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Generative Artificial Intelligence (GenAI) for Sustainability: An Exploration of Emerging Academic Discourses

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ABSTRACT

This paper discusses how generative artificial intelligence (GenAI) transforms sustainability by addressing critical global challenges. It explores academic insights into the ways GenAI drives applications, opportunities, and solutions in education, business, governance, and the pursuit of Sustainable Development Goals (SDGs). The literature analysis highlights that GenAI fosters inclusivity, enhances operational efficiency, and promotes innovative sustainability practices. However, it also presents challenges such as algorithmic bias, digital divides, and high energy consumption. The study calls on stakeholders to adopt ethical frameworks, foster interdisciplinary collaboration, and implement robust policies. These actions will mitigate risks and ensure the responsible deployment of GenAI to achieve sustainable and equitable outcomes globally.

1. Introduction

Generative artificial intelligence (GenAI) holds immense potential for addressing critical sustainability challenges amid escalating environmental, social, and economic pressures. By harnessing advanced capabilities in data processing, problem-solving, and content creation, GenAI offers innovative solutions to enhance resource efficiency, promote inclusivity, and accelerate progress toward the Sustainable Development Goals (SDGs). For example, GenAI applications in education can democratize knowledge access by personalizing learning experiences for diverse audiences and bridging digital divides. In business and industry, GenAI optimizes operations, streamlines supply chains, and drives sustainable innovation. Similarly, in environmental management, GenAI aids data-driven decision-making for climate modeling, biodiversity conservation, and urban planning. However, the technology's dual nature, marked by high energy consumption and risks of exacerbating inequalities, necessitates ethical governance and strategic integration to maximize benefits while mitigating risks.

Following the approach of recent review articles (Dwivedi, 2025; Dwivedi et al., 2024) on GenAI-related issues, a search of the Scopus database conducted in November 2024, using a combination of terms such as "ChatGPT," or "Generative Artificial Intelligence," or "Generative AI," or "GenAI" in conjunction with "Sustainability," or "Sustainable Development Goal," reveals a surge in academic interest at the intersection of GenAI and sustainability over the past 2 years. Research spans diverse domains such as education, business strategy, governance, environmental management, and societal equity. Studies highlight GenAI's contributions to SDGs, such as quality education (SDG 4), responsible consumption and production (SDG 12), and global partnerships (SDG 17), while also addressing systemic risks such as algorithmic bias, digital divides, and the environmental costs of energy-intensive artificial intelligence (AI) models.

The expanding body of literature underscores the need for an early synthesis to map trends (Dwivedi, 2025; Dwivedi et al., 2024), identify opportunities, and pinpoint research gaps. Such an effort provides actionable insights for policymakers and practitioners seeking to leverage GenAI for sustainable development. This paper addresses that need through a thematic review of recent contributions, categorizing findings and/or important arguments across key domains and analyzing both the transformative potential and inherent risks of GenAI in advancing sustainability. The goal is to offer a holistic perspective, inform future research, foster interdisciplinary collaboration, and promote the ethical deployment of GenAI to achieve a sustainable and equitable global future.

To provide a comprehensive overview, Table 1 categorizes the reviewed themes and associated studies, serving as a roadmap for understanding existing research. The table out-

lines themes such as sustainability education, AI alignment with SDGs, business sustainability, and ethical considerations critical for responsible GenAI deployment.

Table 1. Classification of themes with references

Theme	References
Sustainability education (Section 2)	Alarcón-López et al. (2024), Alshamsi et al. (2024), Nedungadi et al. (2024), and Matthew et al. (2024)
Role in achieving SDGs (Section 3)	Fonseca et al. (2024), Raman et al. (2024), Wang and Zhang (2025), and Sashida et al. (2023)
Impact on social sustainability (Section 4)	Al-Emran et al. (2024), Khowaja et al. (2024), and Al-Emran et al. (2025)
Business sustainability and strategic value (Section 5)	AlQershi et al. (2024), Agrawal (2023), and Ghobakhloo et al. (2024)
Sustainability reporting (Section 6)	Bronzini et al. (2024), Apostol et al. (2024), and Sashida et al. (2023)
Higher education and sustainable development (Section 7)	Boustani et al. (2024), Martínez-Martín et al. (2024), and Eisenreich et al. (2024)
Ethical, cultural, and policy considerations (Section 8)	Driessens and Pischetola (2024), Sato et al. (2023), and Khowaja et al. (2024)
AI for sustainability innovations (Section 9)	Bergeron et al. (2023), Bhaskar and Seth (2024), and Giudici et al. (2023)

The remaining paper is structured as follows: Section 2 explores GenAI's role in sustainability education, followed by Section 3, which discusses its contributions to SDGs . Subsequent sections examine its impact on social sustainability, business strategies, sustainability reporting, and higher education. Ethical, cultural, and policy dimensions are discussed, concluding with insights into innovative applications and future research directions.

2. Generative AI and Sustainability Education

Four studies were found to focus on investigating how GenAI, especially ChatGPT, influences critical thinking and educational practices geared toward sustainability. Their analyses suggest that the application of GenAI technologies, such as ChatGPT, presents both opportunities and challenges in advancing sustainability education, with significant overlap in findings across the studies. Alarcón-López et al. (2024) and Nedungadi et al. (2024) converge on ChatGPT's ability to foster inclusivity and critical thinking, particularly in underserved or resource-constrained contexts. Both emphasize the tool's capacity for personalizing learning experiences, improving engagement, and addressing educational disparities. However, while Alarcón-López et al. (2024) highlight the immediate cognitive gains in energy literacy and the varying adaptability of rural versus urban students to ChatGPT, Nedungadi et al. (2024) focus on long-term benefits, such as preparing learners for evolving job markets through vocational training and alignment with SDGs such as quality education and decent work. The integration of ChatGPT in rural schools further underscores its democratizing potential in education, yet both studies warn of ethical and access-related challenges, including digital divides and biases, which necessitate targeted interventions (Alarcón-López et al., 2024; Nedungadi et al., 2024).

