A Survey of Entrepreneurial Ecosystems and Sustainable Innovation

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Abstract

This survey explores the interconnected concepts of entrepreneurial ecosystems, sustainability, and innovation, emphasizing their collective role in fostering environments conducive to sustainable economic growth. Entrepreneurial ecosystems, characterized by dynamic networks of stakeholders, are crucial for nurturing sustainable innovations that align with environmental and social objectives. The integration of sustainability into these ecosystems is essential for maintaining competitiveness and ensuring long-term success, aligning with global objectives such as the Sustainable Development Goals (SDGs). The survey identifies several challenges, including infrastructure and technological barriers, social and educational constraints, and data and measurement challenges, that hinder the effectiveness of entrepreneurial ecosystems in promoting sustainability. Addressing these challenges requires a collaborative approach, leveraging digital technologies and innovative policy mechanisms to enhance resource efficiency and drive sustainable innovation. Emerging trends highlight the potential of circular economy models, community engagement, and the integration of digital technologies, such as AI and IoT, in advancing sustainable development. By fostering environments that support sustainable entrepreneurship and eco-innovation, stakeholders can contribute to achieving long-term economic, environmental, and societal goals. The survey concludes by emphasizing the importance of interdisciplinary approaches, technological advancements, and effective sustainability policies in contributing to a more sustainable and equitable future.

1 Introduction

1.1 Importance of Entrepreneurial Ecosystems

Entrepreneurial ecosystems are crucial for driving innovation and fostering sustainable business practices through a synergistic network of stakeholders, including entrepreneurs, investors, educational institutions, and policymakers. These ecosystems create an environment conducive to developing innovative solutions for contemporary challenges, such as integrating sustainable management techniques in agroecosystems that promote sustainable agricultural practices [1]. Embedding sustainability principles within these systems minimizes negative life cycle impacts while maximizing benefits across environmental, social, and economic dimensions [2].

In technology-driven sectors, these ecosystems facilitate innovation, job creation, and economic growth. A holistic understanding of regional entrepreneurial ecosystems considers the interplay of socioeconomic, institutional, and informational factors influencing urban entrepreneurship [3]. The promotion of innovation is exemplified by advancements in productivity and sustainability through smart farming technologies, which leverage technology to enhance agricultural practices [4].

Moreover, entrepreneurial ecosystems significantly contribute to social sustainability by ensuring economic growth aligns with social cohesion. Equitable distribution of digitalization benefits fosters inclusive innovation [5], emphasizing the need for ecosystems that prioritize social well-being along-

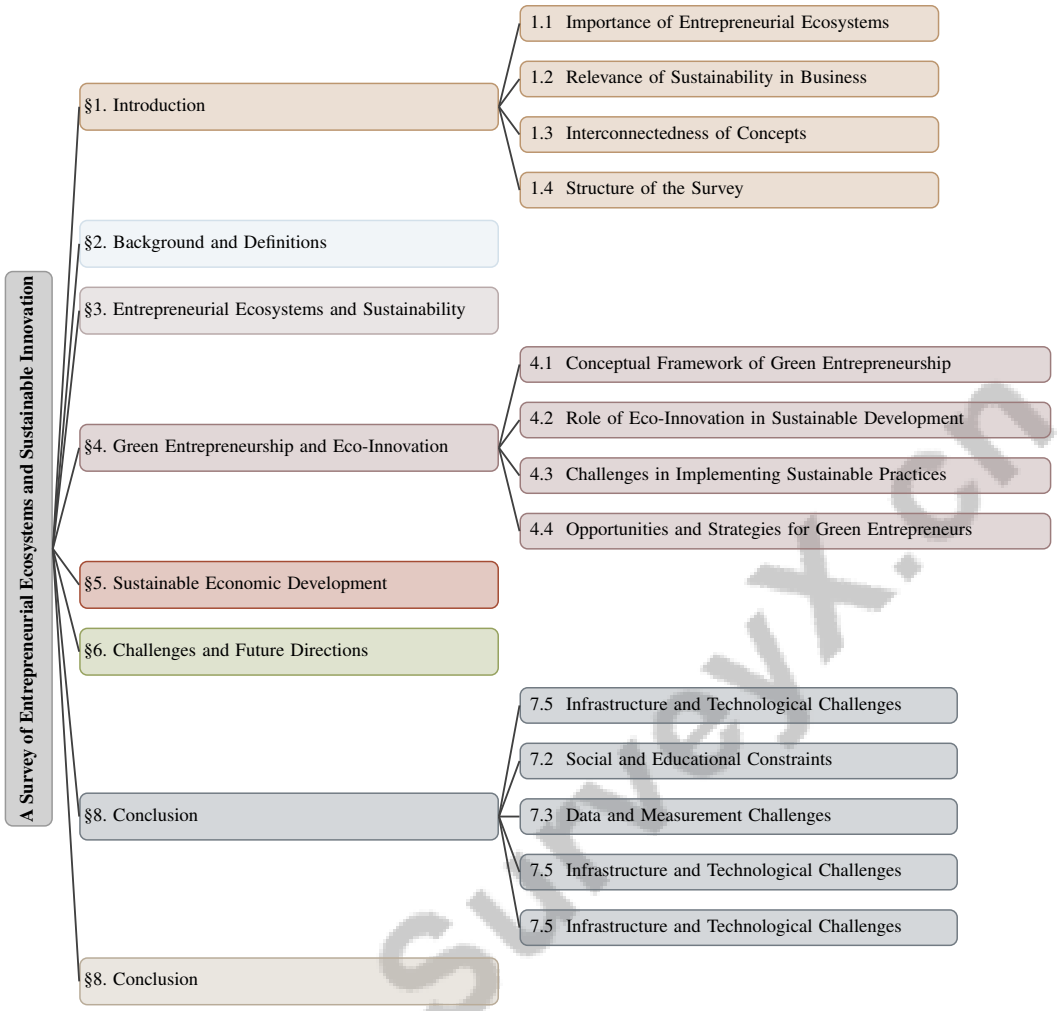

Figure 1: chapter structure

side economic objectives, particularly in light of socio-technological challenges and opportunities arising from digital advancements [6].

Grassroots initiatives within these ecosystems are vital for promoting sustainability in design processes, influencing existing methods, and encouraging sustainable practices [7]. The role of digital procurement tools in enhancing efficiency and sustainability in supply chain management further highlights the innovative capacity of these ecosystems [8]. Additionally, the resilience of supply chains, reliant on complex interconnected networks, underscores the importance of entrepreneurial ecosystems in fostering innovation and supporting sustainable practices [9].

Educational institutions and research centers within entrepreneurial ecosystems enhance research outputs related to sustainable development, promoting sustainability and supporting business practices [10]. By generating new knowledge and fostering skill development, they bolster the ecosystem's capacity to innovate and adapt to evolving environmental and societal needs. Understanding structural changes within social-ecological systems is crucial for transformations toward sustainability [11].

The integration of community relationships, self-organization, and social capital is essential for fostering sustainable practices within ICT4D, illustrating the role of entrepreneurial ecosystems in promoting sustainability [12]. Aligning financial market incentives with carbon emissions disincentives is necessary to mitigate global warming, underscoring the role of financial organizations in decarbonizing human life [13]. The significance of these ecosystems in promoting innovation and sustainable business practices is further emphasized by the need for new methodologies to analyze

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embodied energy flows, which are crucial for understanding energy consumption in sustainability efforts [14].

Furthermore, sustainability in software product line engineering (SPL) significantly enhances economic, social, and environmental outcomes, aligning with entrepreneurial ecosystem goals [15]. Resource usage awareness is vital in digital transformation, reflecting the importance of these ecosystems in promoting innovation and sustainable practices [16]. Blockchain-enabled tokenization enhances investment liquidity, transparency, and efficiency in financing infrastructure projects, particularly within energy sectors, showcasing the innovative potential of these ecosystems [17].

1.2 Relevance of Sustainability in Business

Sustainability is a pivotal aspect of contemporary business practices, serving as a cornerstone for aligning economic growth with environmental stewardship and societal well-being. In developing countries, the significance of sustainability is amplified by challenges such as the COVID-19 pandemic and limited international financial support, necessitating robust strategies to foster resilience and growth [18]. As consumer awareness of social responsibility rises, the demand for sustainable practices intensifies, influencing supply chain dynamics and corporate strategies [19].

