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Harnessing Technological Innovations for Climate Change Mitigation: A Systematic Review of Business and Economic Impacts

Authors:

Misheck Musaigwa (msaigwamish@gmail.com)
Durban University of Technology, Durban, South Africa

Fulufhelo Netswera (fulufhelon@dut.ac.za)
Durban University of Technology, Durban, South Africa

Abstract:

This systematic literature review examines the convergence of technological innovation with climate change mitigation, emphasising the resultant business and economic ramifications. This analysis examines 61 peer-reviewed, open-access papers from 2015 to 2025, following the PRISMA technique to synthesise information regarding the application of digital and green technologies across industries in tackling climate challenges. The findings indicate that advancements like artificial intelligence, blockchain, Internet of Things IoT, big data analytics, and renewable energy technologies fulfill two functions: promoting environmental sustainability and bolstering corporate competitiveness. Technological integration has enhanced ESG performance, enabled circular economy practices, and promoted low-carbon transitions across sectors including as manufacturing, energy, logistics, and finance. The research indicates that digital transformation, in conjunction with contextual governance, organisational preparation, and strategic leadership, serves as a catalyst for sustainable innovation. Green financial instruments, such as carbon trading schemes, green bonds, and fintech platforms, serve as facilitators for connecting investments with sustainability objectives. The study provides a thorough understanding of the strategic, economic, and operational mechanisms via which technology enhances climate mitigation goals and fosters sustainable development in various socio-economic contexts.

Keywords:

Technological Innovation, Climate Change Mitigation, Digital Transformation, Green Finance, Circular Economy, Environmental, Social, and Governance, Sustainable Business Practices

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Background

Climate change continues to be a critical challenge worldwide, imposing significant environmental, economic, and social repercussions. In response, governments, corporations, and civil society are increasingly adopting technology innovation as a strategic approach to attain climate mitigation and adaptation objectives. In the last ten years, technological interventions such as digitalisation, renewable energy solutions, environmental management systems, and circular economy enablers have been recognised for their environmental effectiveness as well as their ability to yield significant business and economic advantages. Recent studies demonstrate that the incorporation of innovation-driven strategies, including environmental management accounting and energy-efficient technologies, results in significant enhancements in environmental outcomes and corporate competitiveness (Kalyar et al., 2024). Innovations in industrial automation, smart manufacturing, and blockchain applications for energy monitoring have equipped enterprises with tools to optimise resource use while adhering to sustainability standards (Zhou et al., 2023). Such synergies are essential for companies in energy-intensive industries, where regulatory pressures and stakeholder expectations increasingly necessitate visible and accountable sustainability performance. Furthermore, technology frameworks enabling circular economy practices have gained prominence as a method to separate economic progress from environmental harm. Empirical evidence from biomass-fired energy systems in Brazil (Pereira et al., 2024) and mining industries in Asia (Chen et al., 2025) suggests that digital tracking, waste valorisation, and process optimisation improve environmental stewardship, cost-effectiveness, and operational resilience. At a macroeconomic level, the proliferation of green technology and eco-innovation correlates with enhanced trade competitiveness, employment creation, and transitions toward more sustainable industrial frameworks, especially in emerging economies (Farooq et al., 2025). Recent studies on global green value chains indicate that executive knowledge and smart finance methods enhance the implementation of low-carbon strategies globally (Huang, and Xie, 2025). The interaction between technological progress and environmental governance frameworks is proving crucial. Firm-level digitalisation activities are increasingly shaped by environmental regulations, with policy-induced innovation acting as a mediator for enhanced ESG performance (Zhao et al., 2025). The co-evolution of regulatory frameworks and industrial innovations highlights a complex yet mutually reinforcing link among policy, innovation, and sustainability. Notwithstanding these favourable developments, obstacles persist in harmonising technological innovation with inclusive and equitable climate mitigation. Challenges related to scalability, financial constraints, and digital preparedness in underprivileged environments continue to exist, necessitating additional examination of facilitating conditions and regulatory measures. This study systematically evaluates the literature to analyse how technology innovations are used across industries to address climate change and the resulting economic and business implications of these interventions.

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Methodology

This study employed a systematic literature review methodology to synthesise and critically evaluate the existing knowledge regarding the role of technological innovation in climate change mitigation. In accordance with the preferred reporting items for systematic reviews and meta-analyses PRISMA guidelines, a meticulous multi-phase procedure for literature identification, screening, eligibility evaluation, and inclusion was executed to guarantee comprehensiveness, transparency, and replicability of the review process.

The preliminary search was performed in Scopus a prominent scientific database using a combination of keywords such as “technological innovation,” “climate change mitigation,” “green technology,” “sustainable innovation,” “climate-smart solutions,” and “environmental sustainability.” Boolean operators (AND, OR) and truncation methods were employed to enhance search accuracy and relevancy. The preliminary search produced a total of 6,707 records. The initial layer of inclusion criteria was implemented by selecting research published exclusively between 2015 and 2025 to focus on contemporary and contextually pertinent literature. This narrowed the selection to 2,245 articles. The second filtering phase was limiting the publishing language to English exclusively, yielding 960 acceptable articles. Acknowledging the significance of transparency and accessibility in academic research, the review subsequently refined the selection to open access papers, reducing the total to 349 articles.