A recurring theme across the studies is the need for strategic integration and robust policy frameworks to mitigate risks while amplifying benefits. Alshamsi et al. (2024) and Matthew et al. (2024) both stress the importance of infrastructure investments and policy design to ensure equitable access and avoid over reliance on AI tools. However, Alshamsi et al. (2024) take a more quantitative approach, using structural equation modeling to directly link AI technologies to educational advancements and SDG attainment. This empirical perspective complements Matthew et al.'s (2024) qualitative focus on fostering inclusivity and critical thinking, demonstrating how AI can be integrated into pedagogical frameworks to enhance digital literacy and higher-order skills. Collectively, the studies recognize the transformative potential of AI in education but highlight varying degrees of progress and challenges in implementing these tools across different socio economic contexts (Alshamsi et al., 2024; Matthew et al., 2024).

Synthesizing the findings, it becomes evident that the transformative potential of GenAI in sustainability education hinges on its contextual adaptability and the ethical frameworks surrounding its deployment. While Alarcón-López et al. (2024) demonstrate ChatGPT's utility in tailoring content to diverse learners, especially in fostering critical thinking, Alshamsi et al. (2024) emphasize its broader implications for aligning educational practices with SDG progress. Similarly, both Nedungadi et al. (2024) and Matthew et al. (2024) argue for AI's role in enhancing vocational training and global citizenship education. However, they also highlight risks, such as algorithmic bias and inequitable access, which could exacerbate existing inequalities. These findings collectively underscore the dual mandate of leveraging AI's potential while addressing systemic barriers to ensure that its adoption benefits all learners and fosters sustainable, inclusive education.

3. Generative AI's Role in Achieving Sustainable Development Goals (SDGs)

Four existing studies have focused on how GenAI, particularly ChatGPT, aligns with and supports the United Nations Sustainable Development Goals (SDGs), offering valuable insights into its transformative potential. Analysis from these studies suggests that AI can address specific challenges and create new opportunities for advancing sustainability objectives across industries. For instance, Fonseca et al. (2024) highlight AI's ability to assist small and medium enterprises (SMEs) in resource-constrained environments by developing sustainability roadmaps and tracking progress through key performance indicators (KPIs). Similarly, Wang and Zhang (2025) emphasize AI's role in improving operational efficiency and fostering digital collaboration in tourism SMEs, aligning with SDGs such as responsible consumption and production (SDG 12) and decent work and economic growth (SDG 8). Both studies illustrate AI's capacity to innovate within sector-specific contexts, showcasing its versatility in addressing diverse sustainability challenges.

Analysis also reveals that GenAI is a powerful tool for advancing knowledge and literacy related to sustainability. Raman et al. (2024) demonstrate ChatGPT's capability to enhance awareness and facilitate cross-sector education on sustainable practices, achieving high scores in SDG-focused assessments such as the sustainability literacy test. This aligns with SDG 4 (quality education) and reflects its potential to bridge knowledge gaps in policy and practice. Similarly, Sashida et al. (2023) discuss AI's contributions to adaptive learning and data accessibility, further reinforcing its educational impact. However, these studies also identify gaps, such as the intermediate-level performance in critical competencies such as systems thinking (Raman et al., 2024) and risks of algorithmic bias and energy consumption (Sashida et al., 2023). These challenges underscore the importance of continuous refinement in AI systems to ensure comprehensive and equitable solutions to SDG interdependencies.

Moreover, these studies suggest that GenAI fosters collaboration and innovation, creating opportunities for multi-stakeholder engagement essential for achieving SDG 17 (partnerships for the goals). Fonseca et al. (2024) highlight how AI supports transparency and trust through effective sustainability communication strategies, while Wang and Zhang (2025) emphasize its role in coordinating digital supply chains and enabling customer co-creation. Sashida et al. (2023) extend this perspective by showcasing how AI-driven localized interventions empower communities to address their unique sustainability challenges. Despite these advantages, all studies converge on the need for robust ethical oversight to mitigate risks such as data inaccuracies and energy inefficiencies. Integrating AI innovations with governance frameworks can ensure that its potential for supporting SDGs is maximized while addressing associated challenges, creating a pathway for sustainable and inclusive development.

4. Impact of Generative AI on Social Sustainability

Three studies examined how GenAI aligns with social sustainability by addressing ethical considerations, digital divides, and societal impacts, offering complementary but distinct perspectives. Al-Emran et al. (2024) and Al-Emran et al. (2025) highlight how GenAI fosters inclusivity and equity by personalizing educational experiences and democratizing access to learning resources. They emphasize its potential to address barriers related to geography, socioeconomic status, and disabilities. Meanwhile, Khowaja et al. (2024) takes a broader societal view, focusing on how GenAI can democratize access to resources and drive innovation but cautions about systemic challenges, particularly its role in exacerbating digital divides. While all three studies converge on the transformative potential of GenAI, Khowaja et al. (2024) uniquely emphasizes the necessity of localized content and affordable infrastructure to ensure these benefits are equitably distributed, complementing the accessibility concerns raised by Al-Emran et al. (2024; 2025).