The role of sustainability in business extends beyond compliance; it is integral to maintaining competitiveness and ensuring long-term success. The reliability of Environmental, Social, and Governance (ESG) scores is crucial for guiding investment decisions, yet incomplete reporting can lead to resource misallocation, highlighting the need for transparency in sustainability metrics [20]. Moreover, the inadequacy in defining sustainability, particularly regarding natural resource consumption, often leads to confusion with stability, emphasizing the need for precise definitions in resource management and strategic planning [21].

In the food industry, sustainability enables consumers to make informed choices that are both nutritious and environmentally sound, reinforcing its importance in fostering informed consumer behavior and supporting sustainable food systems [22]. This aligns with broader global objectives like the Sustainable Development Goals (SDGs), which advocate for sustainable economic, social, and environmental impacts.

In technology and software development, sustainability considerations are vital for addressing economic, social, and environmental factors critical for long-term success. Incorporating sustainability into requirements engineering ensures the development of technological solutions that consider societal impacts. Furthermore, sustainability in scientific computing is imperative for maintaining research productivity while mitigating greenhouse gas emissions, aligning with modern business practices [16].

Region-specific challenges in achieving sustainable development goals highlight the necessity for tailored sustainability strategies in business practices [23]. Innovative financial models, such as blockchain-enabled tokenization, demonstrate the potential to democratize investment opportunities and enhance infrastructure financing efficiency, supporting sustainability efforts [17]. Embedding sustainability into business strategies is imperative for achieving long-term success, contributing to economic objectives, and positioning businesses as leaders in the transition toward a more equitable and sustainable future.

1.3 Interconnectedness of Concepts

The intricate interplay between entrepreneurial ecosystems, sustainability, and innovation is pivotal in shaping contemporary business landscapes, fostering environments conducive to sustainable growth and development. Entrepreneurial ecosystems, characterized by networks of entrepreneurs, investors, and policymakers, nurture innovation that aligns with sustainability goals. The integration of sustainability into these ecosystems is exemplified by technologies like Genesis, which combines solar energy with older server technology to enhance sustainability [24]. This underscores the role of technological innovation in promoting sustainable practices.

The interconnectedness of these concepts is further emphasized by frameworks categorizing research into areas such as pervasive connectivity, sustainability, and demographic inclusion, highlighting their interrelatedness [25]. This categorization underscores the necessity for holistic strategies that integrate these elements to address modern challenges effectively. Integrating thermodynamic concepts into

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economic analysis, viewing the economy as an out-of-equilibrium system, illustrates the need for continuous energy and matter flows, aligning with sustainability objectives [2].

Community-driven initiatives also play a crucial role in promoting sustainability, as demonstrated by integrating grassroots approaches with traditional methods, leading to more effective solutions [6]. The interconnectedness of procurement processes and sustainability metrics highlights the necessity for integrated approaches to address modern supply chain challenges [8].

Understanding resource allocation dynamics, rather than mere availability, is crucial in grasping the interconnectedness of these concepts [26]. A novel mathematical definition of sustainability, focusing on the structural characteristics of resource consumption networks, underscores the importance of integrating these elements into cohesive strategies [21]. This integration is exemplified in software product lines (SPL), where economic, social, and environmental sustainability aspects contribute to each other's success [15].

Digital transformation, particularly in reducing greenhouse gas emissions in scientific computing, demonstrates the interconnectedness of sustainability and innovation, showcasing how these concepts contribute to mutual success [16]. The necessity for innovative policy mechanisms to achieve sustainability and development aims cost-effectively further highlights the interrelated nature of these concepts [18].

1.4 Structure of the Survey

This survey provides a comprehensive analysis of the interplay between entrepreneurial ecosystems, sustainability, and innovation. It begins with an introduction establishing the importance of entrepreneurial ecosystems in fostering sustainable innovation and entrepreneurship, discussing the relevance of sustainability in today's business environment and exploring the interconnectedness of core concepts.

Following the introduction, Section 2 delves into background and definitions, offering detailed explanations of core concepts central to this survey. This examination includes essential concepts such as "entrepreneurial ecosystem," "sustainability," and "sustainable innovation," alongside an exploration of their historical development and contextual evolution, drawing from interdisciplinary insights in sustainability education and historical analysis. The aim is to clarify varying interpretations of sustainability, which have emerged from diverse theoretical foundations and critiques, particularly concerning social, economic, and environmental dimensions, as well as the historical context shaping these discussions [27, 28]. Challenges in defining and measuring these concepts are also addressed.

Section 3 examines the role of entrepreneurial ecosystems in promoting sustainability, highlighting how these ecosystems create supportive environments for businesses prioritizing ecological balance and social responsibility. This section includes case studies and examples illustrating successful sustainable innovation within entrepreneurial ecosystems, as well as frameworks connecting these ecosystems with sustainability.

In Section 4, the focus shifts to green entrepreneurship and eco-innovation, exploring the concept of green entrepreneurship, emphasizing eco-friendly practices, and analyzing the role of eco-innovation in driving sustainable development. Challenges and opportunities faced by green entrepreneurs in implementing sustainable practices are discussed, alongside strategies for overcoming these challenges.

Section 5 addresses sustainable economic development, aiming for long-term economic growth without compromising environmental health or societal well-being. This section explores the relationship between sustainable entrepreneurship and economic development, examining their contributions to achieving sustainability goals, and highlights innovative business models and sector-specific contributions to sustainability.

The survey concludes with Section 6, identifying key challenges faced by entrepreneurial ecosystems in fostering sustainable innovation and entrepreneurship. This section discusses potential future directions and research areas that could enhance the effectiveness of these ecosystems in promoting sustainability, addressing infrastructure, technological, social, educational, and data-related challenges, while identifying emerging trends and future research directions.

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Finally, the conclusion summarizes the main findings, reiterating the interconnectedness of entrepreneurial ecosystems, sustainability, and innovation. It highlights the critical need to cultivate supportive environments for sustainable entrepreneurship and eco-innovation, which are essential for achieving both long-term economic growth and environmental sustainability, as evidenced by research indicating that integrating sustainability concerns into business practices yields positive outcomes across various regions facing unique challenges [27, 29, 23].The following sections are organized as shown in Figure 1.

2 Background and Definitions

2.1 Core Concepts and Definitions

The framework comprising entrepreneurial ecosystems, sustainability, sustainable innovation, sustainable entrepreneurship, green entrepreneurship, eco-innovation, and sustainable economic development is crucial for promoting ecological balance and social responsibility. This framework highlights the interconnectedness of stakeholders within entrepreneurial ecosystems, necessitating integrated resource allocation and governance to foster economic growth alongside environmental stewardship. Stakeholders can navigate the complexities of these ecosystems to implement sustainable practices that contribute to enduring prosperity and resilience on both local and global scales [26, 30, 28, 31, 32].

2.1.1 Entrepreneurial Ecosystems

Entrepreneurial ecosystems are intricate networks of stakeholders, including entrepreneurs, investors, educational institutions, and policymakers, facilitating resource exchange and fostering environments conducive to innovation and sustainability. Effective resource mobilization is critical for supporting new ventures and innovation [26]. However, the lack of a comprehensive evaluation framework for these ecosystems in urban settings contributes to regional disparities in entrepreneurial activities [3]. Understanding strategic energy flows is essential for ensuring sustainability and energy security within these ecosystems [14].

2.1.2 Sustainability and Sustainable Innovation

Sustainability integrates environmental, social, and economic dimensions to ensure long-term ecological balance and societal well-being [33]. In sectors like ICT4D, barriers can impede achieving sustainability outcomes [12]. Sustainable innovation focuses on minimizing negative environmental impacts and enhancing social responsibility, thereby improving economic performance, as seen in optimized supply chain management for sustainable production [9].

2.1.3 Sustainable Entrepreneurship and Green Entrepreneurship

Sustainable entrepreneurship merges social and environmental objectives with economic goals, contributing to sustainable development [19]. Green entrepreneurship emphasizes eco-friendly business practices, aiming to reduce environmental impact through sustainable models like renewable energy adoption and biodegradable waste management [34].

2.1.4 Eco-Innovation

Eco-innovation involves creating new products or processes that reduce environmental impact, enhance resource efficiency, and promote social well-being through innovative technologies and practices aligned with sustainability objectives [21]. It is pivotal in advancing sustainable entrepreneurship by facilitating the creation of sustainable offerings [13].

2.1.5 Sustainable Economic Development

Sustainable economic development seeks long-term growth without compromising environmental health or societal well-being. It involves adopting innovative business models, including renewable energy and biodegradable waste management, aligning with thermodynamic principles that emphasize energy and matter conservation [35, 2]. In agroecosystems, sustainability indicators are vital for maintaining ecological balance [1].

