions frame sustainable entrepreneurship as a response to market failures such as negative externalities, imperfect information, and inefficient resource allocation (Dean & McMullen, 2007; Cohen & Winn, 2007). From this perspective, environmental problems are not only costs imposed on society; they also generate entrepreneurial opportunities for new technologies and business models that internalize externalities or reduce resource intensity.

Definitions and labels vary. Some authors distinguish between "ecopreneurship," "environmental entrepreneurship," and "sustainable entrepreneurship," depending on whether the primary motivation is environmental mission, market opportunity, or a combined triple-bottom-line orientation (Schaltegger & Wagner, 2011). In practice, green ventures often combine environmental intent with pragmatic value propositions such as cost savings, risk reduction, or compliance support for customers. This duality is important because ventures that rely only on altruistic consumer preferences may remain niche, whereas those that embed sustainability into functional performance can scale more broadly (Porter & van der Linde, 1995).

A recurring empirical finding is that sustainable ventures face additional liabilities compared with conventional startups. They may require higher upfront investment (e.g., in cleaner technologies or certifications), operate in markets with uncertain willingness to pay, and depend on complementary infrastructures such as recycling systems, renewable energy, or standards bodies. Moreover, because the benefits of environmental performance can be diffuse and long-term, capturing value requires careful business model design and stakeholder alignment (Bocken, Short, Rana, & Evans, 2014).

Institutional theory adds further insight. Legitimacy and conformity with regulative, normative, and cognitive institutions shape a venture's access to resources and market acceptance (Suchman, 1995). In emerging economies, institutional constraints and "voids" can create both barriers and opportunities (Khanna & Palepu, 2010). For example, limited enforcement of environmental regulation can weaken demand for cleaner solutions, while weak waste management systems can create abundant feedstock for resource recovery ventures—if entrepreneurs can organize collection and quality control.

These observations suggest that sustainable entrepreneurship is not only about inventing greener products. It is also about building socio-technical systems that make greener choices feasible for users and partners. As a result, research increasingly emphasizes business model innovation and ecosystem building as core entrepreneurial tasks (Geissdoerfer, Pieroni, Pigosso, & Soufani, 2020).

Circular Economy and Circular Business Models

The circular economy (CE) is frequently presented as a pathway to combine economic value creation with reduced resource depletion and waste. Although CE is often characterized rather than strictly defined, common elements include the regeneration of natural systems, the preservation of product and material value, and the design of loops that reduce virgin resource inputs and waste outputs (Ellen MacArthur Foundation, 2013; Stahel, 2016). Systematic analyses show that CE definitions vary across academic and policy communities, but most emphasize closing, slowing, and narrowing resource loops (Kirchherr et al., 2017).

Operationalizing CE requires attention to value retention options (VROs). Frameworks such as the "R-ladder" or "10R hierarchy" rank strategies from more desirable (refuse, rethink, reduce) to less desirable (recycle, recover) based on how much embedded value is retained (Reike et al., 2018; Potting, Hekkert, Worrell, & Hanemaaijer, 2017). These hierarchies encourage firms to prioritize inner loops—maintenance, reuse, repair—because they often retain more value and typically require less energy than recycling. However, feasibility constraints (technological, logistical, behavioral, regulatory) can push ventures toward outer loops, particularly in contexts where repair infrastructures or product take-back systems are absent.

Circular business models (CBMs) describe how firms create, deliver, and capture value while enabling circular strategies across stakeholders. CBM research emphasizes that circularity is not achieved by isolated technical fixes; it often requires business model innovation (BMI) such as shifting from product sales to product-as-a-service, establishing take-back schemes, or designing reverse logistics (Geissdoerfer et al., 2020). In this sense, circular business model innovation (CBMI) is both a strategic and an operational transformation that reorganizes activities, partners, revenue logic, and cost structures.

Several typologies and pattern-based approaches support CBM design. Lüdeke-Freund, Gold, and Bocken (2019) identify major CBM patterns including repair and maintenance, reuse and redistribution, refurbishment and remanufacturing, recycling, cascading and repurposing, and organic feedstock models. These patterns can be understood as recurring solutions to the challenge of closing resource flows in different sectors. Complementary visual tools such as the "Value Hill" framework categorize opportunities along the product life cycle—pre-use, in-use, and post-use—helping firms identify where value is created and where it leaks (Circle Economy, 2016).

Importantly, CBM viability depends on the economics of loops. Circular systems often introduce additional costs relative to linear models: collection and sorting, contamination control, testing, storage, and quality assurance. Energy costs can be significant in processes like shredding, drying, or compost aeration, and transport costs can dominate when feedstock is dispersed. Therefore, CBM design is inseparable from operations management, especially in the waste and biomass domains where variability and seasonality are common challenges.

From a strategic perspective, CBMs can create competitive advantage by reducing input costs, securing access to scarce materials, differentiating offerings, or meeting procurement and regulatory requirements. However, because circular value often depends on networks—suppliers of waste streams, municipalities, logistics providers, certification bodies—CBMs are inherently ecosystem-dependent. In emerging economies, building these networks may be both an opportunity for entrepreneurial coordination and a barrier due to limited institutional support.

Green Marketing, Credibility, and the "Proof" Problem

Green marketing broadly refers to marketing activities designed to satisfy human needs and wants with minimal detrimental impact on the natural environment (Dangelico & Vocalelli, 2017). The concept has evolved from early emphases on ecological products toward broader strategic integration involving supply chains, operations, stakeholder engagement, and corporate responsibility. In practice, green marketing includes product and packaging decisions, pricing strategies, distribution choices, and promotional communication, ideally aligned with genuine environmental performance.

A persistent challenge is credibility. Because environmental claims can be difficult for customers to verify, firms may overstate benefits or use vague, non-comparable messages. Such greenwashing can undermine consumer trust and distort competition, penalizing firms that invest in genuine improvements (Delmas & Burbano, 2011). Qualitative analyses of "green marketing" practices highlight a spectrum ranging from substantive, performance-based strategies to symbolic or misleading communication (Peattie & Crane, 2005).

In markets characterized by information asymmetry, credible signals become crucial. Signaling theory suggests that actors can reduce uncertainty by investing in signals that are costly to fake and therefore convey information about underlying quality (Spence, 1973). For green offerings, signals may include third-party certifications, audited performance data, transparent supply chain documentation, or verified life cycle assessments. These signals can be particularly valuable in B2B contexts where procurement teams and corporate sustainability functions require documentation for compliance and reporting.

We define "proof" as decision-useful evidence that a green claim is materially true for a stakeholder. Proof can take multiple forms:
(1) Measurement proof: quantified indicators such as kilograms of waste diverted, cubic meters of water saved, or CO2 emissions avoided, ideally based on transparent methods;
(2) Process proof: documented operational procedures, traceability systems, quality control protocols, and audit trails;
(3) Third-party proof: certifications, labels, expert endorsements, or verified reports;
(4) Experiential proof: demonstrations, trials, and observable outcomes in pilots.
These categories align with the broader marketing literature's emphasis on transparency and with sustainability measurement approaches that link operational data to stakeholder communication (GRI, 2021).

Proof is not merely a communication tool; it is a capability that shapes business model choices. For instance, a venture offering compost to farmers may need field trials and agronomic evidence to justify product performance and differentiate from low-quality alternatives. A service provider handling waste for hotels may need traceability and reporting to support clients' ESG disclosures. An agritech venture selling irrigation optimization may need baseline and post-intervention data to demonstrate water savings and return on investment. In each case, proof is co-produced by operations, measurement, and customer engagement.