Ethical considerations are central to all three studies, underscoring the importance of responsible AI use. Al-Emran et al. (2025) identify perceived threats, such as data breaches and algorithmic biases, as significant barriers to adoption, aligning with Khowaja et al.'s (2024) call for regulatory frameworks such as the Sustainability, Privacy, Digital Divide, and Ethics (SPADE) model to address these challenges. Both studies stress the critical need for transparency, data protection, and fairness in AI operations to build trust among users. Al-Emran et al. (2024) adds a unique perspective by emphasizing the role of societal norms and user perceptions, such as perceived intelligence and animacy of AI, in driving adoption. Collectively, these findings illustrate that, while technological advancements can enhance inclusivity, robust ethical governance is necessary to mitigate risks and ensure long-term societal benefits.

Beyond inclusivity and ethics, the studies also explore the environmental and systemic implications of GenAI. Khowaja et al. (2024) raises concerns about the carbon-intensive nature of large language models and advocates for renewable energy adoption to mitigate environmental harm. This focus complements the sustainability dimensions of the Technology-Environmental, Economic, and Social Sustainability Theory (T-EESST) emphasized by Al-Emran et al. (2024; 2025). Together, the studies call for policies addressing digital literacy gaps, equitable resource distribution, and environmental consciousness, highlighting that the true potential of Generative AI lies in integrating ethical, environmental, and societal frameworks to achieve sustainable and inclusive technological progress.

5. Business Sustainability and Strategic Value through Generative AI

Three recent studies have explored how firms can enhance strategic value and achieve sustainability goals using GenAI technologies, providing complementary yet distinct perspectives on its applications. AlQershi et al. (2024) and Agrawal (2023) emphasize the role of GenAI in driving organizational agility and operational efficiency. While AlQershi et al. (2024) highlight its ability to streamline managerial productivity and enhance organizational support, Agrawal (2023) explores the transformative potential of GenAI optimization intelligence (GenAI-OI) in embedding agile practices and fostering collective action within firms. Both studies underscore the importance of aligning GenAI applications with organizational strategies to maximize impact, but they differ in their focus. AlQershi et al. (2024) stress customer engagement and sector-specific applications such as education, while Agrawal underscores the necessity of organizational norms and continuous reflexive monitoring to ensure the sustainability of AI initiatives.

Ghobakhloo et al. (2024) further expand this discussion by situating GenAI technologies within the Industry 5.0 framework, emphasizing their role in sustainable manufacturing. Their study provides a more detailed roadmap, identifying ten distinct GenAI functions, such as data-driven production insights and advanced quality management, to achieve environmental and economic sustainability. Unlike AlQershi et al. (2024) and Agrawal (2023), Ghobakhloo et al. stress the synergistic deployment of AI functions for enhanced impact, reflecting a more holistic and phased approach to integration. This contrasts with Agrawal's emphasis on cognitive participation and organizational coherence and AlQershi et al.'s focus on leveraging GenAI for competitive advantage in dynamic sectors. However, all three studies agree that GenAI is not a standalone solution but rather requires strategic alignment, employee engagement, and ethical governance for long-term success.

Despite their differing contexts and focuses, the studies collectively highlight key challenges in adopting GenAI, including data accessibility, system compatibility, and ethical concerns such as algorithmic bias and job displacement. Agrawal (2023) and Ghobakhloo et al. (2024) both highlight the role of proactive governance and interdisciplinary collaboration to address these challenges. Ghobakhloo et al. (2024) additionally stress the need for targeted investments in education and training, aligning with Agrawal's call for tailored programs to support employee engagement. Meanwhile, AlQershi et al. (2024) point to the limitations of decision aids in contributing to sustainability goals, adding nuance to the broader discourse on AI's applicability. Together, these studies provide a comprehensive understanding of how GenAI technologies can drive strategic value and sustainability, offering actionable insights for firms to navigate the complexities of implementation in various sectors.

6. Generative AI and Sustainability Reporting

Three recent studies published in the last 2 years utilized GenAI for analyzing and deriving insights from sustainability reports and accountability documentation. Collectively, these studies illustrate the transformative potential of GenAI in improving transparency, efficiency, and analytical depth in sustainability reporting. Bronzini et al. (2024) and Sashida et al. (2023) both highlight the capability of AI to extract structured data from unstructured sustainability reports, though their focus diverges: While Bronzini et al. (2024) emphasize extracting environmental, social, and governance (ESG) data for creating knowledge graphs and statistical analyses, Sashida et al. (2023) concentrate on Sustainable Development Goals (SDG)-related content using specific AI models such as Bidirectional Encoder Representations from Transformers (BERT) and ChatGPT. Both studies demonstrate the value of GenAI in managing thematic diversity and inconsistent formatting in reports, underscoring its role in providing actionable insights. However, their methodologies differ, with Bronzini et al. (2024) employing advanced frameworks such as retrieval-augmented generation (RAG) and Shapley Additive Explanations (SHAP) for interpretive analyses, while Sashida et al. (2023) use BERT and ChatGPT for narrative synthesis to standardize and simplify complex data.