The subsequent phase entailed a more detailed screening process predicated on the pertinence of titles. This phase eliminated research that were irrelevant or not directly associated with the intersection of technological innovation and climate change mitigation, yielding 244 publications. A structured abstract review was subsequently performed to evaluate methodological relevance, context, and topic alignment. Articles failing to satisfy the conceptual and methodological requirements were eliminated, resulting in 94 papers for comprehensive assessment. During the comprehensive review of texts, 22 papers were subsequently removed due to insufficient attention on climate change, inadequate focus on technological innovation, or deficient methodological rigour. Consequently, 72 articles were deemed pertinent. However, while attempting to obtain the complete contents, it was found that just 61 articles were downloadable and accessible for comprehensive analysis. The final dataset for the systematic literature review comprised 61 open access, English-language, peer-reviewed articles.

The detailed selection process is illustrated in the PRISMA flow diagram below (Figure 1).

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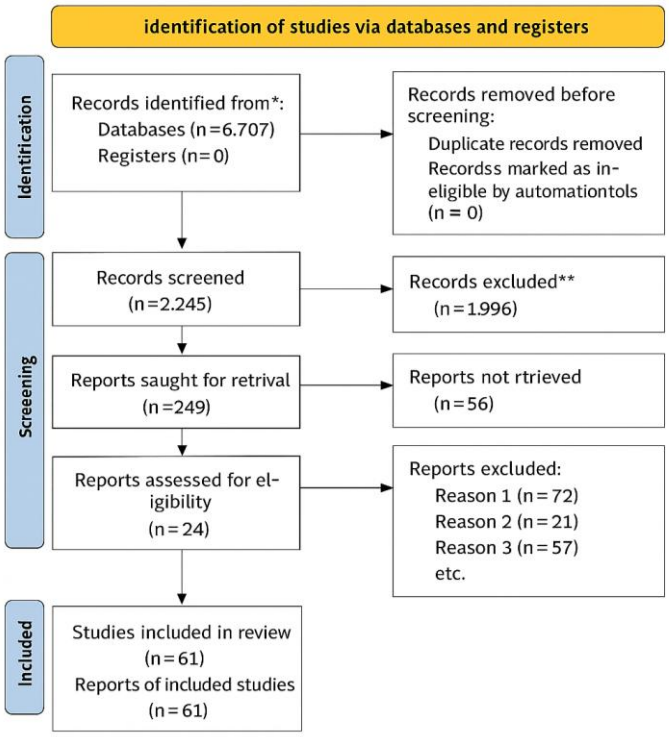

Figure 1: PRISMA flow diagram

Digital Transformation as a Catalyst for Sustainability

The examined literature identifies digital transformation as a crucial catalyst for business sustainability and green innovation. Wang et al. (2023) found that digital transformation in Chinese publicly traded enterprises substantially enhanced social and governance ESG outcomes by improving human capital restructuring, operational performance, and green innovation, especially in capital-intensive and high-tech industries. The GREAN framework, introduced by Ologeanu-Taddei et al. (2025), demonstrates how enterprise architecture may integrate environmental objectives into digital strategies, promoting long-term ecological sustainability. Moreover, the concept of “digitainability” proposed by Gupta et al. (2023) emphasises the deliberate incorporation of digital interventions in accordance with the United Nations Sustainable Development Goals SDGs, rather than solely for immediate efficiency improvements. Their Digitainability Assessment Framework DAF allows organisations to methodically evaluate the environmental and societal consequences of digital initiatives. This viewpoint encourages organisations to evaluate not only the immediate efficiency provided by digitalisation but also the wider socio-ecological consequences.

Digital transformation is pivotal in advancing business sustainability; however, recent literature provides enhanced understanding of how certain digital leadership competencies, technical configurations, and

organisational contexts influence sustainable outcomes. Khan et al. (2025) investigate the synergistic impact of digital leadership and technological innovation on the advancement of circular economy practices. They suggest that companies exhibiting robust digital leadership are more inclined to convert digital expenditures into significant sustainability advancements, especially within the manufacturing industry. This changes the discourse from a generic adoption of digital tools to a transformation paradigm facilitated by leadership. Zhou et al. (2025) expand on this by recognising green knowledge acquisition and innovation performance as essential mediating variables linking digital transformation and business sustainability. This introduces a component of learning and absorptive capability to current models of sustainability-oriented digitalisation. Yin et al. (2024) illustrate how cultural and contextual elements, including corporate transparency and regulatory frameworks in China, influence the effect of digital transformation on ESG performance, particularly in areas where green reporting has recently established.

Sang and Anh (2025) examine the transportation sector and determine that digital logistics and fleet monitoring systems enhance fuel economy while facilitating data-driven eco-routing and predictive maintenance, hence promoting circular resource flows. Huang et al. (2024) emphasise that the integration of intelligent manufacturing with AI and cloud computing platforms enhances transparency, inter-firm collaboration, and traceable metrics for green innovation. Contemporary viewpoints emphasise that the efficacy of digitalisation for sustainability depends on context-specific integration, organisational preparedness, leadership dedication, and adaptive learning frameworks, rather than solely on the implementation of technology.