This insight motivates a shift from "green marketing as promotion" to "green marketing as evidence management." Such a shift can help ventures avoid the pitfalls of overclaiming while building trust-based relationships that support long-term adoption. It also suggests that incubators and support programs should treat measurement, documentation, and proof generation as core entrepreneurial skills rather than peripheral reporting tasks.

2.3.1. Construct Boundaries and Microfoundations of PB-GMC

PB-GMC is conceptually adjacent to green marketing capabilities, sustainability communication, and ESG reporting. We define it as a market-facing dynamic capability that (i) designs segment-relevant green claims and (ii) manages the generation, validation, and translation of evidence into credible signals (e.g., dashboards, technical sheets, certifications) to reduce information asymmetry and greenwashing risk. Construct boundaries and indicative measurement implications are elaborated in Section 5.1.1.

Regulation, Compliance, and Sustainable Finance as Scaling Drivers

In many sustainability markets, demand is shaped not only by consumer preferences but also by regulation, procurement rules, and financing criteria. For circular ventures that handle waste streams, regulatory requirements regarding permits, environmental impact assessments, emissions or effluents, and occupational safety can strongly influence time-to-market and cost structure. Although compliance is often experienced as a burden by early-stage ventures, it can also function as a competitive barrier that protects serious operators from opportunistic entrants, particularly when enforcement is credible.

Compliance also interacts with market segmentation. In B2B markets, customers such as hotels, exporters, or industrial firms may face reputational risks and reporting obligations that increase their willingness to pay for solutions that reduce compliance costs or document sustainability performance. In such segments, the value proposition may be less about "being green" and more about operational continuity, risk avoidance, and measurable performance. Therefore, the ability to deliver credible documentation can itself be a form of customer value.

Sustainable finance amplifies these dynamics. Banks, impact investors, and public programs increasingly require ESG indicators and evidence of environmental performance as part of due diligence. Sustainability reporting standards such as those promoted by the GRI aim to make performance comparable and decision-useful (GRI, 2021). At the venture level, simplified ESG indicator sets can support investment readiness by demonstrating that impact claims are measurable and aligned with a coherent operational plan.

For Tunisia, policy documents and programs have increasingly emphasized sustainable consumption and production, circular economy approaches, and sectoral priorities such as tourism and agri-food (UNEP, 2023). Circular economy initiatives involving the national waste management agency and international partners highlight eco-design, recycling, reuse, and job creation as strategic priorities (GIZ & ANGED, 2023). At the same time, climate and development analyses underline that water shortages and climate risks pose macroeconomic constraints, reinforcing the relevance of water-saving technologies and resilient resource management (World Bank, 2023).

The implication for entrepreneurs is that scaling strategies must be aligned with both market and institutional signals. A venture that can demonstrate measurable waste diversion or water savings, maintain traceability, and comply with relevant rules is more likely to access B2B contracts and blended finance. Conversely, ventures that treat compliance and proof as afterthoughts may face delays, skepticism, and high cost of capital.

Conceptual Synthesis and Propositions

The preceding review suggests a need to integrate CBM design, green marketing credibility, and institutional constraints into a single analytical frame. We propose that circular venture scaling depends on the co-evolution of three design domains: (i) circular operations and loop economics; (ii) proof-based green marketing capability; and (iii) regulatory and finance alignment. These domains interact dynamically over time as ventures learn from pilots, adjust cost structures, and build legitimacy.

Figure 1 presents the conceptual framework. Circular operations generate environmental and economic performance, but these outcomes are not automatically perceived or trusted by stakeholders. PB-GMC is proposed to mediate the relationship by converting operational performance into credible signals—through measurement, traceability, third-party validation, and experiential demonstrations—that reduce information asymmetry and enable adoption. Regulatory and finance alignment moderates this process: when compliance pressures and financing criteria are strong, proof becomes more valuable and can accelerate scaling; when enforcement is weak or finance is scarce, ventures may need different strategies (e.g., export or niche community markets).

We articulate five propositions to guide the empirical exploration:

P1 (Loop Economics): In circular ventures based on waste or biomass valorization, energy, logistics, and quality assurance will dominate unit economics and strongly shape scalability.

P2 (Proof as Market Asset): Ventures that develop stronger PB-GMC will secure more stable B2B contracts and/or access to sustainable finance compared with ventures relying mainly on narrative claims.

P3 (Compliance-by-Design): Regulatory strategy implemented early (permits, documentation, standards) increases investability and reduces time-to-scale, even if it raises short-term costs.

P4 (Segment Fit): The value of proof is highest in segments with high compliance pressure or high willingness to pay for sustainability attributes (e.g., hotels, exporters, corporate buyers).

P5 (Capability Coupling): PB-GMC is most effective when coupled to operational routines (measurement embedded in processes) rather than treated as a standalone communication

function.
The remainder of the article explains the methodological approach used to explore these propositions, presents cross-case results, and discusses implications for research and practice.

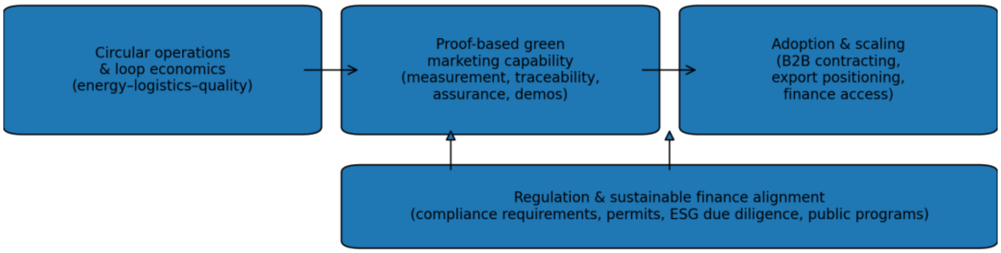

Figure 1. Conceptual framework linking circular operations, proof-based green marketing capability, and scaling pathways.

Materials and Methods

Given the theory-building aim of the research questions and the secondary, pedagogy-oriented nature of the empirical material, we adopt an exploratory qualitative design based on corpus analysis of pedagogical case narratives. This design is well suited to examine how proof requirements, loop economics, compliance constraints, and scaling pathways are articulated in applied entrepreneurship training, and to develop propositions about PB-GMC in water-scarce emerging economies (Eisenhardt, 1989; Yin, 2018).

Case Selection and Context

We used theoretical sampling to select cases that (i) represent diverse circular strategies and business model patterns; (ii) operate in sectors that are salient to Tunisian sustainability challenges (water, waste, agriculture, tourism, and energy); and (iii) explicitly articulate environmental value propositions that require credibility to succeed. The resulting set includes eight ventures that illustrate different combinations of circular value creation, market orientation, and regulatory exposure.

The cases are summarized in Table 1. They include: (1) Namma Compost (Tataouine), a composting venture affected by energy access and administrative procedures; (2) VIVERT (Medenine), an integrated organic waste-to-black soldier fly system producing biofertilizer with regulatory uncertainty around protein production; (3) ECO DEC Djerba (Medenine/Djerba), a service-based waste management model for hotels combining operations with a digital application for traceability and reporting; (4) Smart Farm (Tunis), a precision irrigation and soil-moisture sensing solution with a hardware-plus-subscription model; (5) BIOHEAT (Manouba), biomass briquettes from olive pomace facing price competition but pursuing export and decarbonization-oriented B2B segments; (6) Palmier Decor (Tozeur), circular design using palm wood with ambitions for export; (7) Wood & Rope (Kairouan), agro-residue-based design products constrained by domestic market size; and (8) BioWay by Racha, a natural cosmetics venture using refillable packaging to reduce waste but constrained by local packaging and certification availability.

This diversity enables cross-case comparison and replication logic: similar mechanisms are expected to appear across different sectors (e.g., proof needs in B2B), while differences help identify boundary conditions (e.g., regulatory exposure in waste handling).