An area of convergence among these studies is the emphasis on combining AI-driven automation with human oversight, which has also been discussed in a recently published article on the impact of GenAI on academic publishing (Dwivedi et al., 2024). Apostol et al. (2024) argue that, while large language models (LLMs) can efficiently process and classify sustainability data, their use should be carefully managed to avoid over reliance, errors, and loss of authenticity. This aligns with Sashida et al.'s (2023) caution regarding the need for human validation of AI-generated insights to maintain contextual accuracy and ethical standards. Bronzini et al. (2024) also indirectly reinforce this perspective by focusing on transparency and tailored ESG initiatives that leverage AI outputs for meaningful corporate performance assessments. Together, these studies highlight that the effective use of GenAI is not purely technical; it also involves addressing ethical and interpretive considerations to preserve the integrity and relevance of sustainability analyses.

Despite their shared optimism about AI's transformative potential, the studies differ in addressing the limitations and risks associated with its implementation. Apostol et al. (2024) take a critical stance, highlighting potential pitfalls such as uncritical reliance on AI and diminished research authenticity, which could erode trust in sustainability disclosures. In contrast, Sashida et al. (2023) are more focused on technical integration, emphasizing how specific models such as BERT and ChatGPT can address inconsistencies and enhance the standardization of sustainability metrics. Meanwhile, Bronzini et al. (2024) adopt a broader perspective, showing how AI-facilitated analytics can enable cross-sectoral comparisons and strategic improvements in reporting practices. These di-

verse approaches underline the need for a nuanced and interdisciplinary strategy to harness GenAI's full potential while managing its inherent risks in sustainability accounting and accountability documentation.

7. Generative AI in Higher Education for Sustainable Development

Three recent studies published in the last year examined how to integrate GenAI into higher education to support Sustainable Development Goals (SDGs) and knowledge dissemination. A common theme across these studies is the potential of AI to promote SDG 4 (quality education) through personalized learning and inclusivity. Boustani et al. (2024) emphasize AI's capacity to adapt education to diverse student needs, optimizing resource use and reducing costs, particularly in underserved regions, thereby bridging the digital divide. Similarly, Martínez-Martín et al. (2024) highlight AI's role in creating adaptive learning environments, such as real-time language translation and personalized content, to make education more equitable. Both studies converge on the importance of leveraging AI to enhance accessibility while aligning curricula with sustainability-focused frameworks. Eisenreich et al. (2024) add to this discussion by showcasing how AI supports innovative teaching strategies and disseminates knowledge effectively, especially in fostering cross-disciplinary collaborations. These shared insights underscore the transformative power of GenAI in advancing education's accessibility, effectiveness, and alignment with global challenges.

Despite the shared optimism, these studies also highlight significant challenges in integrating AI into education. Martínez-Martín et al. (2024) stress the ethical concerns of data privacy, energy-intensive AI training processes, and the risk of dehumanizing education. Similarly, Boustani et al. (2024) point to barriers such as infrastructure limitations and resistance to technology adoption, emphasizing the need for robust information and communication technology (ICT) strategies and investments. Eisenreich et al. (2024) identify a novelty–feasibility trade-off, where AI excels in generating creative ideas but often falls short in practical applicability without expert input. Collectively, these challenges underline the need for careful planning, ethical oversight, and human validation in AI-driven education strategies to ensure sustainable and impactful integration.

The synthesis of these findings reveals actionable strategies for higher education institutions to harness GenAI effectively. All three studies advocate for targeted investments in AI literacy and professional development for educators to maximize its potential while addressing resistance and ethical concerns. Eisenreich et al. (2024) propose a systems approach combining human expertise with AI-driven insights to balance creativity and feasibility. Meanwhile, Martínez-Martín et al. (2024) emphasize the importance of policies ensuring transparency and inclusivity, while Boustani et al. (2024) call for partnerships with global experts to tailor integration strategies to local contexts. Together, these studies highlight that the successful adoption of GenAI in education lies in fostering human–AI collaboration, addressing technological and ethical complexities and aligning educational practices with sustainability objectives.

8. Ethical, Cultural, and Policy Considerations

Three recent studies published in the past 2 years examine policy challenges, cultural perceptions, and ethical dilemmas surrounding the use of GenAI in sustainability contexts. A central policy challenge highlighted across these studies is the environmental cost of training and deploying large language models, which consume immense computational resources and contribute significantly to carbon emissions (Driessens & Pischetola, 2024; Khowaja et al., 2024). While AI offers avenues for enhanced efficiency and data-driven decision-making in sustainability practices, its deployment often lacks alignment with established environmental goals. For instance, GenAI's potential to streamline administrative processes in sustainability initiatives must be weighed against its resource-intensive requirements, which exacerbate ecological concerns (Sato et al., 2023). These policy challenges underscore the necessity for robust frameworks to evaluate AI's sustainability, privacy, and equity impacts and ensure its responsible application (Khowaja et al., 2024).

Cultural perceptions surrounding GenAI in sustainability contexts reveal both optimism and critique. On one hand, these technologies are celebrated for democratizing access to information and fostering inclusivity, particularly in educational and conservation efforts (Driessens & Pischetola, 2024; Sato et al., 2023). For example, GenAI can enhance knowledge dissemination and engage broader audiences in environmental initiatives, as seen in its application in nature parks to boost visitor engagement (Sato et al., 2023). On the other hand, critics caution against the cultural homogenization and commodification AI may induce, particularly in heritage- and community-focused contexts. The reliance on AI-driven solutions, often designed with a focus on global scalability, risks sidelining localized cultural practices and values (Khowaja et al., 2024). Additionally, AI's reinforcement of global inequalities, such as the digital divide, further complicates its role in equitable sustainability efforts, necessitating more culturally sensitive designs and implementation strategies.

