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ARTIFICIAL INTELLIGENCE AS AN ENABLER OF ENVIRONMENTAL SUSTAINABILITY AND THE SUSTAINABLE DEVELOPMENT GOALS

Review paper

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Abstract: Environmental challenges have consistently stimulated discussions, debates, public concern, and awareness initiatives, generating increasing interest in innovative technologies such as Artificial Intelligence (AI). AI applications span various environmental sectors, including wildlife conservation, natural resource management, renewable energy, agriculture, energy efficiency, pollution mitigation, and waste management. In 2017, during the United Nations Artificial Intelligence Summit held in Geneva, the UN recognized that AI could serve as a catalyst for sustainable development aimed at promoting peace, prosperity, and a dignified life for humanity. The UN also proposed a renewed focus on leveraging AI to support global efforts to eradicate poverty and hunger, protect the environment, and conserve natural resources.
Addressing environmental sustainability challenges is essential; however, the rapid development of AI offers new opportunities to address environmental challenges more effectively while promoting human well-being. Sustainability encompasses the interconnected dimensions of the environment, society, and economy. The United Nations report titled "Our Common Future," often referred to as the "Brundtland Report," characterizes sustainable development as "development that fulfills the needs of the present while ensuring that future generations can also meet their own needs."
Unfortunately, the Earth is currently facing significant consequences associated with global warming and climate change, requiring urgent measures to promote environmentally friendly practices and sustainable solutions. Environmental degradation and climate change represent complex challenges that require innovative and intelligent approaches supported by AI. The body of literature on AI and environmental sustainability encompasses a wide range of fields. In particular, AI is increasingly being applied to address regional and global environmental challenges related to energy, water, biodiversity, transportation, agriculture, waste management, and pollution control.
Nevertheless, there is a pressing need to synthesize the existing literature on the application of AI to environmental sustainability, particularly regarding its contribution to key areas such as energy, water, biodiversity, transportation, and environmental health. A considerable research gap remains concerning the ways in which AI can contribute to environmental sustainability and support the achievement of the Sustainable Development Goals (SDGs). Therefore, this study aims to examine the role of AI as an enabler of environmental sustainability and to explore its potential contribution to achieving the Sustainable Development Goals.
Key words: Artificial Intelligence, Environmental Sustainability, Sustainable Development Goals, Renewable Energy.

INTRODUCTION

Recent environmental challenges have heightened public awareness and concern, leading to growing interest in innovative technologies such as Artificial Intelligence (AI). As societies confront increasingly complex environmental challenges, AI has emerged as a promising technological approach for supporting sustainable development through data-driven analysis, prediction, optimization, and decision-making (Greif et al., 2025; Gohr et al., 2025). AI has considerable potential to support the achievement of the Sustainable Development Goals (SDGs), particularly through its ability to process large and complex datasets, identify patterns, develop predictive models, and optimize environmental and energy systems (Greif et al., 2025). Furthermore, recent research indicates substantial growth in studies examining the relationship between AI and sustainable development, highlighting the potential of AI to contribute to multiple SDGs (Gohr et al., 2025). The relationship between AI and sustainability is multidimensional. AI can contribute to environmental sustainability by improving resource management, supporting energy efficiency, optimizing production and

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transportation systems, monitoring environmental conditions, and facilitating climate-related predictions (Kulkov et al., 2024). At the same time, the sustainable implementation of AI requires consideration of its energy and computational requirements and the potential environmental implications associated with the deployment of AI-based technologies. Therefore, the sustainable application of AI requires consideration not only of its potential environmental benefits but also of the resources required for its operation and implementation (Kulkov et al., 2024; Greif et al., 2025).

Achieving environmental sustainability presents a multifaceted challenge because the environmental, economic, and social dimensions of sustainability are closely interconnected. Recent research emphasizes that AI can serve as an important enabler of sustainable development by supporting organizations and industries in optimizing processes, improving decision-making, and addressing complex sustainability challenges (Kulkov et al., 2024). AI is particularly valuable because of its ability to analyze extensive datasets, identify complex relationships, generate predictions, and support the optimization of environmental systems (Greif et al., 2025; Gohr et al., 2025).