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2.2 Historical Context and Evolution

The evolution of entrepreneurial ecosystems and sustainability reflects an understanding of broader economic systems where interactions among actors like entrepreneurs, investors, and institutions drive innovation and economic development [3]. These ecosystems have historically adapted to societal needs, technological advancements, and shifts in economic paradigms.

Sustainability has evolved from a focus on environmental conservation to a more holistic approach incorporating social and economic dimensions, as seen in sustainable management practices across sectors like agriculture [1]. This shift is driven by the recognition of global challenges like climate change and resource depletion, supported by methodologies that integrate environmental, social, and economic dimensions into business decision-making, such as strategic energy flow analysis [14].

Educational institutions and research centers have become pivotal in generating knowledge, fostering skill development, and driving innovation in sustainable development [10]. The historical context of entrepreneurial ecosystems and sustainability illustrates a complex interplay among economic, social, and environmental factors, emphasizing how these interconnected elements influence the growth and sustainability of entrepreneurial activities across regions [31, 26, 32].

2.3 Challenges in Definition and Measurement

Defining and measuring the impact of entrepreneurial ecosystems and sustainability is challenging due to their multifaceted nature and the lack of universally accepted criteria. The absence of rigorous sustainability criteria complicates efforts to create coherent frameworks that effectively integrate environmental, social, and economic dimensions [21]. This complexity is exacerbated by missing Environmental, Social, and Governance (ESG) data, which undermines ESG assessments and affects investment decisions [20].

The integration of social networks into sustainability assessments remains complex, as these networks significantly influence outcomes but are difficult to quantify and incorporate into existing frameworks [21]. Subjective evaluations due to varying frameworks and analyst biases hinder standardized sustainability assessments across organizations and sectors [36]. Additionally, the lack of comprehensive methodologies for evaluating circularity within Circular Economy practices poses challenges for sustainable business model implementation.

Technological advancements, particularly in AI and IoT-enabled systems, introduce significant measurement challenges due to high energy consumption and diverse regulatory frameworks across industries. These challenges necessitate thorough assessments of their environmental impacts, as seen in sectors like agriculture, finance, and healthcare [37, 38, 39, 40].

A collaborative approach that integrates diverse stakeholder perspectives and establishes standardized definitions and metrics is essential for effective sustainability assessment and reporting. This strategy enhances the reliability of corporate sustainability evaluations by mitigating subjectivity in data and analysis, leveraging advanced methodologies such as Explainable Natural Language Processing to develop a cohesive understanding of ESG criteria [41, 42, 36]. Innovative data collection and analysis methodologies are crucial for facilitating the transition towards sustainable economic development, ensuring that technological advancements align with sustainability objectives.

In recent years, the examination of entrepreneurial ecosystems has gained significant attention, particularly regarding their role in promoting sustainability. Understanding these ecosystems requires a comprehensive analysis of their hierarchical structures and the various initiatives that drive them. Figure 2 illustrates the hierarchical structure of entrepreneurial ecosystems and their contribution to sustainability. This figure categorizes key initiatives found in case studies and examples, such as the Agro 4.0 initiative and innovations within the energy sector. Furthermore, it explores the interconnections and frameworks that underpin these ecosystems, including sustainability metrics and economic perspectives. By examining these elements, we can better appreciate how entrepreneurial ecosystems function and their potential impact on sustainable development.

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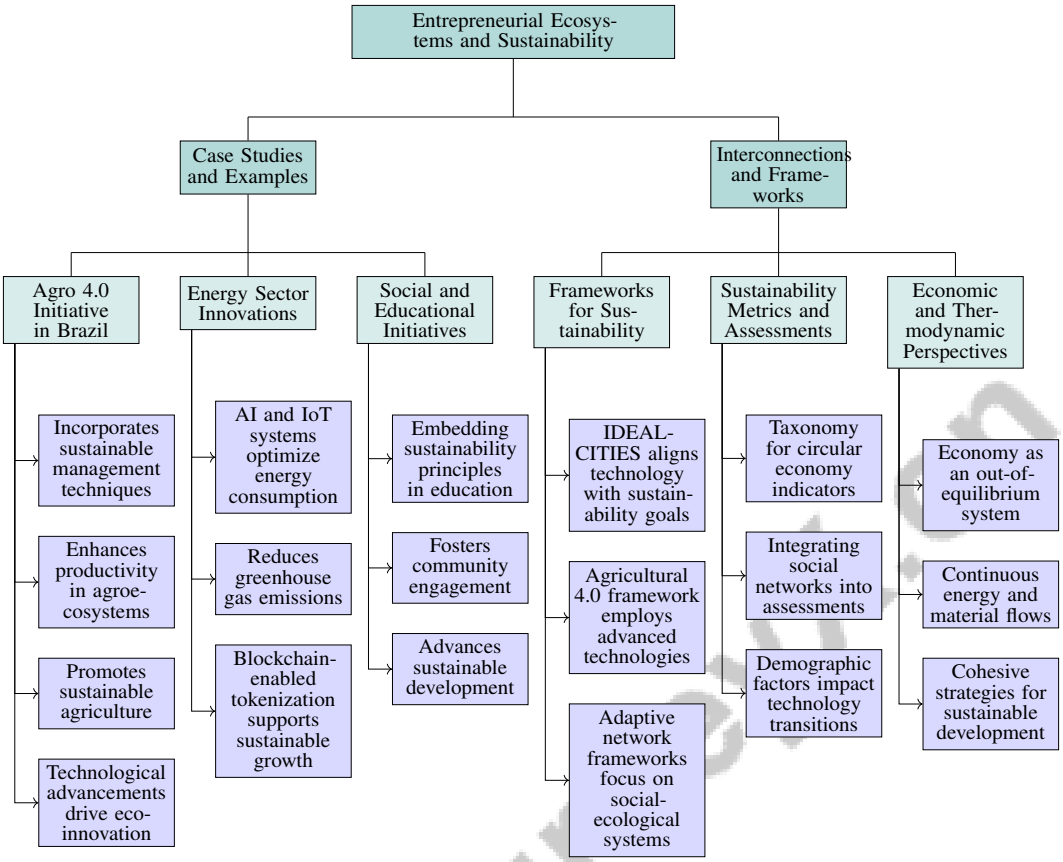

Figure 2: This figure illustrates the hierarchical structure of entrepreneurial ecosystems and their contribution to sustainability. It categorizes key initiatives in case studies and examples, such as the Agro 4.0 initiative and energy sector innovations, and explores interconnections and frameworks, including sustainability metrics and economic perspectives.

3 Entrepreneurial Ecosystems and Sustainability

3.1 Case Studies and Examples

Entrepreneurial ecosystems significantly contribute to sustainable innovation by integrating diverse stakeholders, facilitating collaboration, and promoting resource and knowledge exchange [43]. The Agro 4.0 initiative in Brazil exemplifies this by incorporating sustainable management techniques in agroecosystems, enhancing productivity and promoting sustainable agriculture [1]. This initiative highlights the role of technological advancements in driving eco-innovation within agricultural sectors [4].

In the energy sector, the deployment of AI and IoT systems optimizes energy consumption and reduces greenhouse gas emissions, demonstrating the transformative impact of technology on sustainability [43]. Blockchain-enabled tokenization further supports sustainable economic growth by enhancing investment liquidity, transparency, and efficiency in infrastructure development [13].

Social and educational initiatives also play a pivotal role in advancing sustainability within entrepreneurial ecosystems. Embedding sustainability principles in educational practices fosters community engagement and sustainable development [18].

3.2 Interconnections and Frameworks

The interconnections within entrepreneurial ecosystems are crucial for fostering sustainable innovation and economic development. These ecosystems, comprising entrepreneurs, investors, pol-

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icymakers, and educational institutions, facilitate resource exchange and innovation. Integrating sustainability into these ecosystems is essential for achieving long-term economic and environmental goals [44].