Table 1. Overview of cases and salient proof needs (summary based on case narratives and contextual sources).

Case	Circular offer & target customers	Revenue model	Proof focus
Namma Compost	Composting of organic waste; compost sold to farmers/households	Compost product sales (B2B/B2C)	Waste diverted; process controls; product quality evidence
VIVERT	Organic waste → black soldier fly → biofertilizer (phase 1); protein (future)	Biofertilizer sales; phased expansion	Traceability; safety/hygiene documentation; pilot performance
ECO DEC Djerba	Turnkey hotel waste service + valorization with digital reporting	Recurring service contracts + valorization outputs	App-based traceability; client ESG reporting dashboards
Smart Farm	Precision irrigation and soil-moisture sensing for water/energy efficiency	Device sale + subscription	Measured water savings; pilot plots; ROI evidence
BIOHEAT	Olive pomace briquettes as alternative fuel for industrial users and exports	Fuel product sales; export channels	Performance specs; reliability; emissions-reduction justification
Palmier Decor	Upcycled palm wood products (design/decoration) for tourism and export	Product sales; B2B orders; export potential	Material traceability; quality/durability evidence
Wood & Rope	Upcycled agro-residue design products; pivot to B2B/export	Product sales; partnerships	References; traceability; quality consistency
BioWay by Racha	Natural cosmetics with refillable packaging to reduce waste	B2C product sales	Ingredient transparency; packaging system proof

Data Sources

The primary empirical material comprises a corpus of pedagogical case narratives developed for applied green entrepreneurship training in Tunisia (Ouvrage Entrepreneuriat Vert program; unpublished training manual and associated slide decks). The vignettes are written in a didactic style and are intended to surface practical constraints around unit economics, proof, compliance, and scaling, making them a suitable corpus for analyzing proof expectations and legitimacy signals in an emerging-economy setting.

We accessed the consolidated training manual and the accompanying modules and treated them as a bounded textual corpus of secondary case material. For the present study, we focused on the eight case vignettes summarized in Table 1 and the adjacent instructional passages that explicitly discuss proof systems, measurement, traceability, and scaling decisions. Importantly, the training materials do not provide standardized metadata about the original primary data generation process for each vignette (e.g., interview protocols, observation periods, or dates). We therefore analyze the corpus as a representation of how proof and scaling are framed for entrepreneurship support, not as a verified record of venture performance.

We segmented the corpus into paragraph-level text units to enable consistent coding and cross-case comparison. The resulting dataset contains 143 paragraph-level units that reference circular value creation (biological or technical loops), loop economics (cost and risk drivers), proof mechanisms (measurement, process, third-party, and experiential proof), regulatory exposure, and scaling pathways.

Case and excerpt inclusion followed theoretical sampling. We retained passages that (i) describe circular value-creation logic (biological or technical loops), (ii) specify or imply proof requirements (e.g., pilots, dashboards, traceability, certification), and/or (iii) articulate scaling constraints and pathways. Generic instructional text not linked to proof or scaling decisions was excluded.

To contextualize the cases within national sustainability and circular-economy priorities, we supplemented the corpus with publicly available policy and program documents on circular economy and water/resource management in Tunisia (e.g., World Bank, 2024; World Bank, 2023). These contextual sources are used to ground the macro-level setting (e.g., water stress, waste governance), not to verify venture-level claims.

Light Triangulation with Public Venture Documents

To mitigate the main limitation of pedagogical secondary data—limited verifiability—we conducted a light triangulation exercise for a subset of cases. Specifically, we reviewed publicly available venture documents (e.g., official websites, public case notes, and media reports) to confirm basic descriptive elements (venture existence, product/service category, and stated proof artefacts) and to enrich the description of proof signals (e.g., dashboards, technical sheets, export positioning). For example, publicly available information documents Smart Farm's IoT-based soil-moisture sensing and dashboarding solutions for irrigation decision support (Smart Farm, n.d.), and Bioheat's olive-waste briquette technology and export-oriented scaling narrative (IDEASSonline, 2025). These sources were used conservatively to support context and illustrate proof artefacts; they do not substitute for primary verification of operational performance.

The triangulation is intentionally minimal and selective. Its purpose is to strengthen construct credibility (what counts as "proof" in practice) rather than to validate impact outcomes. We transparently indicate when an example is drawn from public sources versus the training corpus.

Analytical Procedure

We conducted a structured qualitative content analysis in three stages. First, we developed within-case summaries for each vignette, focusing on (a) the circular strategy and value retention logic, (b) dominant loop-economics drivers, (c) explicit or implied proof requirements, and (d) compliance and scaling considerations. Second, we coded paragraph-level units using a structured codebook to enable cross-case comparison. Third, we conducted cross-case pattern matching to identify recurring configurations linking economics, proof, and scaling pathways, and to refine propositions (Eisenhardt, 1989; Yin, 2018).

To increase transparency and reduce interpretive drift, we used a pre-specified coding template and iteratively refined code definitions through constant comparison across cases. We then consolidated coded outputs into a cross-case matrix (Table 3) and an explicit audit trail of paraphrased excerpts (Appendix A / Table A1), enabling readers to trace how textual evidence supports higher-level patterns and propositions.

Given the secondary and pedagogy-oriented nature of the corpus, we calibrated the level of inference in reporting. For each major finding, we distinguish between what the corpus directly states (observed framing in the training material) and what we infer as a plausible mechanism or proposition. To strengthen coding dependability, we implemented a two-pass verification step for the proof-mechanism labels: an initial interpretive assignment of M/P/TP/E categories followed by a rule-based keyword checklist derived from the codebook (e.g., measurement terms, certification markers, traceability artefacts). Discrepancies triggered a return to the excerpt and code definitions. This approach complements the detailed codebook and audit trail as a reproducible transparency mechanism.

Coding Scheme

Table 2. Coding scheme used for within-case and cross-case analysis.

Code family	**Operational definition**	**Illustrative indicators / examples**
Circular strategy (10R)	Primary value retention option(s) emphasized	Repair/reuse; recycling; resource recovery; cascading use
CBM pattern	Recurring business model pattern enabling circularity	Service + valorization; product-as-a-service; upcycling design
Loop economics drivers	Dominant cost and risk drivers shaping unit economics	Energy, logistics, quality assurance, seasonality
Target segment	Primary market orientation and customer type	Hotels (B2B); farmers (B2B); consumers (B2C); exporters
Proof mechanisms	Evidence used to support environmental/performance claims	Dashboards; traceability app; certifications; field trials
Compliance exposure	Degree to which permits/standards constrain operations	Waste handling authorizations; product safety standards
Scaling pathway	Primary growth route articulated or implied	B2B contracting; export; partnerships; franchising/replication

Research Limitations and Ethics

The study has four main limitations. First, the primary empirical material consists of pedagogical vignettes and instructional passages rather than raw primary fieldwork. As such, the corpus may reflect didactic framing, selective emphasis (including potential "success story" bias), and simplification of operational realities. We therefore interpret findings as patterns in proof expectations and scaling constraints as articulated in entrepreneurship support discourse, and we avoid strong causal claims. Second, the vignettes do not provide standardized metadata about original data collection, limiting the ability to verify venture-level assertions. Our light triangulation partially mitigates this concern for a subset of cases, but does not constitute full verification. Third, the sample is limited to eight cases from one national context, so patterns may differ in other institutional settings or sectors. Fourth, the analysis is qualitative and theory-building; propositions require confirmatory testing with primary data, longitudinal designs, and independent measurement of PB-GMC.

Regarding ethics, the study uses educational case material and public contextual sources. No personally sensitive data are analyzed, and the purpose is to extract generalized learning insights rather than evaluate individual ventures.