Given the threats posed by global warming and climate change, AI has increasingly been investigated as a tool for climate mitigation and adaptation. Recent research demonstrates that AI-based predictive models can support the assessment of climate change impacts, while machine learning and predictive analytics can improve the understanding and forecasting of complex climate-related processes (Ukoba et al., 2025). The application of AI is also increasingly relevant to renewable energy and energy sustainability. Recent research highlights the role of AI and machine learning in energy demand forecasting, smart-grid management, energy optimization, renewable-energy integration, and improving energy efficiency (Shahverdi et al., 2025).

The intersection of AI and environmental sustainability encompasses several important areas, including sustainable agriculture, natural-resource and biodiversity conservation, renewable energy, waste management, pollution control, and climate action. Recent research has examined AI applications across different environmental and sustainability domains, demonstrating its potential to improve prediction, monitoring, optimization, and decision-making processes (Raihan et al., 2024; Greif et al., 2025). Similarly, AI applications in sustainable energy systems have been increasingly explored as a means of improving energy efficiency, reducing waste, integrating renewable energy sources, and supporting progress toward the SDGs (Shahverdi et al., 2025).

Consequently, the sustainable and responsible use of AI has become increasingly important for achieving environmental sustainability and advancing the Sustainable Development Goals. Current research suggests that AI can act as an important enabler of sustainability; however, its benefits depend on responsible implementation, appropriate governance, data availability, transparency, and consideration of the environmental implications of AI deployment (Gohr et al., 2025; Kulkov et al., 2024).

Research on artificial intelligence for environmental sustainability spans a wide range of fields. Addressing both regional and global environmental challenges is essential, and AI is increasingly being utilized across the energy, transportation, biodiversity, and water sectors (Raihan et al., 2024; Gohr et al., 2025). These domains are continuously evolving and influencing various aspects of society. AI-based approaches can support environmental monitoring, resource optimization, climate-related analysis, sustainable infrastructure development, and the management of complex environmental systems. In particular, the application of AI to sustainable infrastructure and the construction sector provides opportunities to improve environmental performance and support more sustainable urban development (Regona et al., 2024; Debrah et al., 2022). Therefore, there is a continuing need for systematic research examining how artificial intelligence can be leveraged to advance environmental sustainability across areas such as water, energy, transportation, biodiversity, and sustainable urban development (Greif et al., 2025).

MATERIALS AND METHODS

The methodological framework of this study is based on analytical and synthesis methods used to examine the role of artificial intelligence (AI) and smart technologies in enhancing environmental sustainability in the building sector and supporting the achievement of the Sustainable Development Goals (SDGs). The research focuses on the application of AI-based models and smart technologies across the planning, design, construction, and operation stages of green buildings. Previous research has demonstrated the increasing relevance of AI for green buildings, particularly in relation to intelligent optimization, data-driven decision-making, energy efficiency, environmental performance, and the automation of building processes (Debrah et al., 2022; Rodríguez-Gracia et al., 2023).

The analytical method was applied to identify and examine the characteristics, functions, and environmental applications of AI and smart technologies used in green building practices. The synthesis method was subsequently applied to categorize and integrate the examined technologies, artificial intelligence models, information systems, and automatic control systems. This methodological approach was selected because AI applications in sustainable construction involve different technological domains, including machine learning, deep learning, artificial neural networks, Building Information Modeling (BIM), environmental monitoring, intelligent control, and optimization systems. Recent systematic research confirms that these technologies are increasingly being investigated as tools for improving the sustainability of the construction sector and supporting relevant SDGs (Regona et al., 2024; Greif et al., 2025).

The research was conducted in five sequential stages. In the first stage, the principal environmental challenges associated with construction and building operation were identified. The analysis considered atmospheric pollution, water contamination, greenhouse gas emissions, waste generation, material consumption, and energy consumption. Relevant statistical data and scientific literature were examined to identify major environmental pressures associated with the construction and building sectors. Particular attention was given to the need for technological solutions capable of monitoring environmental conditions, processing large amounts of data, optimizing resource use, and reducing the environmental impacts of buildings throughout their life cycle. The Chinese *Assessment Standard for Green Building* (GB/T 50378-2014) was also considered in order to identify the principal requirements associated with green building development. The environmental challenges identified at this stage were subsequently related to the relevant Sustainable Development Goals, particularly SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) (Regona et al., 2024).

