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From fragmented to unified: redefining eco-innovation for interdisciplinary climate solutions

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Background and significance: The concept of eco-innovation has become more significant as businesses are under increasing pressure to lessen environmental issues while preserving their competitive performance. The field has ongoing definitional fragmentation that hinders both theoretical development and practical implication, despite substantial research spanning almost three decades. Current definitions reveal operational ambiguity that offers little direction for organizational action, theoretical fragmentation across fields, and terminological misunderstanding with related concepts.

Objectives: This study aims to: (1) perform a thorough, systematic review of definitions of eco-innovation from 1996 to 2024; (2) use linguistic analysis to examine theoretical foundations and definitional patterns; (3) identify significant gaps in current conceptualizations; and (4) suggest a unified, theoretically based definition that combines established innovation theories with useful implementation guidance.

Methodology: In accordance with PRISMA guidelines, we used thorough search terms to conduct a systematic search across six databases: Scopus, Web of Science, ScienceDirect, JSTOR, EBSCO, and Google Scholar. By using stringent methods and inter-rater reliability evaluation (Cohen's Kappa>0.89), 85 identified papers satisfied the inclusion criteria. Data extraction used standardized forms that covered topics as implementation issues, theoretical frameworks, publication details, and precise definitions. The analysis integrated action verb categorization, theme analysis, temporal evolution mapping, and theoretical framework classification.

Key results: Four theoretical foundations are identified: innovation systems (16%), stakeholder theory (24%), institutional theory (28%), and resource-based view (32%). Action verb analysis identifies "develop" as most frequent (67%) with very high implementation clarity, while outcome analysis shows environmental objectives dominate (89%) with strong business focus (67%) but limited social integration (34%). Three definitional types with different theoretical emphasis and practical constraints were identified: output-focused (42%), process-focused (31%), and system-focused (27%).

Implications: According to the unified redefinition, eco-innovation is an organizational capability that comprises four action orientations (adopt, integrate, improve, and develop) and three different forms of innovation (management systems, outputs, and markets). Eco-oriented culture and capabilities facilitate these innovations. This approach offers useful implementation guidance along with theoretical integration that addresses disciplinary fragmentation. The new "eco-oriented capabilities" concept serves as a theoretical link between theories. It facilitates capability development planning and practical strategic focus.

KEYWORDS

eco-innovation definition, systematic review, sustainability innovation, eco-oriented capabilities, climate solutions, green innovation, performance

1 Introduction

Eco-innovation has become recognized as a vital instrument for accomplishing sustainable development objectives while preserving economic competitiveness due to the growing urgency of environmental issues. Significant differences in eco-innovation performance across organizational contexts have been shown by recent empirical evidence, with leadership diversity, governance mechanisms, and company size emerging as important success factors (Mansour et al., 2024; Mansour et al., 2025a, 2025b). According to recent research, successful eco-innovation necessitates the fusion of technological capabilities and effective governance, where board independence and gender-diverse leadership significantly influence environmental disclosure and innovation outcomes (Mansour et al., 2025a, 2025b).

In spite of this growing empirical evidence, the conceptual foundations of eco-innovation are still dispersed across discipline boundaries. According to Díaz-García et al. (2015) and Chen et al. (2006), the concept is used interchangeably with green innovation, environmental innovation, and sustainable innovation without any discernible differences, causing conceptual confusion that compromises the validity of research as well as practical application. Recent meta-analyses show significant variation in impact sizes among studies, which can be partially ascribed to ambiguous definitions and contradictory conceptualizations (Zheng and Iatridis, 2022). This fragmentation restricts the accumulation of knowledge and the comparability of studies because it represents the field's emergence from several academic traditions rather than cohesive theoretical development.

The importance of addressing the definitional challenges regarding eco-innovation has increased in light of recent policy changes and empirical findings.

In order to solve systemic sustainability issues, the Paris Climate Agreement and the UN Sustainable Development Goals call for transformative innovation strategies that go beyond incremental improvements. Recent studies show that organizational capabilities that go beyond technical abilities to include leadership traits, governance systems, and cultural orientations are crucial for the success of eco-innovation (Mansour et al., 2024; Mansour et al., 2025a, 2025b). Organizations with diverse leadership and strong governance structures perform better in eco-innovation, underscoring the need for definitions that take these organizational factors into account.

Recent research also shows that organizational size has a major impact on eco-innovation performance, with smaller organizations concentrating on improving operational efficiency while larger firms use resource endowments for radical breakthroughs (Mansour et al., 2024). This size-based variation showcases the significance of adaptable definitional frameworks that can take into account various implementation pathways and organizational contexts. The growing integration of digital technologies with sustainability initiatives, termed "twin transition," further highlights the need for contemporary definitions that reflect current technological and organizational realities.

A thorough examination of the body of literature identifies three crucial shortcomings that stand in the path of both theoretical development and practical implementation.

Theoretical gap: the fundamental theories of innovation and sustainability imperatives are not integrated into current definitions. Although some studies focus on institutional pressures (28% of studies) and others adopt resource-based perspectives stressing capabilities (32% of studies), there is little theoretical coherence between these theories.

Methodological gap: strict PRISMA-compliant techniques have not been used in previous systematic studies to examine the theoretical foundation and definitional evolution. Prior reviews either have a restricted focus on particular features or lack the methodological rigor required for a thorough conceptual investigation. The absence of systematic linguistic analysis of action verbs and implementation orientations restricts understanding of how definitions translate into organizational practice.

Practical gap: organizational implementation is not adequately guided by current definitions, especially when it comes to the capabilities, cultural environments, and governance systems required for success. Recent evidence on board effectiveness, leadership diversity, and size-based performance variations highlights implementation requirements that current definitions fall short in addressing properly.

Four research questions are used in this study to fill the gaps that have been identified:

> *RQ1*: What are the dominant theoretical frameworks underlying eco-innovation definitions, and how do they reflect disciplinary fragmentation in this field?
>
> *RQ2*: How do action verbs in eco-innovation definitions reflect implementation orientations, and what implications do linguistic patterns have for practical application?
>
> *RQ3*: What definitional categories emerge from systematic analysis, and how do they address different aspects of eco-innovation processes and outcomes?
>
> *RQ4*: How can theoretical integration and empirical insights inform a unified definition that addresses current gaps while maintaining practical applicability?

The motivation for this research stems for the crucial gap between eco-innovation's theoretical significance and practical implementation challenges. Due to ambiguous definitions and unclear implementation frameworks, organizations find it difficult to operationalize eco-innovation strategies. The problem statement focuses on the necessity of conceptual clarity for both successful practice and robust research. Current definitional fragmentation hinders the formation of cumulative knowledge, which limits theoretical growth, and operational ambiguity hinders organizational implementation by offering inadequate advice for strategic planning and capability development. The pressing nature of environmental challenges necessitates conceptual frameworks that facilitate quick scaling and successful application in a variety of organizational contexts.