Results

This section presents cross-case patterns organized around the research questions. Because the empirical material consists of pedagogical case narratives, the "results" describe recurring framings and decision rules articulated in the corpus (what the text shows). Where we propose mechanisms (e.g., proof may facilitate adoption or finance), we treat them as theory-building inferences and propositions rather than causal estimates. We support transparency by summarizing case-level patterns in a cross-case matrix (Table 3) and by providing paraphrased evidence excerpts as an audit trail (Appendix A / Table A1).

Loop Economics: Energy, Logistics, and Quality as Dominant Drivers

Across the waste and biomass cases (Namma Compost, VIVERT, ECO DEC Djerba, BIOHEAT), three cost drivers repeatedly emerge as “system constraints”: energy, logistics, and quality assurance. These drivers shape not only unit economics but also feasible customer segments and the timing of investment decisions, supporting Proposition P1.

Energy costs appear as a binding constraint in composting and organic waste processing. Although composting is often perceived as low-tech, operational reality includes shredding, screening, turning, pumping, and internal transport—all of which may require electricity or fuel. In Namma Compost, reliance on generator-based electricity is associated with weak profitability, suggesting that the business model’s viability depends on designing an energy scenario (e.g., grid connection, solar, process optimization) rather than assuming “free” biological processing. Similarly, ECO DEC Djerba’s service model for hotels includes energy-intensive equipment and motivates consideration of solar investment or other energy solutions as part of the business model rather than as a later add-on.

Logistics costs and coordination challenges are central because circular ventures must move low-density materials (organic waste, biomass residues) from dispersed sources to processing sites. The economics depend on stable volumes and predictable collection routes; otherwise, transport costs erode margins. ECO DEC Djerba addresses this by bundling collection, on-site stations, and operations into a turnkey service for hotels, effectively monetizing logistics and compliance support through recurring contracts rather than relying only on compost product sales.

Quality assurance is a persistent challenge across compost, biofertilizer, and circular product cases. For organic inputs, variability and contamination risk require sorting and process control; for insect-based systems, feedstock quality affects safety and regulatory acceptability. In VIVERT, specialized equipment (e.g., screening) and traceability are highlighted as necessary to ensure quality and to document compliance, while uncertainty around protein regulation pushes the venture toward a phased strategy focusing first on biofertilizer markets.

In BIOHEAT, quality is tied to product performance and reliability. Biomass briquettes compete with low-cost conventional fuels, so differentiation depends on consistent calorific performance, stable supply, and credible environmental claims. Because customers are sensitive to price, especially in domestic markets, BIOHEAT’s scaling logic points toward segments that value decarbonization and reliability (e.g., corporate buyers or export channels) rather than purely price-driven consumers.

Taken together, these observations suggest that circularity-by-design requires explicit modeling of system costs. Ventures that treat the circular process as a standalone “green idea” risk underestimating the infrastructure-like nature of circular loops. Conversely, ventures that treat energy, logistics, and quality as design variables can convert constraints into differentiated value propositions (e.g., “we handle everything and provide reporting”).

Proof Mechanisms as a Marketable Asset

Proof mechanisms are not uniformly distributed across cases; they align with stakeholder demands and business model orientation. B2B-oriented ventures systematically emphasize measurement and process proof because customers and financiers require documentation. This supports Proposition P2 and illustrates the role of PB-GMC in reducing adoption barriers.

ECO DEC Djerba provides a clear illustration. The venture’s digital application is described as an instrument for traceability and reporting to hotels. This transforms waste handling from an operational back-office function into a compliance and reputation service. In B2B tourism markets, hotels face increasing pressure to demonstrate responsible practices to tour operators, platforms, and customers, so quantified reporting can be converted into contractual value. In signaling terms, the application and its indicators function as costly-to-fake signals because they require operational measurement routines (Spence, 1973).

Smart Farm illustrates proof in a technology adoption context. The venture's sensor-plus-subscription model depends on demonstrating that irrigation advice generates measurable water savings, energy savings (via reduced pumping), and yield improvements. Because customers may be reluctant to pay for unfamiliar technology, pilot plots and demonstrator projects become a form of experiential proof. In addition, quantified savings data can support B2B distributor partnerships in regional markets where buyers want evidence of return on investment.

In Namma Compost and VIVERT, proof relates to product performance and safety. Compost quality and agronomic benefits are often questioned in markets where informal producers exist. Measurement proof (tons diverted, compost output) can support environmental claims, but market adoption may hinge on performance proof such as field trials and quality certification. For VIVERT, traceability and hygiene are also essential for navigating regulatory uncertainty; documentation can demonstrate that the venture is operating responsibly even when the regulatory framework is evolving.

Circular design ventures (Palmier Decor; Wood & Rope) emphasize a different proof profile: traceability of materials and quality consistency. Here, "storytelling" about agro-residue use is important for differentiation, especially in export or tourism-linked markets, but it becomes credible only when supported by evidence of material origin, production quality, and durability. This suggests that PB-GMC is not limited to environmental metrics; it includes the documentation that links product identity to circular sourcing and processes.

Across cases, the most robust proof strategies appear to combine at least two categories: (i) measurable indicators and (ii) process/traceability evidence. Third-party proof (certification) is desired but often constrained by cost and institutional access, especially for small ventures. This aligns with green marketing scholarship: authenticity and transparency are necessary but not sufficient; stakeholders seek evidence that can be compared and verified (Dangelico & Vocalelli, 2017; Delmas & Burbano, 2011).

Market Segmentation: Selling Sustainability as Cost Saving and Risk Avoidance

A recurring pattern is that successful scaling narratives emphasize functional value: savings, reliability, and risk reduction. This pattern reflects the limits of "green premiums" in price-sensitive markets and supports Proposition P4.

In composting cases, price sensitivity is high because compost competes with low-cost alternatives and because the benefits of improved soil health are sometimes long-term or uncertain for farmers. Therefore, marketing claims that emphasize only environmental benefits may be insufficient. More compelling value propositions link compost use to tangible outcomes such as reduced fertilizer costs, improved water retention, or yield stability, supported by field evidence. Such positioning reduces reliance on moral motivation and aligns with the sustainable entrepreneurship view that innovations must be both environmentally and economically compelling (Dean & McMullen, 2007).

ECO DEC Djerba explicitly frames its value as "peace of mind" for hotels: a turnkey service that manages waste, reduces regulatory and reputational risk, and provides documentation. This reframing is important because it monetizes sustainability through avoided costs and institutional pressures rather than consumer willingness to pay per se.

BIOHEAT's case similarly underscores that circularity alone does not guarantee market success.

Briquettes face competition from cheaper fuels, so the venture needs either cost leadership through scale or a value-based strategy targeting buyers who monetize decarbonization. These buyers may include export markets with stronger environmental preferences or corporate customers integrating emissions reduction into procurement and reporting. The implication is that segmentation should consider not only "green attitudes" but also the economic and institutional incentives of buyers.

Smart Farm's model illustrates segmentation based on productivity and resource efficiency. Farmers and agribusinesses that face water constraints or pumping energy costs may value irrigation optimization as a direct financial lever. However, adoption depends on trust in data and on the perceived reliability of service and hardware—again highlighting the role of proof and after-sales support as part of the value proposition.

Pricing and Revenue Logic: From Product Sales to Service and Subscription

Revenue models differ systematically by sector and by the nature of the circular loop. Waste service models (ECO DEC Djerba) and agritech (Smart Farm) emphasize recurring revenue—service fees, subscriptions, or long-term contracts—while product-based models (compost, briquettes, design goods) rely more on sales volumes. These differences matter because recurring revenue can stabilize cash flows and support financing for capital expenditures, while product sales models may face volatility and price pressure.