Green innovation is increasingly acknowledged as essential for balancing economic growth with environmental sustainability (Huang, Song, and Liu, 2024). The examined literature consistently identifies urban policy integration as a crucial facilitator of green innovation, especially in rapidly urbanising and industrialising environments like China (Qian et al., 2024). These policy interventions encompass frameworks such as low-carbon pilot cities, smart city initiatives, and innovation-driven urban development zones, all of which demonstrate the promotion of environmentally sustainable technological advancement (Qian et al., 2024). Qian et al. (2024) conducted an empirical study using a difference-in-differences methodology to evaluate the interplay between "innovative cities" and "low-carbon pilot city" policies in China. Their findings suggest that the interplay of these policies produces a synergistic effect, augmenting corporate green innovation by transforming employment structures, elevating educational investments, and broadening access to finance services (Wang et al., 2024). The research indicates that policy design incorporating both ecological and economic factors is more likely to promote structural innovation (Wang et al., 2024). Bashayreh et al. (2024) endorse this perspective by examining the mediation function of renewable energy in the correlation between urbanisation and CO_2 emissions in Jordan. Their research demonstrates a non-linear, threshold-dependent relationship

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whereby the expansion of renewable electricity mitigates the environmental effects of urban expansion (Bashayreh et al., 2024). They argue that urban environmental degradation is not a direct result of urbanisation, but rather of the carbon intensity of energy systems used in growing cities.

Liu et al. (2024) offer more evidence about the influence of urban governance on sustainability by analysing the dynamics of digital transformation and organisational resilience in Polish Combined Heat and Power CHP facilities. The study, using fuzzy-set Qualitative Comparative Analysis fsQCA, concludes that digital competence, when coupled with dynamic managerial structures and regional policy backing, fosters green organisational innovation (Liu et al., 2024). The authors contend that decentralised innovation policies, tailored to local infrastructural and economic contexts, are more efficacious than standardised, top-down strategies. Jiang and Zhang (2023) examine China's power battery business and highlight the significance of the extended producer responsibility system in fostering technological innovation. They demonstrate that when local governments incorporate extended producer responsibility into comprehensive industrial policies, companies react by augmenting investments in environmentally sustainable research and development, especially in domains pertaining to recycling, emissions mitigation, and lifetime product management (Kandpal et al., 2024).

Blockchain and cloud computing promote sustainable innovation through enhanced traceability and efficient resource allocation. Vandevenne et al. (2024) suggest that the incorporation of these technologies into enterprise architecture facilitates the development of green value chains and harmonises internal practices with external sustainability standards. These strategies enable organisations to achieve ESG-aligned outcomes at scale. Moreover, digital transformation enhances environmental performance through improved data-driven decision-making. Alamandi (2025) demonstrate that organisations with robust digital infrastructures can respond more swiftly to alterations in climate legislation, incorporate ESG risks into their operations, and execute mitigation methods like eco-innovation. Shao et al. (2024) discovered that cloud-based ESG solutions assist manufacturing companies in Ningbo, China, in improving real-time reporting, which results in increased investor confidence and less environmental compliance concerns. Digitalisation propels organisational sustainability by transforming internal operations and value generation processes. Zhao et al. (2024) assert that organisations using digital performance dashboards can incorporate ESG indicators into corporate performance evaluations, so transforming sustainability into a quantifiable business performance instead of merely an idealistic objective. Blockchain and cloud computing are essential in promoting traceable and responsible supply chains, ensuring compliance with ESG standards. Moreover, these technologies function as foundational facilitators for sustainable enterprise architecture, as noted by Al-Swidi et al. (2024), who found that digital platforms enable enterprises to model and predict environmental impacts prior to policy implementation. Digital maturity is significantly correlated with proactive ESG risk management. Bashynska et al. (2024) observed that companies with elevated

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digital capabilities are better at absorbing shocks and adapting to environmental demands, based on their analysis of data from Chinese industrial businesses engaged in smartisation projects.

The Role of Green Innovation and Urban Policy Integration

Green innovation is constantly considered a vital mechanism for tackling the dual challenges of economic development and ecological sustainability (Shao et al., 2024). In the examined literature, urban policy integration is identified as a key enabler of innovation, especially via specific frameworks like low-carbon pilot cities, green development zones, and smart urban infrastructure initiatives. These actions cultivate a conducive atmosphere for innovation by harmonising environmental objectives with local socio-economic development strategies (Wang et al., 2024). Wang et al. (2024) provide empirical data in the Chinese setting, using a difference-in-differences methodology, demonstrating that the integration of “innovative city” and “low-carbon pilot city” policies yields substantial positive spillovers for green innovation. Their findings indicate that this policy synergy not only augments firms' innovation capabilities but also enhances labour market outcomes, educational quality, and financial infrastructure elements that collectively support a city’s ability to facilitate sustainable industrial transformation.