This study offers the first systematic integration of resource-based view, institutional theory, and dynamic capabilities theory in the conception of eco-innovation, supported by contemporary empirical findings. The emergence of "eco-oriented capabilities" as a unifying concept integrates recent research on organizational factors that influence the success of eco-innovation while bridging disciplinary perspectives. Moreover, this research offers a methodological contribution by using a thorough language analysis of action verbs and implementation orientations along with rigorous PRISMA-compliant systematic review processes. Future definitional development initiatives can benefit from the reproducible framework for conceptual investigation that this methodological approach offers. Last but not last, this research aims to advance the understanding by integrating fragmented perspectives and incorporating contemporary empirical findings; to offer precise implementation guidelines for practice by taking into account specific capabilities, cultural requirements, etc.…; and to support comprehensive frameworks that connect organizational development with the goals of sustainability transition.

This paper's remaining sections are arranged as follows: The theoretical foundations and conceptual evolution in Section 2, and the PRISMA-compliant systematic review approach is presented in Section 3. The results of thematic, temporal, and linguistic analyses are reported in Section 4; the unified redefinition and implementation framework are proposed in Section 5; limitations, future research directions, and implications are concluded in section 6.

2 Theoretical background and literature review

2.1 Theoretical foundations of innovation

Current empirical data supports the significance of combining sustainability standards with well-established innovation theories. *The resource-based view* provides the basis for understanding how businesses create competitive advantage through distinctive environmental capabilities (Barney, 1991). According to recent research, eco-innovation performance varies greatly depending on the size of the company; smaller businesses gain from improved operational efficiency and market positioning, while larger businesses show stronger financial performance outcomes from eco-innovation investments (Mansour et al., 2024). The resource-based perspective is supported by this size-based variation, which illustrates how various resource endowments affect the results of eco-innovation.

Institutional theory explains how regulatory, normative, and cultural factors shape eco-innovation behavior. Governance mechanisms, particularly board independence and expertise, significantly drive eco-innovation adoption (Mansour et al., 2025a, 2025b). Recent studies on board effectiveness show that governance procedures have a major impact on innovation and environmental disclosure practices, and that board independence and expertise are important institutional variables that promote the adoption of eco-innovation (Mansour et al., 2025a, 2025b). Gender diversity improves eco-innovation through better decision-making processes and stakeholder engagement, according to empirical data from the global energy sector, which highlights the significance of female leadership and gender-diverse boards (Mansour et al., 2025a, 2025b).

Dynamic capabilities theory describes how organizations develop abilities to identify environmental opportunities, pursue innovation possibilities, and transform their resources over time (Teece, 2007). Understanding how eco-oriented capabilities develop within businesses and how leadership diversity supports dynamic sensing and seizing processes are two areas in which this theoretical approach is especially pertinent.

The integration of these three theoretical perspectives provides a comprehensive understanding of eco-innovation as both a capability-building process and an institutional response to sustainability demands, with company size, governance structures, and leadership diversity serving as key factors influencing outcomes.

2.2 Evolution of eco-innovation concepts

There have been four main eras in the conceptual evolution of eco-innovation, each with its own theoretical orientations and definitional emphases that reflect broader changes in sustainability policy, environmental science, and innovation theory.

2.2.1 Phase 1: technological determinism era (1960s–1990s)

The concept of "intermediate technology," first proposed by Schumacher (1973), provided the intellectual underpinnings of eco-innovation by promoting technological solutions that minimized resource consumption and environmental deterioration. Environmental issues were primarily seen as technical concerns that required engineering solutions during this early stage of development, when environmental innovation was understood through technological determinism.

Neoclassical economics, which dominated the field, viewed environmental improvements as externalities that needed to be internalized through technological solutions (Jaffe et al., 2002). Organizational, social, or systemic aspects of innovation received little attention in the research, which was primarily concerned with end-of-pipe solutions, pollution control technology, and industrial ecology applications. The disciplinary division between innovation and environmental studies during this time led to limited conceptualizations that persisted into the 1990s.

2.2.2 Phase 2: market-oriented innovation era (1990s–2005)

A major change toward market-based methods to eco-innovation occurred in the 1990s, largely due to the impact of Porter and Van der Linde's (1995) "Porter Hypothesis." By claiming that well-crafted environmental standards could spur innovation that frequently completely covers compliance costs, this paradigm contested the notion that environmental laws inevitably result in costs for enterprises.

Hart's (1995) natural-resource-based view extended classic strategic management theory to acknowledge environmental capabilities as possible sources of competitive advantage. During this time, theoretical frameworks included viewpoints from resource-based views. In policy documents, the European Commission (2011) coined the term "eco-innovation" to refer to technologies that addressed environmental issues and produced economic value at the same time (Secretariat-General, European Commission, 1996).

There has been a lot of empirical study on the Porter Hypothesis as a result of research expanding to look at the connections between environmental regulation and innovation performance. However, institutional and social aspects were not fully integrated into theoretical development, which mostly stayed within neoclassical and resource-based frameworks.

2.2.3 Phase 3: systems integration era (2005–2015)

A paradigm shift toward systems thinking and multi-level perspectives on eco-innovation occurred in the mid-2000s, driven by advancements in sustainability research and the realization that systemic, not incremental, solutions were needed to address environmental concerns. By considering eco-innovation as a component of larger sustainability transitions encompassing technological areas, socio-technical regimes, and landscape pressures, the multi-level perspective (MLP) on socio-technical transitions gained significant traction (Geels and Schot, 2007; Geels, 2005; Oltra and Jean, 2009).

Institutional theory was added to theoretical frameworks in recognition of the intricate relationships that exist between social, institutional, and technological elements that lead to eco-innovation. An example of this more comprehensive viewpoint was provided by the OECD (2008), which defined eco-innovation as "the implementation of new, or significantly improved, products, processes, marketing methods, organizational structures and institutional arrangements which lead to environmental improvements compared to relevant alternatives."

The research's emphasis switched to comprehending network effects, innovation systems, and multi-stakeholder cooperation in eco-innovation processes. During this time, sectoral innovation systems, regional innovation clusters, and the function of intermediary organizations in promoting the adoption of eco-innovation received more attention. However, this theoretical sophistication also created challenges, as the proliferation of theoretical perspectives made it difficult to synthesize findings and build cumulative knowledge.

2.2.4 Phase 4: transformative innovation era (2015-present)

The current phase is distinguished by the understanding that eco-innovation cannot only improve the environmental performance of current systems; it must also help bring about a radical shift toward sustainability. This perspective has been shaped by the Paris Climate Agreement, UN Sustainable Development Goals, and growing scientific evidence of planetary boundaries and climate tipping points (Su et al., 2020; Li et al., 2020; Ding et al., 2021).

To comprehend eco-innovation as a component of larger socio-technical changes, modern theoretical frameworks combine sustainability science, complexity theory, and transition theory. According to Schot et al. (2018), the idea of "transformative innovation policy" highlights the necessity of innovation in addressing societal issues and facilitating systemic changes. Modern eco-innovation concepts now revolve around digital technology, the circular economy, and social innovation aspects.