ECO DEC Djerba illustrates how service logic can internalize circular loop costs. By charging for installation, operation, and reporting, the venture aligns revenue with the true cost drivers of circularity (energy, logistics, compliance) and creates incentives to optimize the system over time. This resembles CBM patterns that integrate service and resource recovery, where value is captured through performance and management rather than through commoditized outputs (Lüdeke-Freund et al., 2019).

Smart Farm's subscription model aligns with digital-service economics: the device enables data collection, and the recurring fee supports software updates, advisory services, and potentially customer success functions. However, the model also faces supply chain risk due to dependence on external manufacturers. This risk influences both pricing (need to cover hardware costs and warranty) and scaling (need for multi-sourcing or eventual local production).

For product-based circular ventures, pricing strategies often need to translate sustainability into justification rather than into a simple premium. Three logics recur across cases: (i) pricing by use value (how much the customer saves in inputs, time, or energy); (ii) pricing by risk avoided (compliance, reputation, supply continuity); and (iii) tiered offers combining accessible entry products with premium services (e.g., delivery, guarantees, traceability). These logics align with green marketing recommendations emphasizing that "green" must be explained in terms that matter to customers and backed by proof (Dangelico & Vocalelli, 2017).

Distribution and Partnerships: The Hidden Constraint

Distribution emerges as a hidden scaling constraint, particularly outside major urban centers. Circular ventures often require both forward and reverse logistics: selling products and securing feedstock or take-back streams. Where distribution infrastructures are weak, partnerships become essential for reducing transaction costs and ensuring stability.

B2B key-account strategies appear robust in several cases. ECO DEC Djerba targets hotels as relatively solvent customers with strong pain points, enabling contract-based revenue. Palmier Decor and Wood & Rope also recognize the importance of B2B channels such as hotels, guesthouses, or corporate gifts, which can stabilize volumes and support quality investments before broader export expansion. Such strategies align with the idea that circular ventures can scale by embedding themselves in organizational procurement routines rather than relying only on fragmented consumer demand.

Intermediated distribution is also prominent. Smart Farm's expansion logic highlights the role of regional distributors in the MENA region and West Africa, suggesting that channel partners can lower customer acquisition costs and provide local legitimacy. However, reliance on intermediaries requires careful governance to preserve service quality and ensure that proof-based claims are consistently supported in local deployment.

For product-based circular design ventures, export distribution requires additional discipline: packaging, catalog development, logistics coordination, and quality standards. Because "circular stories" may attract international buyers, the credibility of material origin and production practices becomes more important, again linking distribution to proof generation.

Compliance-by-Design: Regulation as a Strategic Parameter

Regulatory and administrative factors appear in multiple cases as determinants of feasibility and financing. Namma Compost explicitly highlights administrative procedures and site authorization as constraints that influence investment decisions. In VIVERT, uncertainty around protein production regulation shapes the venture's strategic roadmap, supporting a phased approach that focuses first on allowed markets and prepares documentation for future expansion. These cases illustrate "compliance-by-design": incorporating regulatory requirements and documentation needs at the business model design stage rather than treating them as ex post hurdles. Compliance-by-design can reduce the risk of operational shutdowns, improve customer trust (especially in B2B), and enhance investability by reducing regulatory uncertainty. This aligns with institutional theory's emphasis on legitimacy as a resource for firms and with the finance literature's focus on risk assessment in due diligence (Suchman, 1995).

In ECO DEC Djerba, compliance becomes part of the service value proposition. If waste handling and effluent management requirements are properly met, the venture can differentiate by offering clients a compliant solution along with reporting. This suggests that regulation can create market opportunities for ventures that can navigate and operationalize compliance more effectively than competitors.

Overall, the cases support Proposition P3: early regulatory strategy and documentation can increase investability and reduce scaling friction. However, compliance also requires capability building and may involve costs for permits, audits, or technical upgrades. The viability of compliance-by-design therefore depends on whether the venture's target segment values compliance and is willing to pay for it.

Cross-Case Configurations and Refined Propositions

Cross-case comparison suggests three recurring configurations linking circular design, proof, and scaling.

Table 3 summarizes the eight cases across market orientation, regulatory exposure, dominant circular loop economics, proof mechanisms, and intended scaling pathways.

Case	**Market orientation**	**Regulatory exposure**	**Dominant bottleneck**	**Proof mechanisms (M/P/TP/E)**	**Scaling pathway**	10R / VRO focus	CBM pattern
Namma Compost	B2B/B2C; domestic	Medium	Energy & feedstock logistics	M; P; E	Local contracts & feedstock partnerships; replication	Recycle/Recover (nutrient recovery)	Resource recovery (organic waste-to-compost)

VIVERT	B2B; domestic	High	Quality & compliance (hygiene/traceability); CAPEX	P; TP; E; M	Phased scaling (fertilizer first); regulatory-ready expansion	Recycle/Recover (bioconversion)	Resource recovery (insect-based biofertilizer)
ECO DEC Djerba	B2B; domestic (hotels)	High	Energy-intensive operations & collection logistics	P; M; TP	Recurring service contracts; site replication; finance enabled by dashboards	Recycle/Recover (bio-waste diversion)	Service + valorization (tourism waste management)
Smart Farm	B2B; domestic + regional export	Medium	Adoption & hardware reliability; distribution	M; E; P	Pilot-led diffusion; distributor network; subscription scaling	Reduce (water efficiency)	Product–service system (IoT irrigation decision support)
BIOHEAT	B2B/B2C; domestic + export	Medium	Price competition & quality consistency	M; P; TP	Export channels; B2B decarbonization segments; performance-based positioning	Repurpose/Recover (bioenergy)	Resource recovery (agro-residue to fuel briquettes)
Palmier Decor	B2B/B2C; domestic + export	Low–Medium	Quality & finishing; export logistics	P; TP	B2B hotel furnishing + export positioning; trade support	Repurpose/Reuse (upcycling)	Upcycling design (palm wood products)
Wood & Rope	B2C → B2B pivot; domestic + export	Low	Small domestic market & quality standardization	P; E	Partnership distribution; standardized product lines; export exploration	Repurpose/Reuse (upcycling)	Upcycling design with B2B pivot
BioWay by Racha	B2C; domestic + export aspirations	Medium	Certification & packaging supply constraints	P; TP; M	Trust-building domestically; certification pathway; packaging ecosystem partnerships	Reuse/Reduce (refill packaging)	Reusable packaging + refill (circular supplies)

Table 3. Cross-case matrix mapping each case to circular strategy (10R/VRO), CBM pattern, market orientation, regulatory exposure, dominant bottleneck, proof mechanisms (M/P/TP/E), and scaling pathway (synthesis based on training case vignettes and coding).

Configuration A: "Service + Proof + Compliance" (ECO DEC Djerba). Here, circularity is delivered as an ongoing B2B service rather than as a standalone product. Value creation depends on managing an end-to-end collection–sorting–valorization chain, where unit economics are shaped by energy-intensive processing and route logistics. Proof is not an add-on communication layer; it is embedded in service design through traceability and reporting routines. In the ECO DEC vignette, a digital application is explicitly framed as the proof infrastructure, documenting diverted volumes and valorization outputs in a client-facing format that supports hotels' ESG reporting and compliance narratives. Accordingly, scaling is closely tied to compliance-by-design (permits, procedures, auditability) and to the ability to finance energy investments that stabilize service delivery and costs.

Empirical trace (paraphrased from the training vignettes): ECO DEC is described as designing the service as an integrated package—installation + operations + proof (reporting), with the application generating client-ready indicators; energy costs are highlighted as a scaling constraint motivating investments such as solar panels or methanization units.