Bashayreh et al. (2024) analyse the Jordanian experience and uncover a non-linear link between urbanisation and CO_2 emissions, influenced by the proportion of renewable energy in electricity generation. Their research highlights that merely augmenting urban density is inadequate; instead, urban expansion must be integrated with comprehensive energy transitions to get sustainable results (Bashayreh et al., 2024). Kwiotkowska (2024). offer more insight into the function of urban-level innovation by employing fuzzy-set Qualitative Comparative Analysis fsQCA on Polish combined heat and power CHP facilities. They determine that green innovation is substantially influenced by organisational capacities integrated into digital urban infrastructures and bolstered by region-specific governance frameworks. Their research indicates that place-based policy combinations, particularly when integrated with digital transformation initiatives, concurrently foster ecological resilience and innovation (Kwiotkowska (2024).

Jiang and Zhang (2023) analyse China's power battery industry in the industrial domain, investigating how extended producer responsibility EPR regimes, when harmonised with local urban development plans, promote green technical innovation. The findings indicate that EPR not only encourages companies to minimise lifecycle environmental impacts but also stimulates investment in green research and development, particularly in metropolitan areas with robust governmental support for sustainability Jiang and Zhang (2023). Another study by Liu et al. (2024) reinforces the connection between integrated urban policy and green innovation by illustrating how digital transformation at the municipal level improves sustainability performance. The analysis of firm-level data from Ningbo, China, reveals that cities with digital policy incentives generally promote superior environmental performance among local

firms. In addition, Wang et al. (2023) expand this discourse by examining the influence of digital economy advancement on reducing carbon inequality among Chinese cities. They contend that the integration of digitalisation into urban policy promotes equitable innovation dissemination and enables marginalised areas to engage in sustainable development pathways (Wang et al., 2023). Their findings emphasise the need of inclusive policies to guarantee the equitable distribution of the advantages of green innovation in urban and peri-urban areas. These studies offer a compelling narrative that effective integration of urban policy, particularly at the intersection of innovation and decarbonisation efforts, may foster a conducive climate for green technology progress. This policy cooperation improves environmental results, social inclusion, institutional resilience, and sustainable economic growth.

Green financing is increasingly emerging as a crucial facilitator of climate innovation. Fu et al (2024) demonstrate that digital financial platforms alleviate financial limitations and promote the adoption of green technologies, particularly in capital-intensive sectors such as manufacturing. Moreover, blockchain-enabled smart contracts provide transparency in the allocation of green bonds and financial resources. This has alleviated greenwashing risks and enhanced investor confidence in sustainability-linked financial products, as posited by Tan and Liu (2024). Fintech platforms are becoming essential in expediting climate mitigation financing. These platforms enable investors and regulators to evaluate environmental, social, and governance ESG risks in real time through automation, predictive analytics, and data-driven evaluations. Zaid (2025) illustrate how fintech applications have enhanced transparency and accountability in green financing through the incorporation of real-time carbon tracking, ESG assessment, and environmental impact modelling. Smart contracts ensure that money designated for green initiatives is used in accordance with established environmental criteria. According to Boumaiza (2025), blockchain-enabled green bonds enhance capital allocation efficiency and mitigate the danger of greenwashing, hence promoting institutional investor engagement in ESG-focused markets. Hossain et al. (2024) assert that green micro-investment platforms, through mobile technology, enable individuals to engage in community-level climate initiatives while fostering environmental consciousness. Lu et al. (2024) note that provinces with more robust environmental regulations and integrated digital policies excel in attracting green investments and promoting environmentally responsible entrepreneurship.

Diversified Policy Instruments and Localised Contexts

Benlaria and Almawishir (2025) emphasise that sustainability performance in higher education enhances when green management techniques are bolstered by legal frameworks and environmental awareness initiatives. Their research emphasises that urban policy frameworks cannot depend exclusively on infrastructure development; they must include organisational culture and environmental literacy to facilitate significant innovation adoption. Tao (2025) propose that green transparency in urban enterprises is significantly influenced by cultural and regional circumstances, rather than being merely

a regulatory issue. In Chinese cities, the adoption of sustainability reporting and environmental disclosures at the business level was augmented in areas characterised by increased community engagement and higher social expectations for corporate environmentalism. Farooq et al. (2025) expand the geographic perspective, revealing that the efficacy of urban policy in G7 countries is influenced by levels of economic growth, trade openness, and educational systems. The green economic transition is expedited when municipal policy coordination aligns with international trade and educational agendas, particularly through incentives for the development of green technology and the integration of green skills into educational curriculum. Benlaria and Almawishir (2025) investigate the interplay between educational and economic frameworks and institutional durability in developing regions. Institutional sustainability initiatives are influenced by the robustness of local policy ecosystems, indicating that grassroots policy involvement from universities, SMEs, and local governments can enhance green innovation results. Sang and Anh (2025) examine the progression of green innovation in urban transportation and mobility systems, specifically in Chinese metropolitan areas. Their research indicates that digitalisation in traffic systems, intelligent vehicle infrastructure, and AI-driven energy efficiency foster green innovation in densely populated urban areas. This indicates a transition from conventional environmental policy instruments to technology-driven urban innovation frameworks.