Ethical dilemmas emerge as a significant concern, particularly in balancing AI's innovative potential with the risks of data privacy breaches, bias reproduction, and misinformation. While GenAI holds promise for behavioral guidance and decision-making, such as using tailored experiences to influence sustainable tourist behavior, this raises concerns about user autonomy and informed consent (Sato et al., 2023). Moreover, the commodification of user data without transparent consent mechanisms highlights the urgent need for ethical oversight in AI deployment (Khowaja et al., 2024). Surveillance capitalism and systemic biases embedded in AI outputs further complicate its ethical landscape, as noted by Driessens and Pischetola (2024). Together, these studies

emphasize that the integration of GenAI into sustainability initiatives must be guided by stringent ethical frameworks and policies to balance its benefits with accountability and inclusivity.

9. Generative AI for Sustainability Innovations

Three recent studies published in the last 2 years highlight the application of GenAI for innovative practices in sustainability across various domains, including tourism, geosciences, and environmental management. A key theme across these studies is the potential of GenAI, particularly large language models (LLMs) such as ChatGPT, to advance data analysis and decision-making for sustainability efforts. For example, Bergeron et al. (2023) emphasize the transformative role of LLMs in automating bibliometric mapping of the United Nations Sustainable Development Goals (SDGs), showcasing a remarkable 634% improvement in keyword comprehensiveness. Similarly, Bhaskar and Seth (2024) and Giudici et al. (2023) identify LLMs as pivotal in generating actionable insights across domains, ranging from sustainable tourism strategies to climate change modeling in the geosciences. These studies collectively illustrate how LLMs enable more dynamic, scalable approaches to addressing sustainability challenges. However, they also acknowledge a common concern: the significant energy consumption and environmental costs associated with developing and deploying these AI systems, signaling the need for more efficient AI practices.

Despite their shared optimism about GenAI's potential, the studies diverge in their emphasis on domain-specific applications and the strategies for mitigating AI's environmental impacts. Bergeron et al. (2023) focus on the technical achievements of LLMs in improving the depth and breadth of SDG-related data, which facilitates cross-disciplinary collaboration. In contrast, Bhaskar and Seth (2024) prioritize operational applications, such as optimizing resource use in tourism and enhancing climate resilience in geosciences. Their work also brings attention to the environmental trade-offs of GenAI, including carbon emissions and e-waste, and proposes solutions such as energy-efficient algorithms and renewable energy integration. Meanwhile, Giudici et al. (2023) extend the discussion to user-centric applications, such as embedding LLMs in smart home assistants to promote sustainable behaviors such as energy conservation. Their proposed hybrid models and real-time data integration strategies aim to address the biases and inaccuracies in AI outputs while reducing computational demands. These varied approaches underscore the versatility of GenAI and highlight domain-specific challenges and solutions.

Upon synthesizing these findings, it becomes clear that, while Generative AI presents ground breaking opportunities for advancing sustainability, its effective integration requires a balance between innovation and responsibility. Across the studies, a shared vision emerges: GenAI can redefine sustainability practices by enabling precise environmental monitoring, facilitating eco-friendly planning, and fostering behavioral changes in individuals and communities. However, the associated environmental costs necessitate deliberate efforts to improve AI energy efficiency and sustainability. Proposals such as hybrid AI models (Giudici et al., 2023), regulatory frameworks (Bhaskar and Seth, 2024), and advanced bibliometric methods (Bergeron et al., 2023) offer complementary strategies for maximizing the benefits of GenAI while minimizing its drawbacks. Together, these insights demonstrate how cross-disciplinary collaboration and conscious innovation can harness the full potential of GenAI to address complex global sustainability challenges effectively.

10. Discussions

Sections 2–9 collectively examine GenAI's varied contributions to sustainability, offering insights into its applications across education, Sustainable Development Goals (SDGs), social equity, business strategy, sustainability reporting, ethics, and innovation. A consistent theme throughout these sections is the potential of GenAI to support responses to complex sustainability challenges. At the same time, each section highlights distinct focus areas, reflecting the diverse opportunities and risks associated with its implementation.

The role of GenAI in transforming education is a central focus in Sections 2 and 7. Studies by Alarcón-López et al. (2024) and Nedungadi et al. (2024) emphasize ChatGPT's ability to reduce educational disparities by fostering critical thinking and personalized learning in underserved communities. Section 7 builds on this by illustrating how GenAI can support adaptive learning environments, as highlighted by Eisenreich et al. (2024). These insights are closely related to those in Section 3, which explores how GenAI contributes to SDGs such as quality education (SDG 4) and decent work (SDG 8). For example, Fonseca et al. (2024) describe how AI tools enhance digital collaboration and knowledge dissemination, helping address resource limitations and promote sustainability literacy. Section 6 adds another layer by demonstrating how tools such as ChatGPT and BERT improve data accessibility and standardization in sustainability reporting. Taken together, these studies underscore AI's capacity to democratize access and enhance operational efficiency in support of sustainable development.

Despite this promise, several challenges remain. Ethical, environmental, and structural risks are central concerns. Sections 4 and 8 draw attention to issues such as algorithmic bias, data privacy, and disparities in access to technology. Khowaja et al. (2024) and Driessens and Pischetola (2024) emphasize the importance of robust governance frameworks to ensure that AI adoption supports environmental goals and social equity. Section 8 also highlights the high energy demands of training large AI models, while Section 9 proposes hybrid approaches and energy-efficient algorithms to reduce environmental impact. These discussions further stress the need for culturally appropriate designs that avoid reinforcing existing inequalities, echoing the themes of social sustainability outlined in Section 4.