The focus of current research is on the governance of eco-innovation ecosystems, sustainability transitions, and mission-oriented innovation. While strategies like the "twin transition" acknowledge the ties between digital and green changes, the integration of biotechnology, sophisticated materials, and artificial intelligence has broadened the scope and possible applications.

According to this evolutionary trajectory, the scope has steadily expanded from a restricted technology focus to larger systemic perspectives, from interdisciplinary integration to single-discipline methods, and from environmental improvements to transformative sustainability impact. A variety of theoretical traditions, such as innovation studies, institutional theory, sustainability science, and transition theory, are incorporated into current eco-innovation research.

Nonetheless, this theoretical diversity has exacerbated conceptual ambiguity and definitional fragmentation. Though it deepens comprehension, the field's interdisciplinary nature hinders communication and makes theoretical integration difficult. The primary goal of this study is to construct theoretically grounded yet practically usable definitions, which is highlighted by the conflict between the requirement for effective frameworks and a thorough theoretical knowledge.

2.3 Definitional challenges and inconsistencies

Existing definitions of eco-innovation have three serious challenges that hinder further research and real-world application. First, despite their significant differences, similar terms like green innovation, environmental innovation, and sustainable innovation are frequently employed interchangeably, leading to terminological confusion (Schiederig and Tietze, 2012; Chen et al., 2006). Second, rather than fostering a unified understanding, theoretical dispersion across disciplines—from environmental economics to innovation studies—has resulted in variable definitions that reflect disparate disciplinary goals (Hart, 1995; Geels, 2005). Third, the current definitions lack operational clarity, with ambiguous words such as "significantly improved" providing little advice for organizational implementation (OECD, 2008). In this quickly evolving subject, there is an urgent need for conceptual clarity, as these definitional issues have cascade repercussions that include challenges with research validity, limitations on theoretical advancement, and implementation obstacles (Zheng and Iatridis, 2022).

3 Methodology

3.1 Systematic review protocol and PRISMA compliance

To maintain openness and rigor, this work complies with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) requirements (Page et al., 2021). To find, examine, and compile definitions of eco-innovation from scholarly works, we carried out an extensive systematic review by using a concise research string (Table 1).

The comprehensive screening methodology spanning 1996–2025 identified relevant eco-innovation definitions from academic literature, resulting in 85 studies meeting all inclusion criteria for theoretical and definitional analysis (Figure 1).

3.2 Analysis methods

Thematic analysis of definitions: to find recurrent themes, patterns, and conceptual elements in eco-innovation definitions, a structured content analysis methodology was used. The process comprised the following steps: (1) initial inductive coding of definitional components; (2) iterative comparison of definitions to identify recurrent themes; (3) creation of thematic categories based on frequency and conceptual significance; and (4) synthesis of themes into cohesive definitional dimensions. Two researchers independently coded a 20% subsample to guarantee inter-coder reliability, resulting in a Cohen's kappa of 0.82.

TABLE 1 Search string.

Primary	Secondary	Combined
"eco-innovation"	"green innovation" OR "environnemental innovation" OR "sustainable innovation"	"definition" OR "concept" OR "framework" OR "meaning"

Source: Authors elaboration.

Temporal analysis of definitional evolution: the conceptual evolution from 1996 to 2025 has been tracked using a chronological mapping of definitional changes. In this analysis, definitions were arranged chronologically by year of publication, paradigmatic shifts and transitional periods were identified, definitional complexity changes over time were analyzed, and definitional evolution was correlated with broader theoretical and policy developments. Time-series analysis techniques were applied to identify significant trend breaks and evolutionary phases (Table 2).

Theoretical framework mapping: to understand the disciplinary foundations of various definitions, a comprehensive classification of underlying theoretical viewpoints was carried out. This process involved mapping theoretical combinations and integrations, identifying explicit theoretical references within each study, classifying implicit theoretical orientations according to conceptual emphasis, and evaluating theoretical diversity and convergence patterns. Theoretical frameworks were coded according to established innovation and sustainability theory taxonomies (Table 2).

Gap analysis and synthesis: the following methods were used to conduct a thorough assessment of definitional limitations and

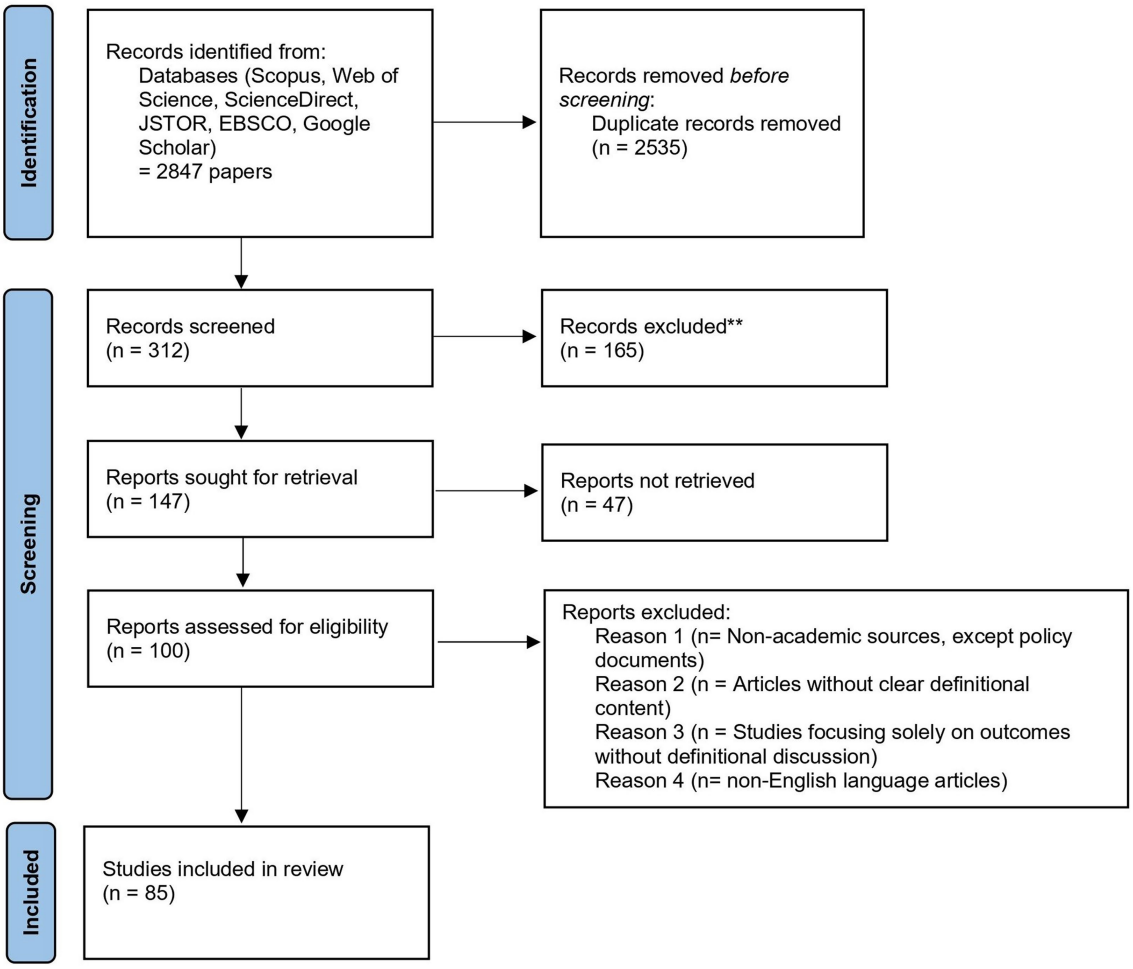

FIGURE 1
Research strategy presentation following PRISMA guidelines. Source: Adapted from PRISMA 2020 flow diagram for new systematic reviews by Page et al. (2021). Licensed under CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/).