Financial Instruments and Green Finance in Promoting Sustainability

A substantial amount of the examined literature stresses the increasing significance of green financial systems in facilitating sustainable corporate conduct. Green bonds, ESG investment methods, fintech platforms, and environmental finance are identified as efficient mechanisms for directing resources towards low-carbon development. Zheng and Jin (2023) demonstrate that green financial development diminishes stock price crash risk in Chinese publicly traded enterprises by alleviating information asymmetry, indicating that financial openness is essential for sustainable investing. Furthermore, fintech exhibits a substantial mediating influence on circular economy results and sustainability performance (Zaid et al., 2024). Wang et al. (2023) further substantiate these findings, illustrating that environmental finance, enhanced by technology innovation, is crucial for enabling clean energy transitions and mitigating financial risks associated with environmental deterioration. These studies collectively conclude that financial innovation and digital infrastructure are crucial for enabling sustainable investment flows and encouraging environmentally responsible behaviour among companies. Lutfi et al. (2023) exemplify that green financial development substantially reduces stock price crash risks in Chinese listed companies. This is accomplished by diminishing information asymmetry, signifying that transparency in financial operations bolsters investor trust and promotes long-term sustainable practices among companies.

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Fintech, especially in relation to circular economy models, significantly enhances company sustainability. Zhou et al. (2025) examine this dynamic and conclude that fintech-driven platforms augment sustainability performance by enabling real-time data exchange, enhancing financial inclusion, and promoting transparency in supply chain finance. Wang et al. (2024) demonstrate that fintech significantly mediates the relationship between circular economy practices and business performance, suggesting that technological infrastructure is a crucial catalyst for contemporary green finance ecosystems. Saeedi and Ashraf (2024) provide complementary conclusions, asserting that environmental finance, when bolstered by digital technology, enhances the efficacy of climate-friendly investment portfolios. Their research delineates how fintech instruments mitigate information disparities and transaction expenses, thereby facilitating capital allocation for renewable energy transitions and the advancement of green technologies.

Ye and Dela (2023) investigate the relationship among green investment, green financing, and corporate social responsibility CSR in Indonesia's chemical sector. They indicate that green financing favorably influences sustainable business performance, with CSR acting as a vital mediating mechanism that converts green investments into quantifiable sustainability results. This highlights the social aspect of green finance, where business ethics and stakeholder involvement enhance environmental goals (Bashayreh et al., 2024). Sun and Saat (2023) evaluate the influence of carbon emission trading schemes (ETS) on the ESG performance of Chinese firms. Their findings indicate that the establishment of an ETS results in favourable enhancements in governance and environmental transparency by establishing market-based incentives for emissions reductions. The study indicates that financial markets positively react to companies using transparent environmental pricing methods, highlighting the need of harmonising financial policy with environmental regulation.

Enhancing Financial Inclusion, Investment Alignment, and Eco-Risk Management

Fintech continues to gain attention as a democratising influence. Asbeetah et al. (2025) examine the role of blockchain-based platforms and digital banking instruments in enhancing financial inclusion and transparency, particularly in sustainability-oriented supply chains and carbon accounting methodologies. Their findings advocate for the establishment of fintech-based regulatory sandboxes that facilitate experimentation with green financial instruments while ensuring environmental accountability. The study of Handoyo and Anas (2024) focus on ESG scoring systems in developing nations, demonstrating that companies with superior ESG practices are more inclined to secure green financing through specific government investment initiatives. Their research demonstrates how the co-evolution of public-sector investment and private ESG adherence fosters sustained ecological and market performance. The study by Chen et al. (2025) indicates that participation in emissions trading schemes ETS not only

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corresponds with green finance objectives but also incentivises enterprises to reinvest their carbon proceeds into technical innovation and sustainability training for staff.

Regulatory Influence and Environmental Governance

A prominent issue in the literature is the influence of environmental rules and governance frameworks on business sustainability practices. Regulatory mechanisms, such carbon trading initiatives, environmental tax incentives, and green credit systems, are often regarded as helpful in promoting green innovation and sustainability-focused decision-making. The study by Yang et al. (2023) demonstrate that China's carbon emission pricing regime significantly enhances corporate ESG performance by compelling enterprises to internalise the environmental costs of their activities. At the organisational level, corporate governance and environmental focus are identified as moderating variables. Governmental environmental focus substantially affects companies' inclination to engage in green technology innovation, with more proactive governance frameworks resulting in more green outputs (Wang et al., 2024). Moreover, company ESG performance is significantly influenced by green innovation initiatives, illustrating a cyclical relationship among regulatory compliance, innovation, and sustainable growth (Chen et al., 2023).

One of the more effective mechanisms examined is carbon emission trading. It was found that the enforcement of China's carbon trading program significantly enhances ESG performance by enforcing accountability for emissions, therefore compelling enterprises to adopt cleaner production methods and imaginative approaches. Li et al. (2024) argue that heterogeneous environmental legislation can either promote or obstruct green innovation, contingent upon firm-specific attributes such as size, location, and financial resources. On a larger scale, green credit schemes have demonstrated effectiveness in enhancing environmental performance.