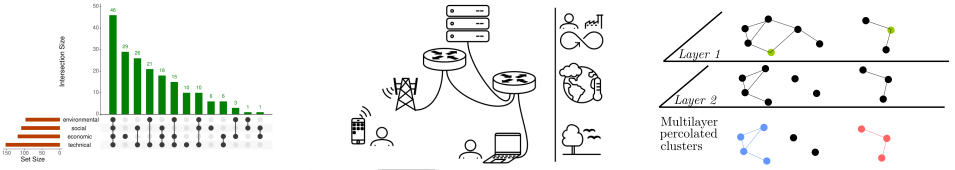
Frameworks like IDEAL-CITIES illustrate how aligning technological advancements with sustainability goals can enhance ecosystem sustainability [12]. In agriculture, the Agricultural 4.0 framework employs advanced technologies such as precision agriculture and AI to improve productivity and sustainability, addressing challenges posed by population growth and climate change while ensuring food security and resource preservation [39, 45, 46, 1].

Adaptive network frameworks provide a comprehensive perspective on sustainability transformations, focusing on structural changes within social-ecological systems [11]. These frameworks emphasize the importance of a systems-oriented approach to understanding complex stakeholder interactions in promoting sustainability.

A taxonomy for circular economy indicators enhances the understanding of sustainability metrics by categorizing indicators based on implementation levels and performance metrics [47]. This underscores the need for standardized definitions and metrics in assessing sustainability efforts.

Integrating social networks into sustainability assessments is vital, as they enhance social capital and community resilience [12]. A framework visualizing board member connections illustrates how social ties influence corporate governance, highlighting the collaborative approaches needed to address sustainability challenges [48].

Demographic factors significantly impact technology transitions, with frameworks modeling technology diffusion providing insights into innovation dynamics within entrepreneurial ecosystems [49]. Additionally, applying thermodynamic concepts to economic analysis views the economy as an out-of-equilibrium system requiring continuous energy and material flows, aligning with sustainability objectives [2]. This perspective stresses the need for cohesive strategies integrating environmental, social, and economic dimensions for sustainable development.



(a) Intersection Size[50] (b) Network Infrastructure and Connectivity[51] (c) Multilayer Percolated Clusters[52]

Figure 3: Examples of Interconnections and Frameworks

In Figure 3, the visual exploration of "Entrepreneurial Ecosystems and Sustainability; Interconnections and Frameworks" depicts the components within an entrepreneurial ecosystem that foster sustainability. The "Intersection Size" image illustrates the multifaceted nature of sustainability across environmental, social, economic, and technical categories. The "Network Infrastructure and Connectivity" image highlights the importance of robust infrastructure for sustainable entrepreneurial activities, while the "Multilayer Percolated Clusters" image demonstrates the complexity of networked relationships through interconnected nodes. Together, these images provide a comprehensive framework for understanding how interconnected systems can drive sustainability within entrepreneurial contexts [50, 51, 52].

4 Green Entrepreneurship and Eco-Innovation

4.1 Conceptual Framework of Green Entrepreneurship

Green entrepreneurship encompasses eco-friendly practices across sectors such as technology, design, finance, and community engagement. It emphasizes entrepreneurial ecosystems that facilitate stakeholder interactions and climate awareness, integrating environmental, social, and economic sustainability dimensions. This interdisciplinary approach necessitates innovative strategies and collaboration to foster sustainable entrepreneurial behaviors in response to climate challenges [31, 56, 29, 28].

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Method Name	Interdisciplinary Approach	Community Engagement	Innovative Strategies
ICP[53]	Technology Integration	Citizen Participation	Iot Devices
HAm-PVA[54]	Biodegradable Polymers	-	Biodegradable Materials
FIN4[55]	Multiple Dimensions Integration	Stakeholder Engagement Workshops	Multi-dimensional Token

Table 1: Overview of interdisciplinary approaches, community engagement, and innovative strategies in green entrepreneurship methods. This table highlights the integration of technology, biodegradable materials, and multi-dimensional finance systems in fostering sustainable business practices.

Business models prioritizing environmental sustainability alongside social and economic objectives are crucial.

The IDEAL-CITIES platform exemplifies green entrepreneurship by optimizing resource usage through real-time data, promoting eco-friendly practices [53]. Sustainable IoT device design, focusing on user education and device longevity, further illustrates technological innovation's role in sustainability [57]. The use of sustainable materials, such as amyloid fibrils for biodegradable bioplastics, highlights eco-friendly business practices in materials production [54]. In finance, a socio-ecological finance system with a multi-dimensional token economy aligns financial innovation with sustainability objectives [55].

Community engagement is integral to this framework. Self-determination theory applied in community-engaged learning underscores the roles of competence, relatedness, and autonomy in fostering sustainable business practices [58]. Grassroots initiatives promoting eco-friendly design demonstrate community-driven approaches to sustainable entrepreneurship [59]. Green Coding integrates sustainable methodologies into programming, exemplifying eco-friendly practices in software development [60]. Open-source principles applied to software, hardware, and education foster sustainable innovation [61]. Research categorization into environmental and ethical dimensions in Creative-AI highlights the importance of aligning technological advancements with sustainability goals [5].

This framework emphasizes eco-friendly practices across sectors and disciplines, promoting innovative practices that incorporate environmental sustainability. As illustrated in Figure 4, the conceptual framework of green entrepreneurship highlights key elements such as eco-friendly practices, sustainable finance, and community engagement. Each component integrates various strategies and methodologies to promote environmental sustainability across different sectors. Table 1 presents a comparative analysis of various methods within the conceptual framework of green entrepreneurship, focusing on interdisciplinary approaches, community engagement, and innovative strategies. Green entrepreneurship significantly shapes business models that foster ecological balance and enhance societal well-being. Supported by frameworks like the Theory of Planned Behavior, it reveals how climate awareness influences sustainable entrepreneurial intentions and underscores the interconnectedness of various actors in fostering sustainable ventures. Addressing theoretical and empirical gaps through future research is crucial for overcoming regional challenges and achieving sustainable development goals [31, 29, 23].

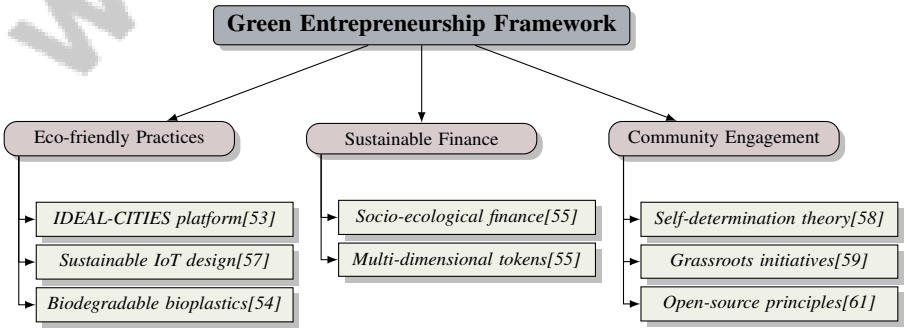

Figure 4: This figure illustrates the conceptual framework of green entrepreneurship, highlighting key elements such as eco-friendly practices, sustainable finance, and community engagement. Each component integrates various strategies and methodologies to promote environmental sustainability across different sectors.

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4.2 Role of Eco-Innovation in Sustainable Development

Eco-innovation advances sustainable development by creating products and processes that minimize environmental impact while enhancing economic and social well-being. It optimizes resource efficiency and minimizes carbon emissions, essential for sustainability goals. Green ammonia in power generation and as a hydrogen carrier exemplifies eco-innovation's role in sustainable products [62]. Tools like the Scale-Score integrate nutritional and environmental scores, influencing consumer behavior towards sustainable consumption [22].

Eco-innovation addresses resource depletion and climate change challenges through innovative technologies and practices aligned with sustainability objectives. In information and communication technology, AI and IoT-enabled systems enhance energy efficiency and reduce carbon emissions, promoting environmentally friendly practices and tackling climate change complexities. AI facilitates sustainable production methods and improves resource management, while IoT systems enable real-time energy monitoring and optimization. It is essential to integrate ecological considerations into their development to ensure long-term sustainability [63, 40, 64]. The circular economy model emphasizes waste minimization and resource efficiency, supporting long-term economic growth.

In education, eco-innovation enhances sustainability education, fostering a deeper understanding of sustainable practices among students. Interdisciplinary collaborations, like integrating historical perspectives into ICT for Sustainability education, increase student engagement and relevance to future careers. Incorporating green and sustainable principles into software engineering curricula equips students to contribute to a sustainable future [65, 27, 66, 67, 68]. By integrating sustainability principles into educational practices, eco-innovation fosters community engagement and supports sustainable development.