Configuration B: "Tech Efficiency + Demonstration Proof" (Smart Farm). This configuration captures circular offerings where environmental value is created through measurable resource-efficiency improvements, and adoption hinges on evidence that is locally credible to risk-averse buyers. Smart Farm combines a soil-moisture sensor with software and a subscription logic, but the case narratives emphasize that the adoption barrier is not purely technological: ventures must build a proof pathway through pilot plots, simple user experience, and distribution partners. In this configuration, measurement proof (e.g., water saved) and experiential proof (observable results in pilots) become central marketing and finance enablers, because early funding is described as "traction-driven" and contingent on demonstrators, contracts or LOIs, and a defensible unit economics story.

Empirical trace (paraphrased): Smart Farm's case emphasizes that proof must be designed upfront through demonstration plots and simple dashboards, with suggested ESG indicators including m^3 of water saved and energy avoided through reduced pumping; scaling is linked to distributor partnerships and demonstrator results that can support financing conversations.

Configuration C: "Product Circularity + Market Discipline" (BIOHEAT; Palmier Decor; Wood & Rope; BioWay). In product-based ventures, circularity is monetized through goods whose adoption is disciplined by price competition, quality expectations, and (often) export requirements. The case vignettes repeatedly stress that circular attributes alone are insufficient: ventures must prove performance and consistency (e.g., calorific value and reliability for BIOHEAT), demonstrate material traceability and quality assurance to access B2B/hospitality and export markets (Palmier Decor; Wood & Rope), and translate circular design choices into visible, credible signals (e.g., refillable packaging as a tangible proof element for BioWay). Scaling pathways therefore rely on quality systems, standards/certifications where relevant, and channel partnerships that can carry the proof story across markets.

Empirical trace (paraphrased): BIOHEAT's case contrasts a volume/low-cost route with an export/value route where buyers demand performance evidence; Palmier Decor and Wood & Rope are framed as export-aspiring design ventures for which financing and market access depend on disciplined quality and material traceability; BioWay's refillable packaging is presented as a visible proof device, while certification and packaging availability are identified as ecosystem bottlenecks.

Based on these configurations and the cross-case matrix (Table 3), we refine the propositions as follows:

RP1: In waste-based circular ventures delivered as services (Configuration A), scaling feasibility increases when proof is embedded in routine operations (traceability and reporting) and when compliance-by-design reduces buyer and financier risk, while unit economics are stabilized through the reduction of loop system costs (energy, logistics, quality).

RP2: In resource-efficiency technologies (Configuration B), adoption and finance access depend on place-based demonstration and measurement proof that is credible under local resource constraints—especially in water-scarce settings—so pilots, baseline metrics, and auditable data trails become central elements of PB-GMC.

RP3: In product-based circular ventures (Configuration C), scaling hinges on converting circular attributes into market discipline through consistent quality, standards/certifications where relevant, and channel partnerships, so that proof operates both as a qualification device in B2B/export markets and as a trust device in B2C.

These refined propositions set the stage for a closer examination of water scarcity as a boundary condition (Section 4.8) and for the subsequent discussion, which connects the findings to existing theory and derives managerial and policy implications.

Water Scarcity as a Proof Amplifier: Evidence Demands and Adoption Trade-Offs

Although energy, logistics, and quality dominate circular loop economics across cases, water scarcity is not merely a background condition in Tunisia. Renewable water availability is low (≈390 m^3/capita/year in 2020) and water stress has been reported at very high levels (≈96% in 2019), with irrigation accounting for the majority of withdrawals (FAO, n.d.). Such conditions make water a high-stakes resource for households, farms, and tourism facilities, and they increase scrutiny of any claim framed as "water saving" or "water resilience," including through price and rationing signals (Reuters, 2024; World Bank, 2023). In this setting, water scarcity amplifies the demand for proof and reshapes adoption trade-offs.

First, water scarcity elevates the importance of measurement proof (M). In the Smart Farm vignette, the value proposition hinges on quantifying "water saved" in operational terms (e.g., irrigation dose optimization, avoided overwatering) and translating these metrics into decision-useful outputs for farmers and partners. Public venture documentation mirrors this proof logic by emphasizing soil-water-status sensing and dashboards/reports for irrigation decision support (Smart Farm, n.d.). In a water-stressed context, such metrics are more likely to be requested by professional buyers (e.g., corporate farms) and by finance partners seeking resource-efficiency evidence.

Second, water scarcity raises adoption barriers when users perceive uncertainty about performance under variability (drought, salinity, uneven water access). The corpus repeatedly frames pilots and experiential proof (E) as necessary to overcome skepticism, particularly when technologies require behavior change (e.g., irrigation scheduling) or recurring payments (subscriptions). This suggests that, in water-scarce settings, "proof" often must be produced locally (field trials, pilot plots) to be trusted.

Third, water stress makes water–energy trade-offs explicit. Water-saving solutions may require energy for pumping, monitoring, connectivity, or on-site processing; conversely, energy constraints can limit the feasibility of water-efficiency interventions. The cases therefore imply that proof should be multi-resource: ventures are pressured to demonstrate not only water impacts, but also the energy and cost implications of achieving them (e.g., kWh per m^3 saved, cost per hectare). This reinforces the need for PB-GMC to integrate operations, measurement, and commercial signals.

Finally, the corpus suggests that water scarcity can change how circular products are positioned. Compost and organic amendments are framed not only as waste-derived products, but also as soil-regeneration assets that can improve moisture retention and resilience—claims that may face heightened proof requirements in drought-prone agriculture. Similarly, waste-management services in tourism areas are framed as protecting local ecosystems and water quality, increasing the perceived value of traceability and compliance proof in B2B contracting.

Taken together, these mechanisms suggest a boundary condition: in water-scarce emerging economies, the proof–adoption–scaling relationship is strengthened for ventures whose PB-GMC explicitly operationalizes water-relevant KPIs, pilots, and auditability. Future primary research can test whether water scarcity systematically shifts the mix of proof mechanisms (toward measurement and third-party assurance) and raises the minimum proof threshold required for adoption and financing.

Discussion

The findings highlight that scaling circular ventures in water-scarce emerging economies is as much a credibility and system-design challenge as it is a technical innovation challenge. This section interprets the results in relation to prior literature, articulates theoretical implications, and outlines practical recommendations for entrepreneurs, ecosystem actors, and policymakers.

Theoretical Implications: PB-GMC as a Bridge between CBMI and Adoption

First, the study suggests that proof-based green marketing capability (PB-GMC) can be conceptualized as a bridging mechanism between circular business model innovation and market adoption. CBMI literature emphasizes redesigning value creation and capture to enable circular strategies (Geissdoerfer et al., 2020; Lüdeke-Freund et al., 2019). Green marketing literature, in turn, emphasizes transparency and credible claims to avoid greenwashing and build trust (Delmas & Burbano, 2011; Dangelico & Vocalelli, 2017). Our cases show that these streams converge operationally: without embedded measurement, traceability, and documentation, circular models may remain untrusted and therefore unscalable.

Construct Boundaries and Measurement Implications

Construct boundaries. PB-GMC is not simply "green communication" or a pro-environmental marketing orientation. It refers to an organizational capability to design specific environmental claims, generate and curate verifiable evidence, and translate that evidence into stakeholder-relevant signals that reduce perceived risk. Accordingly, PB-GMC differs from (i) generic sustainability communication (which can remain symbolic), (ii) organization-level sustainability reporting/ESG disclosure capabilities (often periodic and compliance-driven, e.g., GRI Standards), and (iii) broad legitimacy-building strategies that may rely on reputation without operationally grounded proof (Suchman, 1995). Its focus is the offer-level proof chain that enables adoption and scaling while mitigating greenwashing risk (Delmas & Burbano, 2011).