Corporate governance frameworks interact with legislative requirements to affect environmental results. Chen et al. (2023) emphasise that companies with excellent ESG policies typically demonstrate enhanced innovation performance, indicating that internal governance mechanisms bolster exterior regulatory compliance. This cyclical dynamic demonstrates that governance functions as both a catalyst and a recipient of regulatory compliance. The extended producer responsibility EPR scheme exemplifies good environmental governance. Jiang and Zhang (2023) analyse the influence of EPR standards on China's power battery market and conclude that these regulations encourage companies to engage in sustainable technology and innovation focused on the product lifecycle. The EPR framework serves as a regulatory foundation that directs corporate goals towards sustainability by ensuring accountability for end-of-life products. Moreover, legal frameworks which promote environmental disclosure are associated with improved market perception and increased stakeholder trust. Zhang and Sun (2023) indicate that companies functioning inside transparent carbon trading frameworks are more prone to

display enhanced governance ratings and draw ESG-focused investors, illustrating that disclosure regulations are a fundamental component of environmental governance.

Institutional Capacities, Policy Synergies, and Behavioural Enforcement

The results of Wang et al. (2025) indicate that a synergy of regulatory pressure, internal technology preparedness, and market orientation produces significant green innovation results. This shifts discussion from linear causation models to multidimensional frameworks of facilitating conditions. Concurrently, dos Reis et al. (2025).) examine the frequently neglected aspect of green transparency as a behavioural component of environmental governance. They advocate for governance techniques that are contextualised to recognise regional cultural values while adhering to international reporting standards. Dai et al. (2025) analyse how Kazakhstan integrates eco-branding with governmental environmental policies to concurrently improve manufacturing competitiveness and adhere to carbon reduction regulations. They emphasise that eco-branding functions as a subtle regulatory mechanism, influencing corporate conduct through reputational incentives rather than solely through legislative requirements. Fu and Zailani (2025). present a supplementary analysis of the interplay between educational capacity-building and regulatory compliance, demonstrating that government-sponsored sustainability training programs enhance awareness and execution of green policies in SMEs.

Supply Chain Sustainability and Industry-Specific Insights

Pereira et al. (2024) identify transactional and transformational leadership as essential enablers of sustainable supply chain operations. In specific sectors, such as Brazil's biomass power plants and China's lithium energy chains, circular economy practices and low-carbon technologies are identified as essential options for reconciling economic productivity with environmental sustainability (Pereira et al., 2024; Fu and Zailani, 2025). These insights show that industry-specific routes are important to adapt sustainable development frameworks, especially in high-emission or resource-intensive areas. Abbas (2024) highlight the pivotal importance of leadership in advancing sustainable operations. Their research indicates that both transactional and transformational leadership styles substantially influence the execution of GSCM processes, such as green procurement, reverse logistics, and supplier environmental evaluations. The leadership strategy not only affects internal environmentally sustainable practices but also improves external cooperation within supply chain networks.

Nguyen et al. (2023) argue for lifecycle assessment tools and environmental performance indicators as important components of GSCM frameworks in the industrial sector. The mining industry, a historically high-impact sector, is currently experiencing a digital and sustainable revolution. Osei et al. (2023) advocate for a more cohesive and digitised strategy for managing supply networks in the mining sector to tackle issues related to resource dependency and emissions intensity. Pereira et al. (2024) examine

biomass-fired power plants in Brazil in the energy sector, using the ReSOLVE framework to evaluate circular economy practices. Their research indicates that initiatives including the regeneration of biological materials, optimisation of resource flows, and virtualisation of energy services enhance energy security and decrease carbon emissions. The textile industry, a significant source of pollution, is increasingly being prioritised for sustainable reform. Pereira et al. (2024) emphasise that sustainable supply chain strategies among Portuguese textile exporters provide both environmental benefits and a competitive edge in global markets. Their findings suggest that green logistics, adherence to environmental certifications, and supply chain transparency are essential for entering global markets. Zhang et al. (2023) highlight the significance of GSCM in advancing the UN Sustainable Development Goals SDGs by identifying connections between GSCM research trends and global sustainability initiatives. Their research highlights the need for context-specific and industry-specific methods that tackle both environmental degradation and socio-economic development objectives.

Green supply chain management GSCM strategies are widely implemented to reduce carbon footprints and enhance circularity. Ameh (2024) investigate how digitalisation enables real-time monitoring of carbon-intensive operations throughout the supply chain, hence aiding in carbon audits and compliance with climate mitigation efforts. Moreover, research indicates that AI and IoT facilitate lifetime analysis and predictive maintenance, hence minimising operational waste. The study by Raman et al. (2023) illustrate that GSCM enhances environmental performance while simultaneously promoting green innovation and competitiveness. Biomass and renewable-based circular models are also essential. The ReSOLVE framework used by Pereira et al. (2024) in Brazil assesses and enhances circularity in energy production processes, thereby reducing ecological effect.

The integration of blockchain and IoT technology inside supply chains enhances carbon traceability, risk forecasting, and adherence to environmental regulations. This is especially apparent in the manufacturing and logistics industries, where intelligent technologies optimise inventory management while maintaining environmental responsibility (Chauhan et al., 2024). Furthermore, research conducted by Liu et al. (2024) indicates that AI-driven predictive analytics improve visibility inside intricate supply networks while simultaneously decreasing manufacturing waste and energy usage, resulting in quantifiable enhancements in cost efficiency and carbon intensity. Circular methods, including remanufacturing, eco-design, and reverse logistics, are becoming more prevalent across several industrial sectors. A systematic review by Kosasih et al. (2023) on green lean supply chains in SMEs revealed that the adoption of integrated sustainability strategies mitigated lifecycle environmental consequences and enhanced competitive differentiation.