4.3 Challenges in Implementing Sustainable Practices

Green entrepreneurs face challenges in adopting sustainable practices, often due to complexities in integrating ecological considerations with business objectives. A primary challenge is the lack of empirical validation and a comprehensive framework in Business Process Management (BPM) addressing cultural and strategic dimensions for effectively implementing Green BPM practices [69]. The integration of IoT technologies in urban sustainability efforts presents challenges, particularly concerning data privacy and security, hindering effective implementation [70]. These challenges necessitate robust frameworks for secure and efficient IoT deployment in sustainability initiatives.

As depicted in Figure 5, this figure illustrates the primary challenges in implementing sustainable practices, highlighting distinct areas such as Green BPM, IoT in urban sustainability, and green software engineering. Each category outlines specific issues that need addressing to enhance sustainability efforts. Furthermore, green software projects face limitations in existing methodologies, like the PGQ method, which may not cover all technical aspects influencing software projects' environmental impact. Comprehensive approaches addressing green software engineering's technical nuances are necessary [71]. These challenges highlight the need for integrated strategies addressing sustainability's complex dimensions in business practices, considering diverse regional progress and unique obstacles identified in sustainability research, including social, political, structural, institutional, and economic factors [41, 23, 36, 42]. By addressing these obstacles, green entrepreneurs can better align operations with sustainability goals, contributing to long-term ecological balance and societal well-being.

4.4 Opportunities and Strategies for Green Entrepreneurs

Green entrepreneurship aligns business objectives with environmental stewardship and social responsibility, offering numerous opportunities for innovation within sustainability. The global emphasis on sustainable development goals (SDGs) provides fertile ground for green entrepreneurs to address environmental challenges while creating economic value [72].

A significant opportunity lies in adopting circular economy models, emphasizing waste reduction and resource optimization. Circular economy principles promote resource use through closed-loop systems that minimize waste and maximize material utilization [35]. Integrating these principles into business models allows green entrepreneurs to achieve sustainability objectives while enhancing resource efficiency and reducing environmental impact.

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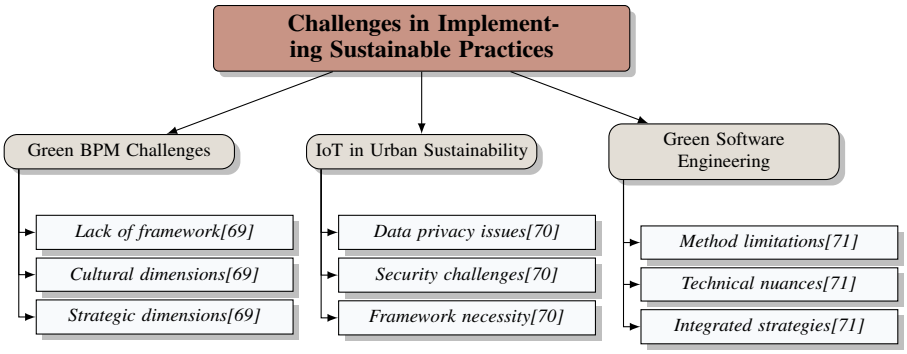

Figure 5: This figure illustrates the primary challenges in implementing sustainable practices, highlighting distinct areas such as Green BPM, IoT in urban sustainability, and green software engineering. Each category outlines specific issues that need addressing to enhance sustainability efforts.

Digital technologies, like blockchain and AI, present further opportunities for enhancing business models. Blockchain-enabled tokenization democratizes investment opportunities, increases transparency, and improves financing efficiency for sustainable infrastructure projects [17]. AI-based predictive analytics optimize resource usage and minimize environmental impact, supporting sustainable business practices [34].

To navigate challenges in implementing sustainable practices, green entrepreneurs must adopt innovative strategies addressing barriers like limited capital access, regulatory constraints, and market competition. Collaborative partnerships among stakeholders, including governments, businesses, and research institutions, are essential for creating an environment conducive to green entrepreneurship [12]. These collaborations facilitate knowledge and resource exchange, enabling green entrepreneurs to overcome challenges and drive sustainable innovation.

Supportive policy frameworks enhance green entrepreneurs' capacity to implement sustainable practices effectively. Policies incentivizing sustainable business models, like tax credits for renewable energy adoption or subsidies for eco-friendly innovations, provide vital support. Creating awareness and fostering a culture of sustainability among consumers can drive demand for sustainable products and services, opening new market opportunities [19].

Investing in education and skill development is another critical strategy for overcoming challenges. Educational institutions and research centers generate knowledge and foster skills necessary for sustainable innovation [10]. By equipping future entrepreneurs with tools and knowledge for sustainable business models, these institutions contribute to the long-term success of green entrepreneurship.

5 Sustainable Economic Development

Exploring the synergy between sustainable practices and economic growth necessitates harmonizing various frameworks and initiatives to achieve shared objectives. The Sustainable Development Goals (SDGs) provide a comprehensive framework that aligns environmental stewardship with economic growth. This section examines the mechanisms linking SDGs with economic growth, emphasizing innovative infrastructure and sustainable practices that foster resilience and prosperity.

5.1 Linking Sustainable Development Goals with Economic Growth

Aligning SDGs with economic growth is vital for sustainable development, integrating environmental, social, and economic dimensions. Innovative infrastructure, such as blockchain-enabled tokenization and drones, enhances investment liquidity and operational efficiency in sectors like energy, water management, and transportation [17, 73, 74]. Constructed wetlands exemplify the benefits of integrating SDGs with economic growth by improving water quality and ecosystem services, contributing to tourism and increased land value [73].

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Urban planning integrating sustainability principles is crucial for achieving SDGs and economic growth. Green infrastructure, such as green roofs and urban forests, enhances resilience, reduces energy consumption, and mitigates the urban heat island effect, attracting investments and generating employment in emerging green sectors [7, 23]. The transition towards a circular economy, emphasizing resource efficiency and waste reduction, aligns with SDG 12 and stimulates innovation in product design and business models [61, 75]. Technologies like drones and AI optimize product lifecycle management, fostering a resilient and inclusive economic landscape [74, 76].

Digital technologies advance SDGs and economic growth, with social sustainability in digital transformation being crucial. Countries prioritizing social sustainability, such as Finland and Denmark, show enhanced SDG performance. Open-source models facilitate technology access, especially in underdeveloped areas, contributing to global development [61, 77]. Smart city technologies, including IoT and AI, optimize resource management and enhance urban service delivery [78].

5.2 Innovative Business Models and Circular Economy

Innovative business models incorporating sustainability principles are key to advancing the circular economy, which emphasizes resource efficiency and waste reduction. This model promotes closed-loop cycles that enhance resource productivity and reduce environmental impact [35]. Digital technologies like blockchain and IoT support these models by enhancing supply chain transparency and providing real-time data for resource optimization [17, 70].

As illustrated in Figure 6, the integration of these innovative business models with the circular economy is crucial. The figure highlights digital technologies, sustainable materials, and collaborative consumption models as key components in promoting resource efficiency and waste reduction. Product-as-a-service models shift focus from ownership to service provision, encouraging product design for longevity and recyclability, ensuring materials are reused or recycled [69]. Developing sustainable materials, such as biodegradable bioplastics, exemplifies eco-friendly innovations reducing environmental impact [54]. Collaborative consumption models, enabling peer-to-peer resource sharing, reduce demand for new products and decrease environmental impact [59].

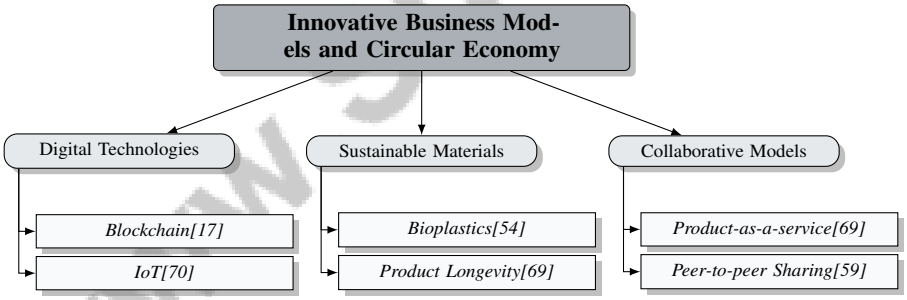

Figure 6: This figure illustrates the integration of innovative business models with the circular economy, highlighting digital technologies, sustainable materials, and collaborative models as key components in promoting resource efficiency and waste reduction.