Dimensions and microfoundations. The cases suggest four tightly coupled dimensions: (1) claim design and materiality (selecting claims that are specific, decision-relevant, and operationally controllable); (2) proof generation (measurement systems, pilots, traceability, and process documentation); (3) proof translation and signaling (dashboards, certificates, technical sheets, and segment-specific narratives); and (4) proof governance (data quality rules, responsibilities, update routines, and readiness for third-party scrutiny). These dimensions operate through routines that sit at the interface of operations, marketing, and compliance—consistent with a dynamic-capability view of how ventures adapt their business models to stakeholder demands (Teece et al., 1997; Teece, 2007).

Indicative measurement items for future research. Building on these dimensions, PB-GMC could be operationalized with survey items such as: (i) "We routinely quantify the environmental outcomes of our offer (e.g., resources saved, waste diverted) using a transparent method"; (ii) "We maintain a documented baseline and measurement protocol for our main sustainability claims"; (iii) "We can provide customers with traceability or process evidence that links operations to our claims"; (iv) "We translate proof into segment-specific decision aids (e.g., ROI calculators, ESG-ready dashboards)"; (v) "We have clear internal responsibilities for data quality and claim approval to prevent overstatement"; (vi) "We can provide third-party verifiable documentation when required (certifications, audits, expert validation)"; and (vii) "We use pilots or demonstrators to reduce adoption uncertainty before scaling."

In theoretical terms, PB-GMC can be interpreted through signaling and legitimacy lenses. Signals such as dashboards, audited indicators, or traceability systems are costly to create and maintain, and thus can reduce information asymmetry about underlying environmental performance

(Spence, 1973). At the same time, proof contributes to legitimacy by demonstrating conformity with stakeholder expectations, including regulatory norms and professional standards (Suchman, 1995). This dual role explains why proof mechanisms are particularly salient in B2B markets where procurement decisions incorporate risk management and compliance requirements.

Second, the results refine how we think about "green marketing." Rather than treating marketing primarily as communication, the cases suggest that marketing credibility is produced by operational routines. This resonates with critiques of early green marketing approaches that relied on symbolic claims and created backlash (Peattie & Crane, 2005). For circular ventures, PB-GMC implies that the marketing function must be tightly coupled with operations, data systems, and compliance processes. In other words, marketing becomes a form of evidence governance.

Third, the cross-case evidence highlights that the economics of circular loops shape which proof mechanisms are feasible. Where energy and logistics costs are dominant, ventures may prioritize proof that supports recurring service contracts and financing for capital expenditures (as in ECO DEC Djerba). Where adoption is uncertain, ventures may emphasize experiential proof through pilots and demonstrators (as in Smart Farm). These patterns suggest that PB-GMC is not a generic capability; it is shaped by business model archetype, sectoral dynamics, and institutional context.

Finally, the results emphasize the strategic role of compliance. The study supports a view of regulation not only as an external constraint but as an endogenous design parameter that shapes venture strategy. This aligns with sustainable entrepreneurship theory's focus on market failures and institutional mechanisms: entrepreneurs can create opportunities by reducing transaction costs and enabling compliance for other actors (Dean & McMullen, 2007). In settings where regulation is evolving, ventures may benefit from phased strategies that secure a legally robust initial market while preparing for future expansion (as in VIVERT).

Managerial Implications: Designing Circular Offerings for Proof, Not Only for Impact

The findings suggest several actionable lessons for entrepreneurs seeking to scale circular ventures in contexts like Tunisia.

1) Start from loop economics, not from the "green story." Entrepreneurs should map energy, logistics, and quality drivers early and treat them as design variables. This includes explicit scenarios for energy supply (grid, solar, shared infrastructure), feedstock stability (contracts, partnerships), and quality control (testing, protocols). Circularity can quickly become uneconomic if these drivers are ignored.

2) Build a minimal proof system from day one. Rather than waiting for later-stage reporting demands, ventures should define a small set of indicators that are meaningful for their business model and stakeholders. A practical approach is to track at least one indicator for environmental performance (e.g., tons of waste diverted, m3 water saved), one for social value (e.g., jobs created), and one for economic viability (e.g., gross margin per unit). Embedding measurement routines early reduces future greenwashing risk and supports investment readiness.

Box 1. Minimum Viable Proof System (MVPS) for Circular Ventures in Water-Scarce Settings

- Define 3–6 segment-relevant KPIs (choose what buyers/financiers actually ask for): e.g., m^3 of water saved per hectare or per unit output; kWh saved or added per unit; kg of waste diverted/valorized; CO_2e avoided; a quality/compliance indicator (e.g., moisture, hygienization step, traceability completeness).
- Establish a baseline protocol: specify the counterfactual (before/after, control plot, standard process), measurement frequency, and who records data.

- Create an audit trail: store raw logs (sensor exports, weighbridge tickets, batch logs), calculation sheets, and assumptions used for impact claims.
- Translate evidence into buyer-ready signals: a one-page technical sheet, a dashboard screenshot, a pilot report, and a 'proof kit' aligned with procurement or ESG reporting needs.
- Plan the validation pathway early: identify whether third-party verification is needed (lab tests, certifications, standard compliance) and budget for it.
- Use MVPS outputs to support pricing, contracting, and financing: link KPIs to customer economics (cost saving, risk avoidance) and to compliance requirements.

3) Translate sustainability into customer economics. Price-sensitive markets require that sustainability be justified in terms of value-in-use or risk avoidance. For example, waste services can be priced as "compliance and reputation management," while agritech can be priced as "water and energy savings with ROI proof." This logic aligns with sustainable entrepreneurship's focus on opportunity creation through efficiency and risk reduction.

4) Use proof to unlock revenue models. Proof may facilitate service-based contracts, subscriptions, and performance-linked pricing by reducing customer risk and clarifying value-in-use. ECO DEC Djerba's reporting tool illustrates how proof may become a contractual deliverable. Smart Farm's dashboarding logic similarly supports subscription renewal by making outcomes visible and comparable across seasons.

5) Treat compliance as a product feature. For ventures in regulated domains, documentation and permits should be integrated into the value proposition and into the data room for financiers. Compliance-by-design can be reframed as a strategic advantage, particularly for B2B segments that face audits and reporting.

6) Design partnerships for stability and legitimacy. Because circular loops are network-dependent, entrepreneurs should prioritize partnerships that stabilize volumes (feedstock contracts, key accounts) and increase legitimacy (municipalities, hotels, professional associations, research institutions). Partnerships can also help share infrastructure costs and facilitate access to certification and export channels.

Policy and Ecosystem Implications

The study also suggests implications for policymakers, financiers, and support organizations aiming to foster circular transitions through entrepreneurship.

1) Invest in enabling infrastructures for circular loops. Energy access, waste segregation, and reverse logistics are foundational. Where these infrastructures are weak, ventures bear quasi-public costs that can make them uncompetitive. Blended finance mechanisms and targeted public investment can reduce these burdens and improve the viability of resource recovery models.

2) Support measurement and certification access for SMEs. Many proof mechanisms require standards, testing labs, or certification bodies that may be costly for small firms. Programs that subsidize testing, provide shared measurement tools, or facilitate credible third-party validation can improve market transparency and reduce greenwashing. Such support aligns with broader sustainable consumption and production goals (UNEP, 2023).

3) Use public procurement and tourism governance to create lead markets. In sectors such as hospitality and municipal services, public procurement and sectoral guidelines can create demand for compliant and traceable waste services. Lead markets can provide reference projects that generate experiential proof and accelerate diffusion.