Furthermore, in energy-intensive sectors, policy-congruent circular economy solutions like waste valorisation and industrial symbiosis have demonstrated efficacy in implementing sustainability. Mahar

et al. (2025) shown that green innovations and inter-firm collaboration in waste-to-energy transitions significantly enhance ecological results and supply chain resilience in Pakistan's industrial sector. The mediating role of green information exchange and customer integration is significant, since they enable the alignment of internal processes with external sustainability objectives. The integration of blockchain for trust and traceability enhances the resilience of GSCM systems, as demonstrated by Mohamed et al. (2024), who empirically confirmed these correlations through SEM-PLS modeling in a Chinese industrial scenario.

Digitally Enabled Resilience, Contextual Adaptation, and Sectoral green Productivity

Zhang et al. (2024) demonstrate that intelligent manufacturing capabilities, facilitated by technologies like blockchain and AI, improve ESG performance throughout supply chains by fostering transparency, green innovation, and inter-organisational collaboration. Their research confirms that supply chain sustainability is not merely an operational issue but a strategic imperative that demands technical advancement and governance coherence. Zhou et al. (2025) examine supply chain optimisation in new energy vehicle NEV industries in emerging markets with a blockchain-based collaborative evolutionary game model. The research indicates that establishing trust through digital traceability systems improves sustainability and collaboration among manufacturers, logistics providers, and recyclers, particularly in the context of environmental uncertainty. Liu et al. (2025) found that integrating sustainable medicine production procedures with digital process tracking can diminish ecological footprints while maintaining profitability and patient outcomes. The findings of Fu and Zailani (2025) indicate that internal environmental training and carbon accounting systems exert a greater influence than external certification schemes, highlighting the significance of internal capacity-building.

Organisational Culture, Green Awareness, and Behavioural Change

Huang and Xie (2025) examine the role of executive green awareness in influencing global green value chains. Their findings indicate that companies with environmentally aware leadership teams are more inclined to integrate sustainability principles into sourcing, production, and logistics strategies. He et al. (2025) explore the influence of cultural and contextual factors on green transparency inside Chinese enterprises. They contend that organisational transparency, trust, and contextual awareness affect organisations' responses to ESG reporting mandates and stakeholder examination. Liu et al. (2025) demonstrate that internal campaigns, sustainability education, and the cultivation of a green culture substantially enhance institutional performance for environmental metrics in the education sector. in addition, a stud by Khan et al. (2024) examine the influence of digital transformational leadership on facilitating green knowledge acquisition and innovation. Leaders that cultivate a culture of learning and

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embrace digital transformation indirectly enhance sustainability by facilitating innovation absorption and team cohesion. Moreover, research by Zhou et al. (2025) ascertain that employee perceptions of environmental responsibility moderate the efficacy of green innovation activities at the employee level. When employees exhibit a robust organisational commitment to environmental principles, they are more inclined to engage in sustainability initiatives, resulting in increased green innovation output.

Advanced innovations, such as artificial intelligence and digital twins, are increasingly used to forecast and reduce carbon emissions. Silva et al. (2025) introduce an intelligent modelling approach that combines GIS and carbon measurements to evaluate emissions hotspots in the textile sector. Robotic applications are increasingly recognised for their contribution to reducing industrial pollution. Huang et al. (2024) assert that industrial robots enhance productivity while concurrently decreasing energy consumption and process emissions, therefore elevating ESG performance. Moreover, artificial intelligence AI in intelligent energy grids facilitates optimised energy utilisation, leading to substantial decreases in carbon emissions. Losada-Agudelo and Souyris (2024) contend that companies utilizing AI-driven solutions demonstrate superior emissions management and adherence to regulations.

Li et al. (2024) illustrate that geographic information systems GIS combined with carbon metric dashboards may proficiently visualise emission hotspots in energy-intensive industries such as textiles.

Through the simulation of process-level emission scenarios, companies can implement targeted interventions, leading to substantial reductions in carbon emissions. AI-driven digital twins have been implemented in manufacturing and logistics to replicate real-time operations and model emissions across various scenarios. Huang ate et al. (2024) assert that predictive analytics integrated inside digital twin frameworks enable organisations to foresee system inefficiencies and carbon surges prior to their manifestation, hence fostering low-emission decision-making. Robotics also play a crucial part in decarbonisation. Khan et al. (2025) demonstrate that the implementation of smart industrial robots not only improves production but also mitigates human-induced inefficiencies, frequently leading to excessive emissions. Automation, combined with real-time environmental monitoring, enhances energy efficiency across several manufacturing lines.

In the energy sector, AI-powered smart grids are assisting companies in shifting from reactive to proactive emissions management. Employing machine learning algorithms, these systems optimize energy loads, effectively incorporate renewable sources, and forecast carbon emissions. Chang et al. (2023) demonstrate that these grid systems are associated with significant decreases in firm-level carbon emissions and improved regulatory compliance results. A further aspect of innovation pertains to process-level carbon accounting instruments. Wang (2024) assert that these tools enable enterprises to evaluate the carbon emission intensities of specific production stages, hence enhancing comprehension of environmental implications and guiding the creation of cleaner processes.