TABLE 2 Eco-innovation's thematic definitions evolution through years (from 1996 to 2024).

Periods	1996–2005	2006–2015	2016–2024
Themes	Technology-focused era	Business integration era	Systems transformation era
Definitional focus	Environmental protection through technological solutions	Environmental improvements with business value creation	Systemic change and sustainability transitions
Charachteristics	- Definitions emphasized technological solutions - Primary focus on environmnetal protection - Limited integration with business strategy	- Broader perspective including organizational innovation - Recognition of business value creation - Introduction of stakeholder considerations	- Empahsis on systemic change and transitions - Integration of social dimensions - Focus on circular economy and digitalization
Representative Definition	"*Technological innovations that reduce environmental impact*" (Kemp and Arundel, 1998)	"*Innovations that reduce environmnetal impacts while providing customer and business value*" (OECD, 2009)	"*Systemic innovations thar contribute to sustainability transitions across technological, institutional, and social dimensions*" (Köhler et al., 2019)
Theoretical emphasis	- Neoclassical economics - Linear innovation models - Industrial ecology	- Resource-based-view - Strategic management - Innovation systems theory	- Transition theory - Sustainability science - Multi-level perspective - Systems thinking

Source: Authors elaboration.

TABLE 3 Classification of eco-innovation definitions based on primary focus and scopeable.

Category	Focus	% of studies	Key characteristics	Representative definition	Theoretical emphasis
Output-Focused	Products, services, technologies	42%	- Environmental performance improvements - Tangible innovation outcomes - Technology-centered approach - Limited organizational context	"*Development of products and services that reduce environmnetal impact*" (Chen et al., 2006)	- Resource-based view - Technological innovation theory
Process-Focused	Organizational processes and systems	31%	- Management and operational innovations - Internal organizational changes - Process improvement emphasis - Implementation mechanisms	"*Innovations in processes, practices, and organizational systems that reduce environmental impact*" (Rennings, 2000)	- Organizational theory - Process innovation frameworks - Institutional theory
System-Focused	Holistic transformation	27%	- Multiple innovation types integration - Systemic transformation emphasis - Technological organizational, and social dimensions - Transition perspectives	"*Systemic innovations that transform production and consumption systems toward sustainability*" (Geels, 2005)	- Systems theory - Transition theory - Multi-level perspective - Sustainability science

Source: Authors elaboration.

integration opportunities: (1) a systematic comparison of definitional scope and emphasis across studies; (2) the identification of conceptual gaps and inconsistencies; (3) an analysis of the practical implementation guidance provided by various definitions; and (4) the synthesis of insights to inform theoretical integration requirements. Constant comparative methods were used in this investigation to find convergence and divergence tendencies among definitional approaches.

Therefore, by (1) systematically comparing the definitional scope and emphasis across studies, (2) identifying conceptual gaps and inconsistencies, (3) analyzing the practical implementation guidance provided by various definitions, and (4) synthesizing insights to inform theoretical integration requirements, a thorough evaluation of definitional limitations and integration opportunities was carried out. To find trends of convergence and divergence among definitional approaches, this investigation used constant comparative methodologies (Table 3).

4 Results: systematic analysis of eco-innovation definitions

4.1 Temporal evolution of definitions (1996–2024)

Our analysis reveals three distinct periods in eco-innovation definitional development:

Temporal evolution of definitions.

The three developmental phases (1996–2025) highlight the temporal growth of eco-innovation definitions, moving from a restricted technological focus to approaches that encompass systems transformation. The analysis shows that conceptual sophistication and scope expansion are growing over time, with Period 1 focusing on technological solutions within environmental protection frameworks (Arundel and Kemp, 2009), Period 2

incorporating stakeholder considerations and business value creation, and Period 3 adopting systemic perspectives that include sustainability transitions and social dimensions. Each period reflects distinct theoretical orientations and practical emphases, demonstrating the field's development from linear innovation models to complex systems approaches that tackle interrelated environmental, economic, and social challenges.

4.2 Theoretical framework analysis

Four prevailing approaches are identified through the analysis of the theoretical foundations of the reviewed literature. The most common theoretical framework, according to 32% of studies, is the resource-based view, which emphasizes organizational capabilities and the development of competitive advantage through environmental improvements. Institutional theory coms in second (28% of studies) with a focus on the normative and regulatory forced that propel the adoption of eco-innovation. Stakeholder theory, which emphasizes multi-actor collaboration and value creation processes in eco-innovation development, makes up 24% of studies. Taking a systemic approach to innovation processes within larger institutional and network contexts, innovation systems perspectives make up 16% of studies.

Despite this theoretical diversity, the literature still has notable integration gaps. Instead of integrating several frameworks, the majority of studies only use one theoretical perspective, which restricts the ability to fully comprehend eco-innovation processes. Organizations' development and evolution of eco-innovation capabilities throughout time may be explained by dynamic capabilities theory, which is not given enough attention. Sustainability transition theories are still not well integrated, even though they are important for comprehending systemic change processes. Furthermore, current theoretical frameworks do not adequately account for implementation mechanisms, focusing primarily on adoption drivers rather than execution processes.

4.3 Definitional categories and types

Our analysis highlights three primary categories of eco-innovation definitions:

The analysis identifies three unique definitional categories, each with varying theoretical focuses and practical consequences (Table 4). Definitions that are output-focused (42%) predominant in the literature but have a narrow scope, whereas definitions that are system-focused (27%) provide thorough perspectives but are unclear in their implementation. Definitions that are process-focused (31%) have a moderate scope and a stronger focus on implementation. The overall definitional fragmentation in the field is a result of the various disciplinary origins and theoretical underpinnings reflected in each category.

4.4 Action verbs analysis

Action verb categories by implementation clarity:

- Creation-oriented (very high): Develop, create, produce, introduce (Carrillo-Hermosilla et al. 2009; Blattel-Mink, 1998; Driessen and Hillebrand, 2002)- emphasize original innovation and new solution development with maximum clarity.
- Enhancement-oriented (high): improve, optimize, enhance, upgrade- focus on measurable performance improvements with clear targets (Kemp and Arundel, 1998).
- Integration-oriented (moderate): integrate, combine, synthesize, align- coordinate different elements with moderate guidance.
- Adoption-oriented (low): adopt, implement; apply, deploy- focus on using or deploying existing solutions with limited innovation intensity.