4) Reduce administrative uncertainty through clearer pathways. For ventures handling waste or producing novel bio-based products, uncertainty about permits and compliance requirements can

deter investment. Transparent decision trees, one-stop support, and predictable timelines could reduce transaction costs and encourage responsible innovation.

5) Encourage regional and export readiness. Given limitations of domestic willingness to pay in some categories, support for export channels (quality standards, packaging, distribution matchmaking) can help circular design and circular fuels ventures scale. However, export strategies should be accompanied by robust proof systems to meet international buyer requirements.

Limitations and Future Research

Future research can extend this study in several directions. First, primary data collection through interviews, site visits, and operational measurements would enable deeper understanding of cost structures and proof generation practices. Second, quantitative studies could test the propositions by measuring PB-GMC, compliance-by-design practices, and scaling outcomes across a larger sample of ventures. Third, comparative research across countries could examine how different institutional environments shape the value of proof and the feasibility of circular loops. Finally, research could explore how digital technologies (IoT, traceability platforms) and emerging regulations on environmental claims influence green marketing strategies over time.

Conclusions

This article examined how circular ventures in a water-scarce emerging economy navigate the intertwined challenges of operational feasibility, market adoption, credibility, and institutional alignment. Through an exploratory multiple-case analysis of Tunisian green ventures, we found that the scalability of circular business models is frequently constrained by the economics of the loop—especially energy, logistics, and quality assurance—rather than by the technical feasibility of the underlying idea.

We introduced the concept of proof-based green marketing capability (PB-GMC) to explain how ventures convert circular value creation into credible market signals. Across cases, proof mechanisms such as measurement dashboards, traceability applications, demonstrations, and documentation enabled more stable B2B contracting, facilitated partnerships, and supported investment readiness. Crucially, proof was effective when embedded in operational routines rather than treated as a superficial communication layer, reinforcing the need to couple marketing to operations and compliance.

The study also highlighted compliance-by-design as a strategic dimension of circular entrepreneurship. In regulated domains, early attention to permits, standards, and documentation reduced perceived risk and could be converted into customer value (risk avoidance, reputation) and finance value (due diligence readiness). These insights suggest that entrepreneurship support programs should integrate circular design, proof systems, and regulatory strategy into coherent venture-building pathways.

While exploratory, the framework and refined propositions offered here provide a basis for future empirical testing and for practical diagnostics. Scaling circular economy solutions through entrepreneurship requires not only innovative products but also credible evidence infrastructures that allow stakeholders to trust, adopt, and finance circular change.

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Data Availability Statement

The study relies on secondary educational case vignettes and associated instructional passages. To support transparency, the codebook (Table 2), cross-case matrix (Table 3), and a paraphrased audit trail of evidence excerpts (Appendix A / Table A1) are provided in the manuscript. The underlying training vignettes form part of proprietary educational materials and cannot be publicly shared within this article; access may be considered upon reasonable request subject to permission and any applicable intellectual-property constraints. Publicly available sources used for light triangulation are cited in the reference list.

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Conflicts of Interest

The authors declare no conflict of interest.

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Appendix A. Evidence Excerpts and Coding Examples

This appendix provides paraphrased excerpts from the training case vignettes and illustrates how key segments were mapped to the proof categories (measurement proof = M; process proof = P; third-party/compliance proof = TP; experiential/use proof = E). Excerpts are paraphrased to preserve the pedagogical nature of the materials while enhancing transparency and allowing readers to trace the empirical basis of the coding logic.

Table A1. Paraphrased evidence excerpts and coding examples (audit trail for PB-GMC categories).

Case	**Paraphrased evidence excerpt**	**Coding illustration (M/P/TP/E) and rationale**
Namma Compost	Compost is framed as a soil-regeneration lever that strengthens agriculture under water stress, implying that agronomic adoption depends on observable field performance (e.g., soil quality and resilience).	E (experiential proof): field-relevant outcomes must be demonstrated to users; links circular loop to adoption.
Namma Compost	Scaling is constrained by energy costs (e.g., electricity generation) and permits; suggested proof includes tonnes of organic waste diverted and compost volumes produced, with potential water-related indicators if agronomic effects are documented.	M (measurement proof) + TP (third-party/compliance): quantified outputs and regulatory readiness support credibility.
VIVERT	Regulation is described as restricting insect-protein production; the strategy is to decouple fertilizer vs protein and to document safety/traceability while preparing for regulatory change.	TP + P (process proof): compliance and traceability routines underpin market access and staged scaling.
VIVERT	Because inputs are mixed organic waste, the design is described as requiring control of inputs, hygienization, and proof of conformity, plus management of by-products.	P + TP: operational controls and compliance evidence are part of the offer's proof chain.
VIVERT	High CAPEX equipment (e.g., sieving) motivates modular/phased investment; proof needs extend to ROI	M: proof of economic viability complements environmental proof in scaling conversations.

	logic for the staged business model.	
ECO DEC Djerba	The offer is described as an integrated hotel service (installation + operations) where an application produces reporting indicators (diverted quantities, outputs) for clients.	P + M: traceability/reporting transforms operations into stakeholder-ready proof.
ECO DEC Djerba	Energy-intensive equipment and collection logistics are highlighted as dominant cost drivers; financing is described as contingent on contracts and proof-enabled dashboards.	M + E: recurring service performance must be evidenced to secure contracts and financing.
ECO DEC Djerba	The case explicitly notes that proof/reporting may be complemented by certifications, turning assurance into a differentiator in B2B markets.	TP: third-party assurance can function as a market access signal.
Smart Farm	The venture combines sensor sales with a software subscription; adoption barriers imply that proof must be designed through pilot plots and a very simple user experience.	E + P: demonstrators and process simplification reduce adoption uncertainty.
Smart Farm	Suggested ESG proof includes m^3 of water saved and energy avoided through reduced pumping (and potentially CO_2 avoided).	M: quantified resource outcomes anchor the proof-based value proposition.
Smart Farm	Financing is framed as traction-driven; demonstrators, pilot results, and distributor contracts are listed as data-room elements for investors.	E + P: experiential outcomes plus documented evidence packages support legitimacy and finance access.
BIOHEAT	Two routes are contrasted: competing on volume/cost domestically versus targeting export/value segments; proof is tied to performance (e.g., consistency) and measurable	M + P: performance metrics and quality assurance underpin differentiation.

	decarbonization benefits.	
BIOHEAT	Export-oriented scaling implies the need to meet buyer expectations and standards, positioning third-party evidence as a qualifier.	TP: standards/certifications operate as entry tickets in some channels.
Palmier Decor	The case points to material-quality constraints and export ambitions, alongside permissions linked to saline-water exploitation and institutional trade support.	TP + P: permits and traceability support the credibility of resource use and sourcing.
Palmier Decor	Financing and export access are framed as depending on disciplined quality and material traceability (with quality systems potentially supporting market entry).	P + TP: governance and assurance mechanisms translate craft into scalable proof.
Wood & Rope	Remaining in local B2C with high costs is described as limiting; a pivot toward B2B (hotels/companies) and export requires standardizing product ranges.	P: standardization routines enable consistent quality and scalable delivery.
Wood & Rope	Distribution partnerships and a consistent “material story” are highlighted as levers, implying the role of references and repeat orders as credibility signals.	E + P: experiential proof (references) complements process proof (quality routines).
BioWay by Racha	Refillable packaging is presented as a visible, tangible ‘zero-waste’ proof element; constraints include limited local sustainable packaging options and certification barriers.	P + TP: design-based proof is strengthened (or constrained) by assurance ecosystems.
BioWay by Racha	Market access (especially international) is described as depending on quality certification and ecosystem partnerships, not on claims alone.	TP: third-party assurance and ecosystem readiness shape credibility and scaling.