While many sections raise shared concerns around ethics and governance, each one offers a different perspective based on its area of focus. Section 5, for instance, concentrates on business applications of GenAI. Ghobakhloo et al. (2024) describe how AI can support strategic agility and operational performance within Industry 5.0 frameworks. This business-oriented view contrasts with Section 2's focus on inclusive education and Section 4's emphasis on equitable access. Section 9 adds yet another perspective, focusing on innovation in specific domains such as climate modeling and sustainable tourism. These contrasts reinforce the multifaceted nature of GenAI's impact and the need for tailored approaches to its application across sectors.

Together, these insights suggest that the potential of GenAI to advance sustainability depends on integrating technical capabilities with ethical, cultural, and environmental considerations. Achieving this balance will require cross-disciplinary collaboration, alignment with policy frameworks, and engagement with a broad range of stakeholders. This broader understanding provides the foundation for the research propositions developed in the remainder of this section.

To bring structure to the wide-ranging themes in Sections 2–9, Table 2 connects the reviewed literature with the propositions that follow. Table 2 aligns GenAI's key areas of application with relevant scholarly insights and identifies the specific propositions that emerge from each domain. It is organized around eight core areas: education, SDG alignment, social sustainability, business strategy, sustainability reporting, higher education, ethics and policy, and domain-specific innovation. Table 2 reflects the complex and context-sensitive role that GenAI plays in advancing sustainability.

As shown in Table 2, each proposition is supported by thematic evidence drawn from the literature. Together, these propositions illustrate the dual nature of GenAI: It can support inclusive and forward-looking sustainability practices, while also introducing important ethical, policy, and infrastructure challenges. By synthesizing these elements, Table 2 provides a foundation for the research propositions outlined in the following paragraphs.

A research proposition emerging from Section 2 posits that strategic integration of GenAI in education can bridge digital divides and foster inclusivity. For example, Alarcón-López et al. (2024) highlight ChatGPT's capacity to personalize learning and democratize access, particularly in rural areas. However, digital inequalities persist, necessitating infrastructure investments and equitable policy frameworks to ensure that AI benefits all learners. This aligns with the proposition emerging from Section 7 that AI-driven innovations in higher education can promote sustainable development by personalizing learning and fostering cross-disciplinary collaboration. Eisenreich et al. (2024) emphasize AI's role in creating adaptive educational environments, though ethical concerns such as data privacy and resistance to technology adoption must be addressed.

From Section 3, another proposition can be deduced-that GenAI accelerates SDG achievement by facilitating cross-sector collaboration and optimizing resource use. Studies such as Fonseca et al. (2024) demonstrate AI's ability to align SMEs with SDGs through KPI-based progress tracking. Despite its potential, challenges such as algorithmic bias and energy consumption require robust ethical oversight to ensure inclusive progress. Similarly, Section 6 provides a basis for proposing that GenAI enhances sustainability reporting

Table 2. Mapping Generative AI's engagement with sustainability areas and related propositions.

Domain	Key focus areas	Example references	Related proposition
Sustainability education	Personalized learning, digital inclusion, critical thinking, and SDG 4	Alarcón-López et al. (2024), Nedungadi et al. (2024), and Matthew et al. (2024)	Strategic integration of Generative AI in education can bridge digital divides and foster inclusivity.
Higher education	Adaptive platforms, interdisciplinary collaboration, and access equity	Eisenreich et al. (2024), Boustani et al. (2024), and Martínez-Martín et al. (2024)	AI-driven innovations in higher education can promote sustainable development by personalizing learning and fostering cross-disciplinary collaboration.
SDG enablement	KPI-based progress, SME support, digital collaboration, and operational efficiency	Fonseca et al. (2024), Wang and Zhang (2025), and Raman et al. (2024)	Generative AI accelerates SDG achievement by facilitating cross-sector collaboration and optimizing resource use.
Sustainability reporting	Automation, narrative synthesis, ESG data analysis, and transparency	Sashida et al. (2023), Bronzini et al. (2024), and Apostol et al. (2024)	Generative AI enhances sustainability reporting through automated data synthesis and actionable insights.
Social sustainability	Digital equity, access barriers, ethical design, and localized interventions	Al-Emran et al. (2024; 2025) and Khowaja et al. (2024)	Generative AI fosters social sustainability by enhancing inclusivity and equity, contingent upon localized interventions.
Business and Industry 5.0	Agility, strategic value, manufacturing optimization, and employee engagement	Ghobakhloo et al. (2024), Agrawal (2023), and AlQershi et al. (2024)	Generative AI, when embedded within Industry 5.0 frameworks, enhances business sustainability through strategic alignment and agility.
Ethics and policy	Data privacy, algorithmic bias, digital divide, energy consumption, and regulatory frameworks	Khowaja et al. (2024), Driessens and Pischetola (2024), and Sato et al. (2023)	Policy frameworks are essential to mitigate AI's ethical and environmental risks, balancing innovation with accountability.
Domain-specific innovation	Smart tourism, geosciences, climate modeling, and hybrid AI models	Giudici et al. (2023), Bhaskar and Seth (2024), and Bergeron et al. (2023)	Domain-specific applications of Generative AI can drive sustainability innovations, provided energy-efficient practices are adopted.

through automated data synthesis and actionable insights. Tools such as ChatGPT and BERT improve reporting consistency and accessibility (Sashida et al., 2023), but human oversight remains crucial to maintain accuracy and authenticity (Dwivedi et al., 2024; Dwivedi, 2025).