5.3 Sector-Specific Contributions to Sustainability

Various sectors contribute significantly to sustainability and economic development by implementing innovative practices aligning with environmental, social, and economic goals. Collaboration between academia and industry, particularly in energy and technology, advances research and practical applications for achieving SDGs [79, 42]. Precision agriculture enhances productivity while minimizing environmental impact by integrating IoT and AI technologies for efficient resource use.

In energy, transitioning to renewable sources like solar and wind reduces fossil fuel reliance and greenhouse gas emissions [13]. Smart grid technologies optimize energy distribution and consumption. The manufacturing sector adopts circular economy principles, implementing closed-loop systems to reduce waste and increase material recyclability [35]. Sustainable materials like biodegradable bioplastics further reduce ecological footprints [54].

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The construction sector promotes sustainability by using sustainable materials and energy-efficient technologies, reducing urban development's environmental impact [73]. The financial sector advances sustainability by providing capital for green projects, with green finance instruments supporting environmental and social objectives [55]. These innovations facilitate scaling sustainable practices across sectors, contributing to ecological balance and economic growth.

6 Challenges and Future Directions

6.1 Infrastructure and Technological Challenges

The advancement of sustainable innovation within entrepreneurial ecosystems is significantly impeded by infrastructure and technological barriers. A notable challenge is the lack of centralized digital procurement tools, leading to fragmented methods that hinder real-time insights and environmental adaptability [8]. This fragmentation restricts effective resource management, complicating the implementation of sustainable practices. AI systems' environmental impact, due to their high computational demands, further exacerbates these challenges. Current carbon footprint assessment methods for AI, especially in banking, are inadequate, necessitating innovative strategies to align technological progress with sustainability goals [13]. Additionally, insufficient data on director connections and influence metrics limits understanding of board dynamics, crucial for sustainable decision-making [48].

Figure 10 illustrates the hierarchical structure of infrastructure and technological challenges impacting sustainable innovation, highlighting key areas such as digital procurement tools, the environmental impact of AI, and the regulatory and data challenges faced by organizations. Regulatory discrepancies between the United States and the European Union regarding ESG disclosures complicate sustainability assessments by affecting data quality and consistency [20]. This inconsistency poses challenges for businesses operating across diverse regulatory landscapes. Technological barriers also impede the implementation of network weaving and community-driven processes in ICT4D, limiting resilience and sustainable practices [12]. Furthermore, decentralized decision-making in supply chains often results in suboptimal outcomes, obstructing the integration of social responsibility and sustainability [19].

Consumer confusion due to multiple sustainability labels leads to price-based choices rather than informed decisions based on nutritional or environmental quality, highlighting the need for clear labeling [22]. Subjectivity in sustainability assessments, driven by data incompleteness and biases, complicates the evaluation of sustainable practices, particularly for SMEs facing uncertainties in supply chains, risking financial instability and hindering innovation [36, 9]. Moreover, the absence of comprehensive frameworks capturing technology's diverse impacts on sustainability presents a significant hurdle to advancing sustainable innovation [43]. Developing robust monitoring systems and technical expertise is essential for successful sustainable practices integration within entrepreneurial ecosystems.

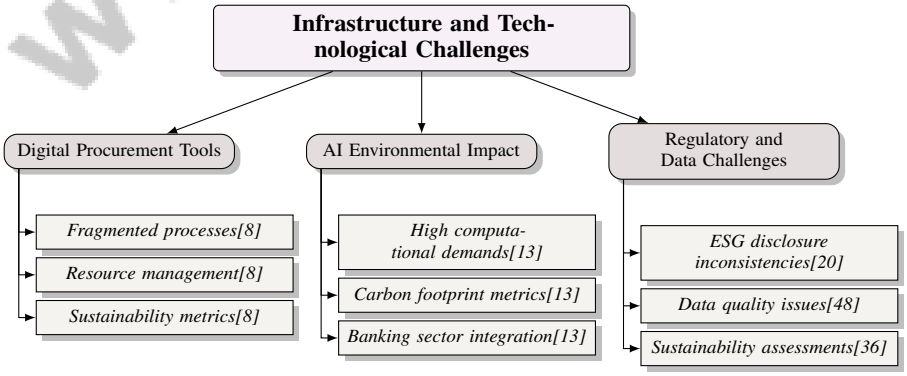

Figure 7: This figure illustrates the hierarchical structure of infrastructure and technological challenges impacting sustainable innovation, highlighting digital procurement tools, AI's environmental impact, and regulatory and data challenges.

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6.2 Social and Educational Constraints

Social and educational barriers significantly hinder the development of sustainable entrepreneurial ecosystems by affecting innovation capacity. A lack of awareness and understanding of sustainability principles, particularly in regions with traditional business practices, poses social constraints [12]. Educational barriers arise as institutions struggle to integrate sustainability into curricula, limiting the development of skills and knowledge necessary for driving sustainable innovation. The absence of interdisciplinary approaches exacerbates this issue, hindering students' ability to tackle complex sustainability challenges [10].

Current sustainability education frameworks often fail to address the dynamic nature of sustainability, encompassing environmental, social, and economic dimensions, restricting future entrepreneurs from developing innovative solutions aligned with sustainability objectives [43]. Social networks and community engagement are crucial for overcoming these barriers, yet their integration into sustainability initiatives remains complex due to their informal and difficult-to-quantify nature, limiting their potential to promote sustainable practices [21].

Addressing these constraints requires a collaborative approach involving educational institutions, policymakers, and community leaders. Enhancing awareness and understanding of sustainability principles can bolster entrepreneurial ecosystems' capacity to drive sustainable innovation. Creating interdisciplinary educational programs incorporating sustainability across various fields is vital for equipping future entrepreneurs with the skills necessary to tackle contemporary challenges. This integration enhances traditional curricula and aligns with the increasing need for sustainability-focused practices in engineering and computing disciplines [27, 80, 67].

6.3 Data and Measurement Challenges

Benchmark	Size	Domain	Task Format	Metric
EIKON[81]	6,529	Environmental Performance	Benchmarking	CO2 emissions, Energy use
CW-Benchmark[73]	2,000	Water Management	Cost-Benefit Analysis	Benefit-Cost Ratio, Net Present Value

Table 2: This table presents a comparative analysis of two representative benchmarks used in sustainability assessments, highlighting their size, domain, task format, and evaluation metrics. The benchmarks, EIKON and CW-Benchmark, are utilized in environmental performance and water management domains, respectively, providing insights into CO2 emissions, energy use, and cost-benefit analysis.

Challenges in data collection and measurement impede the assessment of sustainability initiatives, which is crucial for evaluating their impact. The fragmented nature of knowledge surrounding circular economy indicators leads to variability in definitions and a lack of a unified evaluation framework [47]. This fragmentation complicates the development of standardized metrics for sustainability assessments, hindering effective comparisons across contexts. Table 3 provides a detailed overview of representative benchmarks employed in sustainability assessments, illustrating the diversity in domains, task formats, and metrics used to evaluate environmental and economic performance.

Eliciting parameters for composite indices in sustainability assessments is challenging due to imprecision and the failure to capture sustainability's complexities, as existing models often oversimplify ecological and economic interactions [82, 2]. Diverse data collection methodologies and the absence of standardized criteria for evaluating fairness in sustainability metrics further complicate achieving precise assessments. The complex criteria involved in selecting sustainability indicators (SIs) and varied approaches across industries add to this complexity. While frameworks like Fuzzy-AHP and DEMATEL provide robust techniques for assessing SIs' relative importance, their static nature limits adaptability to evolving organizational contexts and sustainability priorities. Addressing these gaps is crucial for enhancing sustainability practices and achieving the Sustainable Development Goals across regions facing unique socio-economic and institutional challenges [41, 23].

The interplay of sustainability indicators complicates parameter elicitation for composite indices in sustainability assessments. Various methodologies, such as stakeholder interviews, questionnaires, and advanced analytical techniques like Fuzzy-AHP, often overlook critical issues of imprecision and the dynamic relationships between economic, social, and environmental criteria. This oversight can

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lead to inaccuracies in indices, hindering effective sustainability evaluation and decision-making. The subjective nature of data interpretation further complicates assessments, necessitating future research to enhance the robustness and adaptability of these indices to better reflect real-world sustainability dynamics [41, 82, 23, 37, 36]. Developing standardized definitions and metrics for these indices is essential to improve the reliability and comparability of sustainability assessments across diverse contexts.

6.4 Emerging Trends and Future Directions

The landscape of entrepreneurial ecosystems and sustainable innovation is continually evolving, presenting both challenges and opportunities for future research and development. A key trend is the growing emphasis on integrating digital technologies, such as AI, blockchain, and IoT, into sustainability initiatives. These technologies enhance resource efficiency, optimize operations, and drive sustainable innovation across various sectors [13].