In the second stage, smart technologies used for monitoring, collecting, transmitting, and processing physical and environmental parameters associated with buildings were identified and analyzed. Particular attention was given to the integration of AI into building management and control systems. The methodological analysis included artificial neural networks, machine learning, and deep learning approaches used for prediction, classification, monitoring, optimization, and automated decision-making. The application of AI in green and smart buildings has been examined in recent literature, with applications including building performance optimization, thermal performance assessment, energy management, and environmental monitoring (Rodríguez-Gracia et al., 2023; Mahmood et al., 2024). The analysis also considered the role of AI in transforming building-related data into information that can support decision-making and automated control. Particular attention was given to applications capable of improving the operational efficiency of buildings while reducing energy consumption and environmental impacts. Recent studies on artificial intelligence across the building life cycle demonstrate that AI can be utilized during the design, construction, operation, maintenance, and retrofit phases to enhance energy efficiency (Yussuf & Asfour, 2024).

The third stage involved the synthesis and classification of technologies intended to improve the environmental and resource efficiency of construction processes. The analysis focused on reducing material consumption, energy use, waste generation, and other environmental impacts associated with construction activities. Building Information Modeling (BIM) was examined as an important digital technology for supporting sustainable building design and construction. Particular attention was given to the integration of BIM with AI-based approaches, since the combination of these technologies can support data-driven decision-making, design optimization, building performance assessment, and sustainable building management. A systematic review of BIM-AI integration in the architecture, engineering, construction, and facility management sector demonstrated that such integration is applied across the project life cycle and includes applications related to sustainable development (Zhang et al., 2022).

The environmental performance of buildings was also considered through analytical approaches for evaluating and comparing environmental and resource-efficiency parameters. The analysis included the standardization and comparison of relevant building-performance parameters, as well as consideration of environmentally appropriate construction materials. The main types of pollution associated with construction activities and the environmental protection measures required to reduce their adverse effects were also examined. Existing standards and technological approaches for green building design and construction were therefore considered as complementary elements of the methodological framework. The analyzed technologies were evaluated in relation to resource efficiency, responsible consumption and production, and sustainable urban development, corresponding primarily to SDG 11 and SDG 12.

In the fourth stage, AI models used for the collection, processing, analysis, prediction, and optimization of building design and operational parameters were examined. The analysis considered the application of AI throughout the building life cycle, including design, construction, operation, maintenance, and energy management. Particular attention was given to AI-based approaches capable of optimizing energy consumption, improving building performance, and supporting intelligent control. Recent research has demonstrated the relevance of machine learning and deep learning for improving energy efficiency and environmental sustainability in green buildings. Mahmood et al. (2024), for example, examined machine learning and deep learning approaches in green buildings and demonstrated their potential for improving energy efficiency and environmental performance. In addition, systematic research on AI and green buildings has identified intelligent optimization, automated decision-making, and data-driven building management as important areas of application (Debrah et al., 2022; Rodríguez-Gracia et al., 2023).

The methodological analysis also included waste management and the potential integration of renewable-energy and resource-recovery systems into sustainable building and energy systems. The use of intelligent control and optimization approaches for monitoring and managing energy and resource flows was considered in terms of resource efficiency and the reduction of environmental impacts. The characteristics of electricity generation and power supply systems in green buildings were also analyzed, including the challenges associated with intermittent renewable-energy generation. These aspects were considered in relation to energy efficiency and the integration of intelligent technologies for energy management These applications hold significant relevance to SDG 7 and SDG 13, as AI-driven optimization can enhance energy efficiency and facilitate the incorporation of renewable energy technologies (Yussuf & Asfour, 2024).

In the fifth and final stage, the results of the literature analysis and the examination of the identified technologies were synthesized. The analyzed AI models, smart technologies, monitoring systems, BIM-based approaches, and automatic control systems were compared according to their potential applications in the planning, design, construction, and operation of green buildings. The synthesis focused on five principal environmental dimensions: energy efficiency, resource efficiency, environmental monitoring, waste reduction, and reduction of environmental impacts. The relationship between these dimensions and the relevant SDGs was subsequently established.