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Discussion

This systematic review offers a comprehensive overview of how technological advances are transforming business and economic environments in response to climate change mitigation requirements. The analysis of 80 documents reveals a strong consensus that digital and green innovations, specifically artificial intelligence AI, blockchain, Internet of Things IoT, big data analytics, and clean energy technologies, are crucial for decarbonising industries, optimising resource utilisation, and enhancing ESG performance. Nonetheless, their influence varies significantly among industries and regions, primarily shaped by regulatory maturity, organisational preparedness, and cultural environment. This review reveals the dual function of technology innovation as an environmental enabler and an economic catalyst. In the energy sector, AI and blockchain have significantly enhanced the integration and traceability of renewable sources, improving system flexibility and driving cost reductions. In manufacturing and logistics, digital twins and IoT-based monitoring systems have facilitated predictive maintenance and emissions reduction, yielding measurable environmental benefits in conjunction with productivity enhancements. The transportation and textile industries have notably profited from digital technologies focused on circularity, demonstrating that sustainability and competitiveness may be mutually reinforcing when technology is effectively utilised. Financial innovation serves as a fundamental element of the climate-technology relationship. Green finance instruments, including carbon pricing, green bonds, and fintech-enabled environmental platforms, have been essential in aligning financial flows with sustainable development goals. These instruments not only mitigate investment risks in clean technology but also foster market discipline through improved transparency and ESG disclosure regimes. Nonetheless, obstacles remain, especially in the Global South, where the implementation of such instruments is hindered by infrastructural and institutional deficiencies. This review highlights an increasing focus on collaborative and cross-sectoral methodologies. Numerous studies emphasise that attaining climate resilience necessitates collaboration among politicians, businesses, academia, and civil society. Regional plans that combine low-carbon urban design with technological innovation hubs have demonstrated considerable potential in China, Indonesia, and Brazil. These synergies demonstrate how place-based strategies and policy coherence enhance the efficacy of climate technologies in practical applications. Nevertheless, the assessment highlights some significant deficiencies. Many studies remain confined to their respective disciplines and do not adequately address the systemic interdependencies among technology, governance, and business models. Moreover, although the economic advantages of innovation are frequently lauded, there is a lack of research offering detailed insights into the social ramifications, including labor displacement and digital inequality. Rectifying these oversights is essential for fostering inclusive and equitable climate transitions. W hereas technology innovation possesses transformational potential, its effectiveness depends on conducive policy frameworks, capacity development, and ethical governance. The business and economic effects

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are favourable but necessitate a more cohesive, equity-centered, and systemic approach to properly capitalize on the prospects for climate change mitigation.

Conclusion

This comprehensive review has rigorously analysed the use of technical advancements to tackle the dual concerns of climate change and economic development. The results clearly indicate that digital technology and green innovations are viable solutions and strategic assets that facilitate organisations in transitioning to low-carbon, circular, and resilient operational models. Technologies like AI, blockchain, and IoT are transforming company strategies by enhancing environmental monitoring, energy efficiency, and supply chain transparency. Financial instruments like green bonds and ESG-linked financing are enhancing this momentum by channeling investments into sustainable initiatives. Furthermore, the convergence of urban policy, targeted sector initiatives, and organisational culture proved to be essential facilitators of success. Nonetheless, the implementation of climate technology must not transpire in isolation. The literature indicates that systemic alignment among technical competence, institutional preparation, and inclusive governance is crucial for optimising their potential. Future research must embrace transdisciplinary approaches to elucidate the intricate and interrelated dynamics of climate, technology, and business. Increased emphasis is required on the socio-economic trade-offs of innovation, especially in emerging regions with significant vulnerabilities. This study enhances the existing expertise advocating for innovation-driven climate action and emphasises the need for evidence-based policy frameworks that facilitate sustainable business transformation. By responsibly and inclusively using technological advancements, businesses and policymakers can jointly expedite progress towards climate resilience and sustainable development. The recommendations of the study are discussed below;

- **Invest in organisational digital readiness**: Companies must emphasise internal capacity development, encompassing digital skills training, environmental awareness initiatives, and investment in ICT infrastructure to successfully use sustainability solutions.
- **Advocate for executive green leadership**: Organisations must foster environmentally aware leadership to embed sustainability into fundamental strategies, operations, and company culture.
- **Fintech for sustainable financing**: Financial institutions and governments ought to enhance fintech platforms and blockchain-enabled green bonds to augment transparency, bolster investor confidence, and facilitate access to climate finance, especially in poor regions.
- **Enhance the integration of urban policies**: Policymakers ought to formulate urban development strategies that integrate low-carbon programs with digital innovation zones

(e.g., smart cities, green infrastructure) to foster conducive settings for the adoption of sustainable technologies.

- **Promote circular economy initiatives:** Businesses ought to use circular models such as waste valorisation, remanufacturing, and reverse logistics to dissociate economic expansion from environmental harm.

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