The circular economy concept is gaining traction as a promising approach to sustainable development, emphasizing waste minimization and resource efficiency through closed-loop systems. This model offers significant opportunities for innovation in product design, business models, and supply chain management, aligning with sustainability objectives and supporting long-term economic growth [35].

The integration of social networks into sustainability assessments is increasingly important, as these networks influence sustainability outcomes and foster community resilience [12]. Developing novel frameworks for visualizing and analyzing these networks highlights their interconnectedness with corporate governance and sustainability [48].

Recognizing the importance of community engagement in promoting sustainability is also growing. Grassroots initiatives that blend traditional and innovative approaches have shown significant potential in addressing contemporary sustainability challenges [6]. These initiatives underscore the value of community-driven approaches in fostering sustainable development.

To address data collection and measurement challenges, innovative methodologies are needed to facilitate accurate sustainability assessments. Developing standardized definitions and metrics is crucial for ensuring the reliability and comparability of sustainability assessments across different contexts. Integrating advanced data analytics, including AI and IoT technologies, can significantly enhance the precision of sustainability assessments. This improvement aids in formulating impactful sustainability strategies and facilitates monitoring resource consumption and societal impacts, aligning corporate practices with the Sustainable Development Goals (SDGs). Furthermore, AI can help identify potential benefits and costs associated with sustainability initiatives, enabling organizations to make informed decisions that consider the broader implications of their technological implementations [40, 83, 37, 70, 64].

7 Conclusion

This section examines the complex interplay between entrepreneurial ecosystems and sustainable innovation, emphasizing the challenges and future directions crucial for enhancing these ecosystems' effectiveness in promoting sustainability. It addresses infrastructure and technological barriers and highlights emerging trends that offer potential pathways for future research and practice in sustainable entrepreneurship.

Entrepreneurial ecosystems and sustainable innovation are deeply interconnected, significantly influencing evolving business practices. A nuanced understanding of these systems is essential for fostering growth-oriented entrepreneurship and addressing theoretical gaps. Tailored policy interventions are necessary to support diverse ecosystem actors, shaping the future landscape of entrepreneurship and innovation [31, 26, 32, 30]. These ecosystems, characterized by dynamic stakeholder networks, prioritize ecological balance and social responsibility, contributing to long-term economic growth and sustainability goals.

Sustainability is now central to modern business practices, requiring alignment between economic growth and environmental stewardship. Integrating sustainability into business strategies enhances competitiveness and long-term success, aligning with the Sustainable Development Goals (SDGs). This integration necessitates proactive strategies and control systems to translate these goals into mea-

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surable corporate performance. Early planning for systemic changes is crucial to transitioning from traditional business models to sustainable pathways, addressing pressing challenges and establishing conditions for success beyond the 2030 Agenda [72, 84, 85].

The interconnectedness of entrepreneurial ecosystems, sustainability, and innovation underscores the need for holistic approaches integrating these elements into cohesive strategies for sustainable development. By fostering supportive environments for sustainable entrepreneurship and eco-innovation, stakeholders can advance economic viability, environmental stewardship, and social equity. This approach addresses unique regional challenges in achieving sustainable development goals, enhancing corporate sustainability initiatives by integrating diverse frameworks and standards, such as the UN's SDGs. Leveraging advanced analytical tools, like Explainable Natural Language Processing, can improve sustainability assessments, enabling informed decision-making [31, 26, 32, 30].

7.1 Infrastructure and Technological Challenges

Infrastructure and technological challenges significantly hinder sustainable innovation within entrepreneurial ecosystems. A critical issue is the lack of centralized digital procurement tools, leading to fragmented processes that impede real-time insights and adaptability to environmental changes [8]. This fragmentation limits effective sustainable practices due to inadequate resource management systems.

As illustrated in Figure 10, which depicts the hierarchical structure of these challenges, the interconnections between digital procurement tools, AI's environmental impact, and regulatory and data challenges become apparent. AI systems exert a substantial environmental impact due to their high computational demands, with current methods for assessing AI's carbon footprint, especially in the banking sector, proving inadequate. Innovative strategies are needed to align technological advancements with sustainability goals [13]. Additionally, the absence of comprehensive data on board director connections and influence metrics hampers understanding governance dynamics crucial for sustainable decision-making [48].

Regulatory inconsistencies, particularly between the United States and the European Union regarding Environmental, Social, and Governance (ESG) disclosures, complicate sustainability assessments by affecting data quality and consistency [20]. These discrepancies pose challenges for businesses operating within diverse regulatory frameworks.

Technological barriers also obstruct network weaving and community-driven processes in Information and Communication Technology for Development (ICT4D), limiting resilience and sustainable practices [12]. Decentralized decision-making in supply chains often leads to suboptimal outcomes, hindering the integration of social responsibility and sustainability [19]. Consumer confusion from multiple sustainability labels results in price-based decisions rather than informed choices based on nutritional or environmental quality, underscoring the need for clear labeling [22]. Subjectivity in sustainability assessments, driven by incomplete data and analyst biases, complicates the evaluation of sustainable practices, especially for small and medium-sized enterprises (SMEs) facing supply chain uncertainties that threaten financial stability and innovation [36, 9].

The lack of comprehensive frameworks to capture technology's diverse impacts on sustainability presents a significant barrier to advancing sustainable innovation [43]. Developing robust monitoring systems and technical expertise is essential for integrating sustainable practices within entrepreneurial ecosystems.

7.2 Social and Educational Constraints

Social and educational barriers significantly hinder the development of sustainable entrepreneurial ecosystems by affecting innovation capacity. Many regions, particularly those dominated by traditional business practices, face limited awareness and understanding of sustainability principles [12].

Educational institutions often struggle to integrate sustainability into their curricula, limiting the development of skills and knowledge necessary for sustainable innovation. The lack of interdisciplinary approaches exacerbates this issue, hindering students' abilities to address complex sustainability challenges [10]. Current frameworks are inadequate, often failing to address sustainability's dynamic

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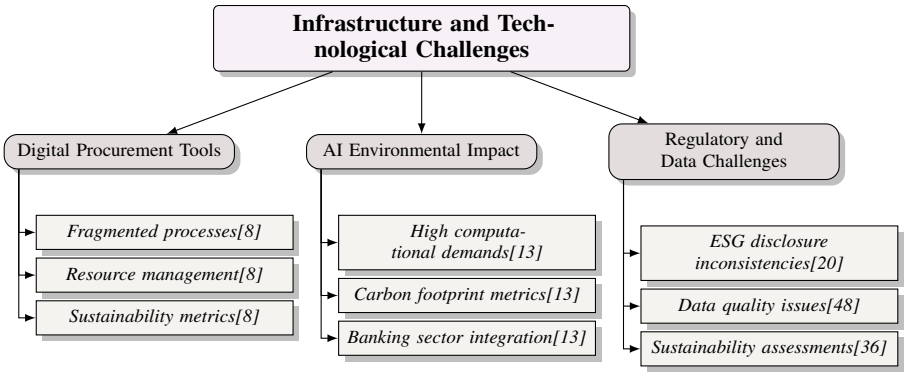

Figure 8: This figure illustrates the hierarchical structure of infrastructure and technological challenges impacting sustainable innovation, highlighting digital procurement tools, AI's environmental impact, and regulatory and data challenges.

nature, which includes environmental, social, and economic dimensions [43]. This restricts future entrepreneurs from developing innovative solutions aligned with sustainability objectives.

Social networks and community engagement are vital for overcoming these barriers, yet their integration into sustainability initiatives remains complex due to their informal and hard-to-quantify nature. This complexity limits leveraging social capital to promote sustainable practices within entrepreneurial ecosystems [21].

Addressing these constraints requires a collaborative approach involving diverse stakeholders, including educational institutions, policymakers, and community leaders. Enhancing awareness and understanding of sustainability principles can strengthen entrepreneurial ecosystems' capacity to drive sustainable innovation. Creating interdisciplinary educational programs that incorporate sustainability across various fields is crucial for equipping future entrepreneurs with the skills necessary to tackle contemporary challenges. This integration not only enhances traditional curricula, as seen in innovative collaborations between history and ICT for Sustainability education, but also aligns with the growing need for sustainability-focused practices in engineering and computing disciplines [27, 80, 67].