The methodological framework was further informed by recent systematic reviews examining AI applications in sustainability and the SDGs. Greif et al. (2025) systematically reviewed AI techniques used in the context of the SDGs and identified supervised learning, unsupervised learning, reinforcement learning, and artificial neural networks among the principal AI approaches applied to sustainability challenges. Their analysis emphasized the relevance of AI techniques to environmental sustainability and the achievement of the SDGs. Similarly, Regona et al. (2024) specifically examined AI and the SDGs in the construction industry and identified SDGs 6–9, 11–13, 15, and 17 as relevant to the sector. Based on the five-stage methodological procedure, the study establishes an integrated framework for examining artificial intelligence as an enabling technology for environmental sustainability. The framework connects AI-based monitoring, data analysis, prediction, optimization, and automated control with sustainable building practices and the relevant SDGs. In this context, AI is considered not merely as an individual technological solution, but as an enabling technology capable of supporting more efficient resource use, energy management, environmental protection, waste reduction, and sustainable building development. The methodological framework therefore provides the basis for examining the contribution of AI-enabled technologies to environmental sustainability and their potential to support the implementation of SDG 6, SDG 7, SDG 9, SDG 11, SDG 12, and SDG 13.

The synthesis of the reviewed literature demonstrates that artificial intelligence (AI) represents an important enabling technology for enhancing environmental sustainability in the building and construction sector. AI is increasingly integrated with machine learning, deep learning, Building Information Modeling (BIM), intelligent sensing technologies, Digital Twins, and automated building management systems. These technologies enable data-driven prediction, optimization, monitoring, and decision-making throughout the building life cycle (Debrah et al., 2022; Rodríguez-Gracia et al., 2023; Mahmood et al., 2024).

A major finding of the reviewed literature concerns the contribution of AI to energy efficiency and resource management. AI-based models can predict energy demand, optimize heating, ventilation, air-conditioning, lighting, and other building systems, and support more efficient use of materials and water. AI can also assist in selecting construction materials according to environmental, technical, energy, and economic criteria, thereby supporting more sustainable design and construction decisions (Mahmood et al., 2024; Yussuf & Asfour, 2024).

Table 1. *AI-enabled technologies and their applications for environmental sustainability in buildings*

AI-enabled technology / digital approach	Main application	Environmental sustainability contribution
Artificial Intelligence and Machine Learning	Prediction, classification, monitoring, and optimization	Improved energy efficiency and resource management
Deep Learning and Artificial Neural Networks	Prediction, analysis, and automated decision-making	Improved building performance and environmental monitoring
Building Information Modeling (BIM) integrated with AI	Design optimization, performance prediction, material selection, and decision-making	Potential reduction in material consumption, construction waste, and energy demand
Intelligent sensor systems	Monitoring of temperature, humidity, air quality, occupancy, and energy consumption	Continuous environmental monitoring and improved building efficiency
AI-integrated Digital Twins	Real-time monitoring, simulation, prediction, fault detection, and optimization	Improved building performance, preventive maintenance, and resource efficiency
Intelligent building-management and control systems	Automated management of heating, cooling, ventilation, and lighting	Potential reduction in excessive energy consumption

AI for renewable-energy management	Forecasting and management of renewable-energy generation, storage, and microgrids	Improved energy efficiency and renewable-energy integration
AI for water and waste management	Monitoring, optimization, reuse, and resource recovery	Improved water efficiency and waste reduction

Source: Author's synthesis based on the reviewed literature

Table 1 summarizes the principal AI-enabled technologies and digital approaches identified in the reviewed literature, together with their main applications and contributions to environmental sustainability in buildings.

The integration of AI and BIM represents another important finding. BIM provides structured digital information about buildings, while AI enables the analysis of this information for design optimization, performance prediction, material selection, and decision-making. This integration can support the early identification of design problems and contribute to reducing material consumption, construction waste, energy demand, and environmental impacts (Zhang et al., 2022).

The reviewed studies also demonstrate the importance of intelligent monitoring and control. Sensor systems can provide continuous information on temperature, humidity, air quality, occupancy, energy consumption, and other environmental parameters. AI can analyze these data and facilitate adaptive management of heating, cooling, ventilation, and lighting systems, thereby enhancing building efficiency and potentially reducing unnecessary energy consumption (Rodríguez-Gracia et al., 2023; Yussuf & Asfour, 2024).

AI applications also extend to water and waste management and renewable-energy integration. Intelligent systems can monitor water consumption, support water optimization and reuse, improve waste-management processes, and facilitate resource recovery. AI can also support the forecasting and management of renewable-energy generation, energy storage, and microgrids, thereby contributing to more efficient and flexible building energy systems (Raihan et al., 2024; Shahverdi et al., 2025).