In line with Section 4, a related proposition can be deduced-GenAI fosters social sustainability by enhancing inclusivity and equity, contingent upon localized interventions. Al-Emran et al. (2024) demonstrate how AI personalizes resource access, addressing barriers related to geography and socioeconomic status. However, systemic challenges such as digital divides and environmental costs persist, requiring localized content strategies and affordable infrastructure to ensure equitable distribution of benefits.

A proposition can be drawn from Section 5: GenAI, when embedded within Industry 5.0 frameworks, enhances business sustainability through strategic alignment and agility. Ghobakhloo et al. (2024) highlight AI's role in sustainable manufacturing through advanced quality management and data-driven production insights. However, ethical governance and employee engagement are critical for long-term success, as demonstrated by Agrawal (2023), who stresses the importance of aligning AI initiatives with organizational norms.

Section 8 supports a proposition advocating for policy frameworks to mitigate GenAI's ethical and environmental risks, balancing innovation with accountability. Khowaja et al. (2024) emphasize the need for culturally sensitive GenAI designs and policies that bridge digital divides while aligning technological advances with sustainability goals. Ethical challenges posed by GenAI and the need for a policy framework have also been discussed in other contexts. For example, Al-Busaidi et al. (2024) recently examined these issues in relation to the ethical challenges posed by GenAI for copyright and intellectual property rights, highlighting the need for a policy governance framework to tackle such challenges. Finally, Section 9 underpins the proposition that domain-specific applications of GenAI can drive sustainability innovations, provided energy-efficient practices are adopted. Giudici et al. (2023) highlight hybrid AI models as scalable solutions for challenges such as climate modeling and sustainable tourism, though balancing innovation with environmental responsibility remains a priority.

Together, these propositions reflect GenAI's potential to drive transformative change in sustainability practices across education, business, and governance. However, they also emphasize the necessity of addressing ethical, cultural, and environmental complexities to realize this potential. By fostering cross-sector collaboration and implementing robust governance frameworks, stakeholders can harness the power of GenAI I to achieve inclusive and impactful sustainability outcomes. This holistic approach ensures that AI's benefits are maximized while its risks are carefully mitigated, making the way for sustainable development in a rapidly evolving technological landscape.

11. Conclusions

This review demonstrates that Generative AI (GenAI) holds significant promise for advancing sustainability across education, business, policy, and innovation. Its strengths include democratizing access to knowledge, improving operational efficiency, and supporting practices aligned with the Sustainable Development Goals (SDGs). However, this transformative potential is accompanied by challenges such as algorithmic bias, digital inequality, and the environmental cost of energy-intensive AI systems. As the literature shows, realizing the benefits of GenAI requires ethical frameworks, cultural sensitivity, and collaboration across sectors. Effective integration depends on domain-specific strategies, responsible governance, and the adoption of energy-efficient technologies. GenAI's impact is inherently complex, acting both as a driver of inclusive progress and a source of new risks. To fully leverage its potential, we must align technological development with ethical, environmental, and social priorities. Looking ahead, a critical question remains: ***Can we design GenAI systems that not only produce sustainable outcomes but are themselves built on sustainable foundations?***

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12. References

Alarcón-López, C., Krütli, P., & Gillet, D. (2024, May). Assessing ChatGPT's Influence on Critical Thinking in Sustainability Oriented Activities. In 2024 ***IEEE Global Engineering Education Conference*** (EDUCON) (pp. 1-10). IEEE.

Al-Busaidi, A. S., Raman, R., Hughes, L., Albashrawi, M. A., Malik, T., Dwivedi, Y. K., ... & Walton, P. (2024). Redefining boundaries in innovation and knowledge domains: Investigating the impact of generative artificial intelligence on copyright and intellectual property rights. ***Journal of Innovation & Knowledge***, 9(4), article 100630.

Al-Emran, M., Abu-Hijleh, B., & Alsewari, A. A. (2024). Exploring the effect of Generative AI on social sustainability through integrating AI attributes, TPB, and T-EESST: A deep learning-based hybrid SEM-ANN approach. ***IEEE Transactions on Engineering Management***, 71, 14512 – 14524.

Al-Emran, M., Al-Qaysi, N., Al-Sharafi, M. A., Khoshkam, M., Foroughi, B., & Ghobakhloo, M. (2025). Role of perceived threats and knowledge management in shaping generative AI use in education and its impact on social sustainability. ***The International Journal of Management Education***, 23(1), article 101105.

AlQershi, N. A., Thursamy, R., Alzoraiki, M., Ali, G. A., Mohammed Emam, A. S., & Nasir, M. D. B. M. (2025). Is ChatGPT a source to enhance firms' strategic value and business sustainability? ***Journal of Science and Technology Policy Management***, 16(1), 121-142.

Alshamsi, I., Sadriwala, K. F., Alazzawi, F. J. I., & Shannaq, B. (2024). Exploring the impact of generative AI technologies on education: Academic expert perspectives, trends, and implications for sustainable development goals. ***Journal of Infrastructure, Policy and Development***, 8(11), 8532.

Apostol, O., Dey, C., & Thomson, I. (2024). Reflecting on the Impact of Generative AI for Sustainability Accounting Scholarship. ***Social and Environmental Accountability Journal***, 44(3), 181-192.