7.3 Data and Measurement Challenges

Benchmark	Size	Domain	Task Format	Metric
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Table 3: This table presents a comparative analysis of two representative benchmarks used in sustainability assessments, highlighting their size, domain, task format, and evaluation metrics. The benchmarks, EIKON and CW-Benchmark, are utilized in environmental performance and water management domains, respectively, providing insights into CO2 emissions, energy use, and cost-benefit analysis.

Significant challenges exist in data collection and measurement for assessing sustainability initiatives, which are crucial for evaluating their impact. The fragmented knowledge surrounding circular economy (CE) indicators leads to variability in definitions and a lack of a unified evaluation framework [47]. This fragmentation complicates developing standardized metrics for effective sustainability assessments and comparisons across contexts.

The elicitation of parameters for composite indices in sustainability assessments is complicated by imprecision and the failure to capture sustainability's complexities, as existing models often oversimplify ecological and economic interactions [82, 2]. Furthermore, diverse data collection methodologies and the absence of standardized criteria for evaluating fairness in sustainability metrics complicate achieving precise assessments. This situation is further complicated by the complex

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criteria involved in selecting sustainability indicators (SIs) and the varied approaches employed across industries. While frameworks like Fuzzy-AHP and DEMATEL provide robust techniques for assessing SIs' relative importance, their static nature limits adaptability to evolving organizational contexts and sustainability priorities [41, 23].

The subjective nature of data interpretation further complicates assessments, necessitating the development of standardized definitions and metrics to improve the reliability and comparability of sustainability assessments across diverse contexts [82, 23, 37, 36]. Addressing these gaps is crucial for enhancing sustainability practices and achieving the Sustainable Development Goals across regions, each facing unique socio-economic and institutional challenges [41, 23]. "

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7.4 Infrastructure and Technological Challenges

Sustainable innovation within entrepreneurial ecosystems is significantly challenged by infrastructure and technological barriers. The absence of centralized digital procurement tools results in fragmented processes, hindering real-time insights and adaptability to environmental changes [8]. This fragmentation leads to ineffective implementation of sustainable practices due to inadequate resource management systems.

Figure 10 illustrates the hierarchical structure of these infrastructure and technological challenges, emphasizing the critical areas of digital procurement tools, the environmental impact of AI, and the regulatory and data challenges that entrepreneurs face. AI systems have a substantial environmental impact, primarily due to their high computational demands. Current methods for assessing AI's carbon footprint, especially in the banking sector, are insufficient, necessitating innovative strategies to align technological advancements with sustainability objectives [13]. Moreover, the lack of comprehensive data on board director connections and influence metrics hinders understanding governance dynamics crucial for sustainable decision-making [48].

Regulatory inconsistencies, particularly between the United States and the European Union regarding Environmental, Social, and Governance (ESG) disclosures, complicate sustainability assessments by affecting data quality and consistency [20]. Such discrepancies pose challenges for businesses operating within diverse regulatory frameworks.

Technological barriers also hinder the implementation of network weaving and community-driven processes in Information and Communication Technology for Development (ICT4D), limiting resilience and sustainable practices [12]. Moreover, decentralized decision-making in supply chains often leads to suboptimal outcomes, hindering the integration of social responsibility and sustainability [19].

Consumer confusion due to multiple sustainability labels results in price-based decisions rather than informed choices based on nutritional or environmental quality, highlighting the need for clear labeling [22]. Subjectivity in sustainability assessments, driven by incomplete data and analyst biases, complicates the evaluation of sustainable practices, especially for small and medium-sized enterprises (SMEs) facing supply chain uncertainties that threaten financial stability and innovation [36, 9].

Furthermore, the lack of comprehensive frameworks capturing technology's diverse impacts on sustainability presents a significant barrier to advancing sustainable innovation [43]. Developing robust monitoring systems and technical expertise is essential for integrating sustainable practices within entrepreneurial ecosystems.

7.5 Infrastructure and Technological Challenges

In the context of sustainable innovation, understanding the infrastructure and technological challenges is paramount. These challenges are multifaceted and can significantly influence the adoption and effectiveness of innovative practices. Figure 10 illustrates the hierarchical structure of these challenges, highlighting key components such as digital procurement tools, the environmental impact of artificial intelligence, as well as regulatory and data challenges. This visual representation not only emphasizes the interconnectedness of these elements but also serves as a framework for analyzing how each component can either facilitate or hinder sustainable innovation efforts. By addressing these challenges systematically, stakeholders can better navigate the complexities of integrating new technologies into sustainable practices.

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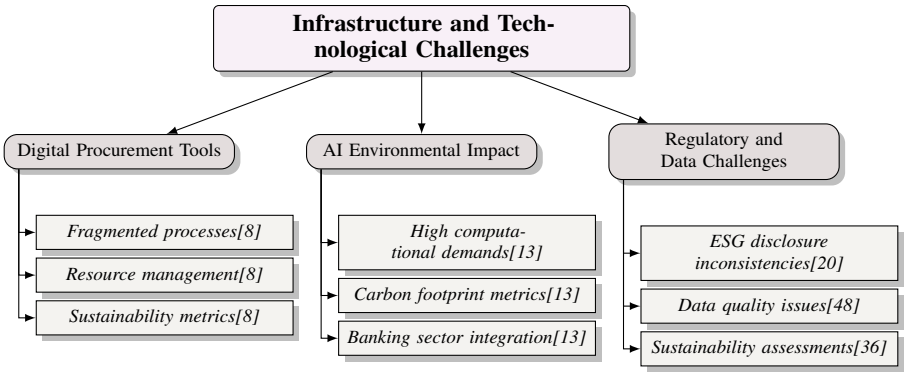

Figure 9: This figure illustrates the hierarchical structure of infrastructure and technological challenges impacting sustainable innovation, highlighting digital procurement tools, AI's environmental impact, and regulatory and data challenges.

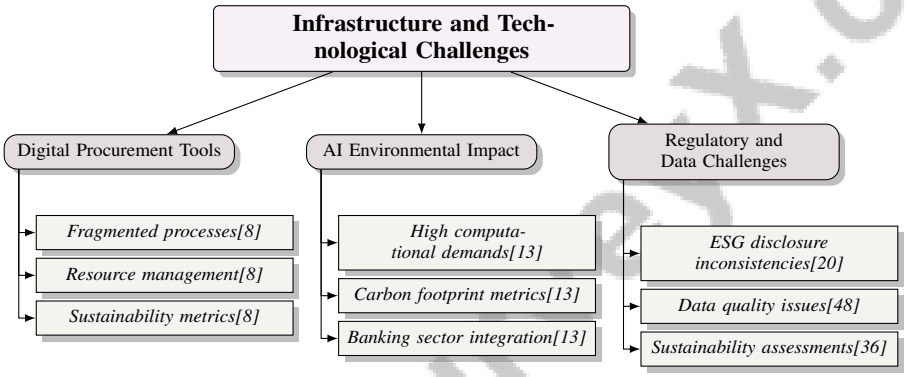

Figure 10: This figure illustrates the hierarchical structure of infrastructure and technological challenges impacting sustainable innovation, highlighting digital procurement tools, AI's environmental impact, and regulatory and data challenges.

8 Conclusion

The intricate relationship between entrepreneurial ecosystems, sustainability, and innovation forms the backbone of contemporary business strategies, driving both economic growth and environmental stewardship. Entrepreneurial ecosystems, with their dynamic networks of stakeholders, provide fertile ground for sustainable innovations that prioritize ecological integrity and social equity. The integration of sustainability into these ecosystems is not merely advantageous but essential for sustaining competitive advantage and aligning with global frameworks such as the Sustainable Development Goals (SDGs).

Enhancing the sustainability and resilience of ICT4D projects through network weaving approaches underscores the significance of community-driven initiatives, fostering environments conducive to sustainable entrepreneurship and eco-innovation. This is crucial for achieving long-term economic and environmental sustainability. Furthermore, employing blockchain-enabled tokenization in infrastructure financing exemplifies how technological advancements can enhance transparency and efficiency, thereby supporting sustainable economic development.

The imperative for immediate action to elevate awareness and implement sustainable practices is paramount, as it directly correlates with enhanced research productivity and sustainable outcomes. Crafting innovative policies that harmonize economic incentives with sustainability objectives is vital, especially for progressing towards the SDGs in developing regions. This survey highlights the necessity of cultivating ecosystems that not only support but actively drive sustainable entrepreneurship and innovation, essential for addressing the multifaceted challenges of our time.

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