Action verb usage in eco-innovation definitions from 85 studies employing typical definitions from the literature was analyzed for frequency. The word "develop" (67%) dominates the literature with extremely high implementation clarity for the creation of original invention (Baroulaki and Veshangh, 2007), whereas "improve" (54%) provides strong practical direction through quantifiable performance targets. There is a distinct hierarchy in eco-innovation implementation approaches, with creation-oriented verbs offering the most implementation clarity for innovation activities and adoption-oriented verbs concentrating on the deployment of pre-existing solutions with lesser innovation intensity (Table 5).

4.5 Expected results and outcomes

According to the outcome investigation, eco-innovation stands out from other forms of innovation because it has a clear focus on fusing economic and ecological advantages (INNOVA, EUROPA, 2006). Eco-innovation definitions consistently incorporate both environmental (89%) and business (67%) outcomes as core objectives, in contrast to green innovation, which focuses primarily on environmental outcomes (Andersen, 2008; Chen et al., 2017; Kanerva et al., 2009; Driessen and Hillebrand, 2002; Chen et al., 2006), or environmental innovation, which emphasizes technical pollution reduction (Rennings, 2000). This dual emphasis sets eco-innovation apart from the more comprehensive triple bottom line strategy of sustainable innovation, which incorporates social aspects (Zubeltzu-Jaka et al., 2018; Adams et al., 2016). This unique dual value proposition is illustrated in the literature by researchers such as Fussler and James (1996), who stress the simultaneous supply of environmental and consumer value, and the OECD (2008) definition, which calls for both economic competitiveness and environmental improvement (Table 6).

4.6 Implementation requirements and capabilities

4.6.1 Organizational capabilities for eco-innovation

Implementing eco-innovation successfully calls for particular organizational capabilities that allow businesses to overcome environmental obstacles while preserving their competitive performance. Environmental capabilities and knowledge, including technical knowledge of environmental impacts, regulatory frameworks, and sustainability science, become essential requirements (Hart, 1995; Russo and Fouts, 1997; Klemmer et al., 1999). Innovation management systems

TABLE 4 Representative action verbs used in eco-innovation definitions.

Verb	Frequency	Definition focus	Implementation clarify	Representative definition
Develop	67%	New solution creation	Very high: Clar innovation intent and direction	"Development of products and services that reduce environmnetal impact throughout their life cycle" (Chen et al., 2006)
Improve	54%	Performance enhancement	High: Measurable targets and outcomes	"Innovations that improve environmental performance compared to relevant alternatives" (Rennings, 2000)
Implement	43%	Practical deployement	Low: Rquires existing solutions	"*Implementation of new or significantly improved products, processes, and organizational methods*" (OECD, 2009)
Integrate	31%	System coordination	Moderate: Coordination focus with some direction	"Integration of environmental considerations into innovation processes" (Fussler and James, 1996)
Adopt	28%	External solution acceptance	Low: Passive acceptance approach	"Adoption of cleaner technologies and environmental management practices" (El-Kassar and Singh, 2019)
Create	23%	Original innovation	Very high: Original innovation emphasis	"Creation of new business opportunities through environmental innovation" (Andersen, 2008)
Apply	19%	Solution deployement	Low: Application of existing solutions	"Application of environmental technologies to reduce pollution and resource consumption" (Kemp and Arundel, 1998)
Introduce	16%	Market entry	Very high: Market introduction focus	"Introduction of environmentally beneficial innovations to the market" (Blattel-Mink, 1998)
Produce	14%	Output generation	Very high: Tangible output creation	"Production of goods and services with reduced environmental impact" (Carrillo-Hermosilla et al., 2009)
Combine	12%	Element integration	Moderate: Combination of elements	"Combination of environmental and economic objectives in innovation activities" (Foxon and Anderson, 2009)

Source: Authors elaboration.

TABLE 5 Eco-innovations expected outcomes.

Outcomes	Environnemental	Business	Social
% of identification in definitions	89%	67%	34%
Characteristics	- Reduction of environmental impacts - Resource efficiency improvements - Pollution prevention and control - Climate chage mitigation - Biodiversity	- Competitive advantage creation - Cost reduction and efficiency gains - New market opportunities - Risk management and compliance - Brand value and reputation enhancement	- Employement creation - Halth and safety improvements - Community development - Social equity and inclusion - Stakeholder engagement

Source: Authors elaboration.

TABLE 6 Current definitions synthesis per categories.

Authors	Verbs					Types			Resources and capabilities	Results	
	Making something new	Better	Addition	Usage	Not taken	Output	Management system	Market		Environment	Business
Oltra and Jean (2009)		To modify				Products	Processes, practices and systems			Benefit the environment and contribute to environmental sustaianbility	
Andersen (2008)	N/A					Innovations					Attract green rentson the market
Kemp and Pearson (2008) and Arundel and Kemp (2009)	To produce		To assimilate	To exploit		Product and service	Production process, management and business method			Reduction of environmental risk pollution and other negative impacts of resource use: Reduce resource, pollution control, or waste management costs, or to sell into the world market for eco-products	Economic benefits
OECD (2008)	To create and new	To improve		To implement		Products and services	Organizational structures and processes	Marketing methods and institutionalarragements		Environmental improvements	
Kanerva et al. (2009)	N/A					Any innovation				Reduced environmental harm	
Chen et al. (2006)	N/A					Products	Processes, product design, and environmental management		Technologies	Energy saving, pollution prevention, and waste recycling	
Driessen and Hillebrand (2002)	To develop					Innovations				Reducing environmental burdens andyielding significant environemental benefits	
Foxon and Anderson (2009)	To create		To include	To use and to adopt	To learn and to search for	Products	Rules and processes		Technologies, learning, knowledge, values,capabilities	Pollution and resource handling with less environmentally harm	
Baroulaki and Veshagh (2007)	To alter and to develop			To adopt		Products	Processes, product andprocess design, and organizational changes	Marketing strategy	Ideas	Being in the harmony with the environment	Provide customer and business value

(Continued)

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TABLE 6 (Continued)

Authors	Verbs					Types			Resources and capabilities	Results	
	Making something new	Better	Addition	Usage	Not taken	Output	Management system	Market		Environment	Business
Chen et al. (2017)	To create	To transcend			To transform		Organizations	Institutions	Technologies and coordination	Coordination of the relationship between man and nature when humans face resource depletion, environmentaldegradation, and ecological damage	
European Commission (2011)	N/A					Any form of innovation				Reducing the impact on the environment and achieving a more efficient and responsaible use of natural resources	
Klemmer et al. (1999) and Rennings (2000)	To develop and to introduce			To apply		Products	Processes		Ideas and behaviours	Target ecologically specified sustainability targets and reduce environmentalburdens	
Fussler and James (1996)	To develop					Products and services	Processes			Decrease environmental impact	Provide customerand business value
Kemp and Arundel (1998) and Rennings and Zwick (2012)		To modify				Products	Processes, techniques and management systems		Equipment	Avoid or reduce harmful environment impacts	
INNOVA, EUROPA (2006)	To create					Goods and services	Processes, procedures and systems			Provide a better quality of life for all, life cycle minimal use of natural resources, a,d minimal release of toxic substances	Price competitivity
Carrillo-Hermosilla et al. (2009)	N/A					Innovations				Improve environmental performance	
Blattel-Mink (1998)	To introduce	To reingineer			To considerate	Products	Processes and systems	Markets	Ideas, behavior, and technologies	Reduce environmental impact, achieve specific ecological sustainable development goals, environmentalprotection	

Source: Authors elaboration.