Bergeron, L., François, J., State, R., & Hilger, J. (2023, November). ULA, a Bibliometric Method to Identify Sustainable Development Goals using Large Language Models. In 2023 ***IEEE International Humanitarian Technology Conference*** (IHTC) (pp. 1-6). IEEE.

Bhaskar, P., & Seth, N. (2024). Environment and sustainability development: A ChatGPT perspective. In ***Applied Data Science and Smart Systems*** (pp. 54-62). CRC Press.

Boustani, N. M., Sidani, D., & Boustany, Z. (2024). Leveraging ICT and Generative AI in Higher Education for Sustainable Development: The Case of a Lebanese Private University. ***Administrative Sciences***, 14(10), 251.

Bronzini, M., Nicolini, C., Lepri, B., Passerini, A., & Staiano, J. (2024). Glitter or gold? Deriving structured insights from sustainability reports via large language models. ***EPJ Data Science***, 13(1), article 41.

Driessens, O., & Pischetola, M. (2024). Danish university policies on generative AI: Problems, assumptions and sustainability blind spots. MedieKultur: ***Journal of Media and Communication Research***, 40(76), 31-52.

Dwivedi, Y. K. (2025). Generative Artificial Intelligence (GenAI) in entrepreneurial education and practice: emerging insights, the GAIN Framework, and research agenda. ***International Entrepreneurship and Management Journal***, 21(1), 1-21.

Dwivedi, Y. K., Malik, T., Hughes, L., & Albashrawi, M. A. (2024). Scholarly Discourse on GenAI's Impact on Academic Publishing. ***Journal of Computer Information Systems***, 1-16. Available at https://doi.org/10.1080/08874417.2024.2435386

Eisenreich, A., Just, J., Jiménez, D. G., & Füller, J. (2024). Revolution or inflated expectations? Exploring the impact of generative AI on ideation in a practical sustainability context. ***Technovation***, 138, 103123.

Fonseca, L., Oliveira, E., Pereira, T., & Sá, J. C. (2024). Leveraging ChatGPT for Sustainability: A Framework for SMEs to Align with UN Sustainable Development Goals and tackle sustainable development challenges. ***Management & Marketing***, 19(3), 471-497.

Ghobakhloo, M., Fathi, M., Iranmanesh, M., Vilkas, M., Grybauskas, A., & Amran, A. (2024). Generative artificial intelligence in manufacturing: opportunities for actualizing Industry 5.0 sustainability goals. ***Journal of Manufacturing Technology Management***, 35(9), 94-121.

Giudici, M., Abbo, G. A., Belotti, O., Braccini, A., Dubini, F., Izzo, R. A., ... & Garzotto, F. (2023, November). Assessing LLMs Responses in the Field of Domestic Sustainability: An Exploratory Study. In 2023 Third International Conference on Digital Data Processing (DDP) (pp. 42-48). IEEE.

Khowaja, S. A., Khuwaja, P., Dev, K., Wang, W., & Nkenyereye, L. (2024). Chatgpt needs spade (sustainability, privacy, digital divide, and ethics) evaluation: A review. ***Cognitive Computation,*** 16(5), 2528-2550.

Martínez-Martín, J. E., Rosado-González, E. M., Martínez-Martín, B., & Sá, A. A. (2024). UNESCO Global Geoparks vs. Generative AI: Challenges for Best Practices in Sustainability and Education. ***Geosciences***, 14(10), 275.

Matthew, U. O., Oyekunle, D. O., Akpan, E. E., Oladipupo, M. A., Chukwuebuka, E. S., Adekunle, T. S., ... & Onumaku, V. C. (2024). Generative Artificial Intelligence (AI) on Sustainable Development Goal 4 for Tertiary Education: Conversational AI With User-Centric ChatGPT-4. In ***Impacts of Generative AI on Creativity in Higher Education*** (pp. 259-288). IGI Global.

Nedungadi, P., Tang, K. Y., & Raman, R. (2024). The Transformative Power of Generative Artificial Intelligence for Achieving the Sustainable Development Goal of Quality Education. ***Sustainability***, 16(22), 9779.

Prasad Agrawal, K. (2023). Organizational Sustainability of Generative AI-Driven Optimization Intelligence. ***Journal of Computer Information Systems***, 65(3), 265-279.

Raman, R., Lathabai, H. H., Mandal, S., Das, P., Kaur, T., & Nedungadi, P. (2024). ChatGPT: Literate or intelligent about UN sustainable development goals? ***Plos One***, 19(4), e0297521.

Sashida, M., Izumi, K., & Sakaji, H. (2023, July). Extraction SDGs-related sentences from Sustainability Reports using BERT and ChatGPT. In ***2023 14th IIAI International Congress on Advanced Applied Informatics*** (IIAI-AAI) (pp. 742-745). IEEE.

Sato, R., Shimazaki, Y., & Yamaguchi, T. (2023, December). Sustainability of Nature Parks by Changing Tourist Behavior Using Donations and Generative AI. In ***2023 International Conference on Computational Science and Computational Intelligence*** (CSCI) (pp. 1014-1021). IEEE.

Wang, S., & Zhang, H. (2025). Promoting sustainable development goals through generative artificial intelligence in the digital supply chain: Insights from Chinese tourism SMEs. ***Sustainable Development***, 33(1), 1231-1248. DoI: https://doi.org/10.1002/sd.3152