10.3389/frsus.2025.1531747

is another essential capability that offer organized methods for locating, creating, and promoting eco-innovation while incorporating environmental factors into conventional innovation processes (Chen et al., 2006; Rennings, 2000). As eco-innovation increasingly encompasses multi-actor networks stakeholder cooperation capabilities have become more important, necessitating the ability to plan collaborative initiatives and manage complicated relationships (Del Río et al., 2016; Foxon and Anderson, 2009). Change management capabilities become essential as eco-innovation often requires fundamental shifts in organizational practices, technologies, and business models (Geels, 2005; Adams et al., 2016).

4.6.2 Cultural requirements and organizational context

In addition to technical capabilities, success in eco-innovation is largely dependent on company culture and values that encourage environmental stewardship and innovative endeavors. According to Schein (2017) and Banerjee (2002), environmental consciousness is a fundamental cultural component that needs to be ingrained in corporate identity and decision-making procedures in order to support long-term eco-innovation initiatives. By encouraging creativity, experimentation, and ongoing learning, an innovation-oriented mindset enhances environmental consciousness. However, because eco-innovation technologies and markets are unpredictable, organizations need cultural support for taking risks and being tolerant of failure (Martins and Terblanche, 2003; Ahmed, 1998). According to Hart and Milstein (2003), many eco-innovations take a long time to develop and may not yield immediate benefits, therefore long-term planning becomes essential.

4.6.3 Resource requirements and implementation support

Implementing eco-innovation necessitates large resource commitments (Rennings and Zwick, 2012) in a number of areas to support development, deployment, and scaling strategies. Since eco-innovations frequently entail large upfront investment in new technologies, processes, and market growth, financial resources for research and development (R&D) represent the most obvious demand (Kemp and Pearson, 2008; OECD, 2008). According to Horbach et al. (2012), human capital requirements go beyond typical innovation skills to incorporate knowledge of sustainability, environmental expertise, and interdisciplinary collaboration capabilities. While network relationships and partnerships have grown in importance as organizations realize the limitations of isolated eco-innovation efforts, technological infrastructure serves as the foundation for eco-innovation activities, requiring investment in clean technologies, monitoring systems, and information management capabilities (El-Kassar and Singh, 2019; Bos-Brouwers, 2010; Triguero et al., 2013).

5 Discussion

5.1 Critical gaps in current eco-innovation conceptualization

Five key limitations are identified by our methodical investigation as restricting the theoretical development and practical application of eco-innovation. The field's fragmented evolution is the cause of these gaps, which emphasize the urgent need for conceptual integration.

5.1.1 Theoretical fragmentation and disciplinary isolation

The theoretical fragmentation across discipline borders is the most notable gap. Although 28% of studies use institutional theory that focuses on regulatory pressures and 32% use resource-based view perspectives that emphasize organizational capabilities, there is little integration between these approaches (findings from section 4.2). Because of this disciplinary isolation, it is impossible to fully comprehend how organizational capabilities and institutional forces interact to form the results of eco-innovation. The field's development from several academic traditions rather than from integrated theoretical growth is reflected in the predominance of single-theory methods.

5.1.2 Implementation ambiguity and practical guidance deficits

Even though definitions frequently use action-oriented language, our verb analysis (section 4.4) demonstrates a great deal of implementation ambiguity. Even if creation-oriented verbs like "develop" are used in 67% of definitions with extremely high implementation clarity, there is still a lack of helpful guidance on how to turn these objectives into organizational action. The continuing divergence between academic theory and corporate practice is exacerbated by the gap between conceptual clarity and operational advice, which puts practitioners at a disadvantage when attempting to adopt eco-innovation practices.

5.1.3 Outcome integration and measurement challenges

A crucial gap in merging corporate (67% of definitions) and environmental (89% of definitions) objectives while addressing social dimensions (34% of definitions) is revealed by the analysis of expected results (section 4.5). Despite the widespread recognition of eco-innovation's unique dual value proposition, current frameworks do not offer a clear direction for managing potential tensions between environmental and economic objectives. The underrepresentation of social outcomes indicates incomplete integration of sustainability imperatives despite growing recognition of systemic transformation requirements.

5.1.4 Capability development and organizational requirements

The organizational capacities and cultural prerequisites required for the successful implementation of eco-innovation are not sufficiently covered by current definitions (section 4.6). Although the literature identifies environmental knowledge, innovation management systems, and stakeholder collaboration skills as essential requirements, it offers little information on organizational learning mechanisms, capability development processes, and the temporal dynamics of eco-innovation capability building. This gap hampers organizations' ability to systematically develop eco-innovation capabilities.

5.1.5 Dynamic perspective and evolutionary understanding

Current definitions primarily take static perspectives, which leaves out the dynamic character of eco-innovation processes. Although the temporal analysis (section 4.1) demonstrates a

substantial conceptual shift from technology-focused to systems transformation perspectives, the contemporary definitions fall short of capturing this dynamic nature. The lack of learning and evolutionary perspectives restricts our comprehension of how eco-innovation capabilities evolve over time and how businesses modify their strategies in response to experience and changing contexts.

5.2 Theoretical synthesis: toward integrated understanding

5.2.1 Integration of core theoretical perspectives

Addressing identified gaps requires integrating three fundamental perspectives that complement rather than compete with each other. The resource-based view, which emphasizes the development and application of rare, valuable, and inimitable environmental capabilities, serves as the basis for comprehending eco-innovation and the development of organizational capabilities. These capabilities are contextualized by institutional theory within the normative, regulatory, and cultural-cognitive frameworks that influence innovation adoption and organizational behavior. These viewpoints are reconciled by dynamic capabilities theory, which explains how businesses recognize environmental opportunities, seize innovation possibilities, and gradually change their resource base.

5.2.2 Reconciling innovation intensity with implementation clarity

Effective definitions of eco-innovation must strike a balance between innovation ambition and practical applicability, according to the integration of our verb analysis results. While enhancement-oriented approaches (high clarity) offer quantifiable performance targets, creation-oriented approaches (very high clarity) offer significant directional guidance for innovation initiatives. Both aspects should be included in a single framework, acknowledging that eco-innovation includes processes for both radical innovation development and incremental improvement, each requiring different organizational capabilities and implementation approaches.

5.2.3 Capability-based integration framework

Expanding upon the examination of implementation requirements, we suggest that eco-oriented capabilities work as the unifying factor that connects theoretical viewpoints and takes into account practical implementation requirements. These capabilities allow firms to successfully handle the complex relationship between environmental and business objectives. They include not just technical and managerial capabilities but also cultural orientations and network relationships. This capability-based approach outlines the organizational requirements for the successful implementation of eco-innovation, offering both theoretical rigor and practical relevance.

5.2.4 Conceptual foundation for unified definition

The theoretical synthesis and gap analysis serve as the cornerstone for creating a single definition of eco-innovation that overcomes noted limitations while maintaining important insights from earlier methodologies. This foundation is based on four fundamental principles: multi-dimensional action orientation that combines approaches for creation, improvement, integration, and adoption using the four key action verbs (adopt, integrate, improve, and develop) to provide stepwise implementation clarity while maintaining innovation ambition; capability-enabled implementation acknowledging that certain organizational capabilities, including environmental knowledge, innovation management, stakeholder collaboration, are necessary for successful eco-innovation and are backed by suitable cultural orientations and resource commitments; dual value creation imperative that recognizes possible social benefits and contributions to system transformation while specifically acknowledging eco-innovation's unique focus on attaining both environmental and financial outcomes; and a dynamic, adaptable viewpoint that takes into account learning and evolutionary aspects, acknowledging eco-innovation as a continuous organizational capability that evolves and changes over time in response to shifting market conditions and environmental challenges. By addressing the fragmentation and ambiguity that have defined the discipline and building on its accumulated insights and knowledge, this conceptual foundation lays the groundwork for the proposal of a single definition that combines theoretical rigor with practical feasibility.

5.3 A unified proposed definition of eco-innovation

Based on our systemic analysis and theoretical integration, we propose the following definition:

> *Eco-innovation is the organizational capability to adopt, integrate, improve, and/or develop eco-innovative management systems, eco-outputs, and/or eco-markets through eco-oriented culture and capabilities, creating value for both environmental sustainability and business performance while contributing to broader sustainability transitions.*

Each aspect of our suggested definition fills in the gaps observed in present approaches in a particular theoretical and practical manner. In order to emphasize that eco-innovation is an organizational ability to generate and manage innovations rather than just results or activities, the term "organizational capability" grounds the definition in resource-based view and dynamic capabilities theory. In order to address the implementation ambiguity, present in current definitions, the four action verbs "adopt, integrate, improve, and develop" provide precise action orientations that offer helpful advice while acknowledging varying degrees of organizational capacity and innovation intensity. By defining particular areas where eco-innovation might take place, the three innovation types-"eco-innovative management systems, eco-outputs, eco-markets"-allow businesses to pursue strategic emphasis and implementation planning. The focus on "eco-oriented culture and capabilities" highlights important organizational prerequisites for effective eco-innovation, formally acknowledging both cultural and capability aspects that are frequently missed by current definitions. The expression "value for environmental sustainability and business performance" avoids making assumptions about trade-offs between environmental and economic goals while clearly recognizing eco-innovation's unique dual value creation requirement. Last but not least, the link to "sustainability transitions" ties eco-innovation to

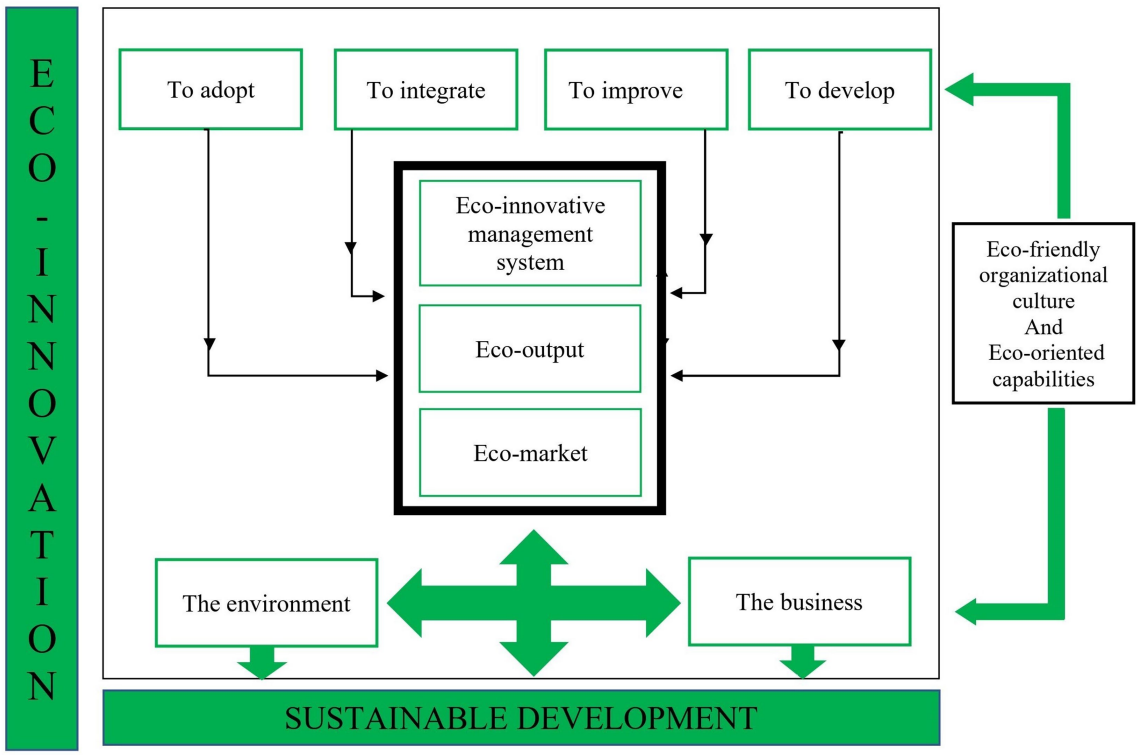

FIGURE 2
Eco-innovation redefinition framework. Source: author's elaboration.

more general systemic change goals, addressing the systems-level perspective that has surfaced in recent eco-innovation research and recognizing the transformative potential of innovation activities beyond individual organizational benefits (Figure 2).

5.4 Comparison with recent literature and theoretical convergence

Our methodical investigation identifies patterns that both support and go beyond current empirical findings in eco-innovation studies. Recent meta-analyses demonstrating the popularity of these theoretical frameworks in empirical research are consistent with the dominance of resource-based view (32% of studies) and institutional theory (28% of studies) in definitional approaches (Zheng and Iatridis, 2022). Nevertheless, our research reveals a crucial gap: current definitions do not sufficiently take into account these organizational factors, despite recent empirical studies showing the significance of leadership diversity and governance procedures for eco-innovation success (Mansour et al., 2025a, 2025b).

Current empirical evidence on the impact of firm size on eco-innovation performance (Mansour et al., 2024) confirms our conclusion that definitional approaches need to take into account various organizational contexts and capabilities. According to our analysis, large organizations' inclinations toward radical innovation are reflected in creation-oriented verbs (67% frequency for "develop"), but smaller firms' emphasis on operational improvements is better reflected in enhancement-oriented approaches. This conceptual-empirical connection supports the need for adaptable definitional frameworks that take into account various contexts in which eco-innovation is implemented.

Our theoretical framework fills in the gaps identified in the current literature by establishing a link between institutional governance mechanisms and resource-based capabilities. The focus on eco-oriented capabilities that include both technical capabilities and governance structures is supported by recent empirical studies showing that board effectiveness significantly influences environmental disclosure and innovation success (Mansour et al., 2025a, 2025b). The integration of dynamic capabilities theory with contemporary leadership research (Mansour et al., 2025a, 2025b) provides theoretical grounding for understanding how gender-diverse leadership enhances environmental innovation through improved sensing and seizing processes.

5.5 Distinctiveness of eco-innovation concepts

Making a clear distinction between eco-innovation and similar concepts is essential for both academic development and practical implementation.

Eco-innovation vs. green innovation: findings clarify that eco-innovation specifically combines environmental goals with economic viability concerns, while green innovation focuses largely on environmental benefits without necessarily guaranteeing company sustainability (Chen et al., 2006; Schiederig and Tietze, 2012). This distinction is supported by recent empirical evidence demonstrating that effective eco-innovations necessitate market development

capabilities and business model innovation beyond technical environmental solutions (Mansour et al., 2025a, 2025b).

Eco-innovation vs. environmental innovation: environmental innovation focuses on technical solutions for particular environmental issues, frequently within the parameters of regulatory compliance. Beyond a technological focus, eco-innovation includes system-, market-, and organizational-level improvements that benefit a variety of stakeholders. This distinction is demonstrated by recent studies on environmental disclosure and governance mechanisms, which show that eco-innovation necessitates organizational capabilities that incorporate environmental considerations into business operations rather than treating them as distinct technical challenges (Mansour et al., 2025a, 2025b).

Eco-innovation vs. sustainable innovation: sustainable innovation embraces triple bottom line strategies that specifically incorporate economic, social, and environmental factors. Findings highlight that eco-innovation recognizes but does not always incorporate social goals while maintaining a dual focus on economic and environmental results.

5.6 Implementation challenges and organizational barriers

This research highlights a number of implementation issues that companies encounter when putting eco-innovation definitions into practice, especially when it comes to creating eco-friendly organizational culture.

Barriers to cultural transformation are arguably the biggest implementation issue. Fundamental changes in attitudes, beliefs, and behavioral norms are necessary to create an eco-friendly corporate culture, and these changes frequently run counter to established organizational procedures and performance indicators. Resistance to change can be a problem for organizations, especially if environmental initiatives are thought to limit operational profitability or efficiency. Strong leadership commitment and governance support are crucial for effective cultural transformation, according to recent empirical research (Mansour et al., 2025a, 2025b). However, many organizations lack the governance capabilities required for long-lasting cultural change.

Capability development challenges arise from eco-oriented capabilities' intricate, multidisciplinary nature. Stakeholder cooperation capabilities, innovation management systems, technical environmental knowledge, and change management capabilities need all to be developed concurrently by organizations. This capability portfolio necessitates a large investment in organizational learning systems, training initiatives, and human capital development. It is important for definitional frameworks to recognize that implementation barriers may arise due to the lack of resources required for complete capability development, particularly in smaller businesses.

Measurement and evaluation difficulties emerge from the multifaceted character of eco-innovation outputs and the temporal discrepancy between performance outcomes and environmental investments. Companies find it difficult to create suitable measures for evaluating the effectiveness of eco-innovation, especially when definitions place an emphasis on abstract concepts like "environmental improvements" or "sustainability transitions" without providing precise measuring standards.

6 Conclusion

By carefully examining 85 studies from almost three decades, this systematic review tackles the crucial conceptual fragmentation in eco-innovation research. Our study found five key gaps in current definitions: lack of integration of business (67% of definitions) and environmental (89% of definitions) outcomes while underrepresenting social dimensions (34% of definitions); lack of attention to capability development requirements; implementation ambiguity despite action-oriented language; theoretical fragmentation across disciplines (32% using resource-based view and 28% institutional theory but limited integration); and static perspectives that ignore the dynamic nature of eco-innovation processes.

In order to overcome these gaps, a unified redefinition has been developed to describe eco-innovation as an organizational capability that encompasses particular action orientations across various innovation types, made possible by eco-oriented capabilities and culture, and that generates value for both business performance and environmental sustainability.

This redefinition presents several important theoretical contributions. It overcomes the disciplinary isolation that has defined the field's development by integrating the resource-based view, institutional and dynamic capabilities theories. The framework presents "eco-oriented capabilities" as a unifying concept that links institutional contexts, cultural orientations, and organizational capabilities. It strikes a balance between innovation ambition and implementation clarity through four specific action orientations (adopt, integrate, improve, develop) within three different innovation types (management systems, outputs, and markets), offering both theoretical rigor and practical guidance.

For a variety of stakeholder groups, the unified framework provides obvious practical implications. It gives managers strategic guidance for the development of eco-innovation that takes into account various organizational contexts and financial resources. It provides policymakers with a thorough framework for creating policies that enable wider sustainability transitions while acknowledging organizational needs. It gives scholars theoretically based frameworks for developing hypotheses and conducting empirical research, facilitating interdisciplinary collaboration and rigorous testing.

This framework's main components are validated by recent research findings. The focus on organizational capabilities and cultural variables in the concept is supported by research on leadership diversity and governance effectiveness (Mansour et al., 2025a, 2025b). Research demonstrating size-based performance variations (Mansour et al., 2024) confirms the need for flexible approaches that recognize different organizational contexts and innovation intensities.

It is important to recognize a number of limitations in this research. The systematic review approach may overlook significant gray literature and practitioner insights, while the emphasis on English-language publications may ignore significant contributions from other academic traditions. The suggested redefinition has to be empirically validated in a variety of organizational contexts to prove its theoretical validity and practical usefulness.

It is recommended that future research emphasize empirical validation studies that test the framework across various industries and organizational sizes, create reliable tools for identifying and measuring eco-oriented capabilities, and investigate moderating factors and performance relationships. Longitudinal case studies could shed light on capability building procedures, and comparison analyses could demonstrate how broadly applicable the framework is in various contexts.

This unified redefinition offers the conceptual clarity required to enhance eco-innovation research and practice as firms deal with increasing environmental challenges while retaining competitive performance standards. The foundation for the methodical capability development necessary for effective eco-innovation and more general sustainability transitions is provided by the integration of well-established innovation theories with sustainability imperatives. In a time when eco-innovation has become crucial for both organizational survival and ecological protection, the framework's emphasis on organizational capabilities, cultural transformation, and dynamic capability places it in a position to direct both scholarly study and practical application.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

Author contributions

BE: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. SB: Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that Gen AI was used in the creation of this manuscript. During the preparation of this work the authors used AI-assisted technologies (Chat-GPT) in order to enhance the stylistic quality of the text via grammar correction, sentence structure and language refinement. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Publisher's note

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