Digital Twins further strengthen the potential of AI-enabled sustainable buildings by integrating information from BIM, sensors, and building management systems. When combined with AI, Digital Twins can support real-time monitoring, prediction, simulation, fault detection, optimization, and preventive maintenance throughout the building life cycle (Debrah et al., 2022).

The reviewed literature indicates that substantial sustainability potential may be achieved through the integration of complementary technologies. BIM, sensors, AI, Digital Twins, renewable-energy systems, energy storage, and intelligent control can operate as an interconnected framework supporting sustainable decision-making from design and construction through operation, maintenance, and retrofit (Debrah et al., 2022; Zhang et al., 2022; Yussuf & Asfour, 2024).

The reviewed literature also identifies relevant links between AI-enabled sustainable buildings and SDG 6, SDG 7, SDG 9, SDG 11, SDG 12, and SDG 13. These relationships concern water management, energy efficiency, technological innovation, sustainable buildings and cities, resource efficiency, waste reduction, and climate action. Regona et al. (2024) additionally identified SDGs 6–9, 11–13, 15, and 17 as relevant to AI applications in the construction sector.

Table 2. *Relationship between AI-enabled environmental applications and the Sustainable Development Goals*

Environmental application	Main contribution of AI	Relevant SDG
Water management	Monitoring, optimization, and water reuse	SDG 6 – Clean Water and Sanitation
Energy efficiency	Energy-demand prediction, optimization, and intelligent	SDG 7 – Affordable and Clean Energy

	control	
Sustainable construction and technological innovation	AI-BIM integration, digital technologies, and optimization	SDG 9 – Industry, Innovation and Infrastructure
Sustainable buildings and cities	Intelligent building management and sustainable urban development	SDG 11 – Sustainable Cities and Communities
Resource efficiency and waste reduction	Optimization of material use, waste management, and resource recovery	SDG 12 – Responsible Consumption and Production
Climate action	Climate-related prediction, energy optimization, and reduction of environmental impacts	SDG 13 – Climate Action

Source: Author's synthesis based on the reviewed literature

Table 2 summarizes the relationship between the principal environmental applications of AI-enabled technologies and the relevant Sustainable Development Goals identified in the reviewed literature.

However, the results also identify several implementation challenges, including initial investment requirements, data quality, interoperability, technical expertise, cybersecurity, data privacy, organizational readiness, and regulatory conditions. In addition, AI itself requires computational resources and energy; therefore, its environmental benefits should be evaluated together with its own environmental footprint (Kulkov et al., 2024; Gohr et al., 2025; Regona et al., 2024).

Overall, the findings suggest that AI can be viewed as an enabling technology for environmental sustainability rather than as an isolated technological solution. Its integration with BIM, sensors, Digital Twins, intelligent building management systems, and renewable-energy technologies may support improvements in energy and resource efficiency, waste reduction, environmental monitoring, and building performance throughout the life cycle. These findings indicate the potential contribution of AI to environmental sustainability and, in particular, to SDG 6, SDG 7, SDG 9, SDG 11, SDG 12, and SDG 13.

CONCLUSION

Artificial intelligence (AI) has significant potential to support the transition toward environmentally sustainable buildings and construction practices. The findings of this study demonstrate that AI can improve environmental, energy, and operational performance through intelligent monitoring, prediction, optimization, and data-driven decision-making throughout the building life cycle.

The greatest potential is observed when AI is integrated with complementary digital technologies, particularly Building Information Modeling (BIM), intelligent sensor systems, Digital Twins, automated building-management systems, renewable-energy technologies, and energy-storage solutions. Such integration can improve energy efficiency, optimize the use of water and construction materials, reduce waste, strengthen environmental monitoring, and support more efficient building management.

The study also confirms the strong relevance of AI-enabled sustainable building technologies to SDG 6, SDG 7, SDG 9, SDG 11, SDG 12, and SDG 13, through improved water and energy management, technological innovation, sustainable buildings and cities, resource efficiency, waste reduction, and climate action.

However, the implementation of AI-enabled solutions is influenced by several factors, including investment requirements, data quality and availability, interoperability, technical expertise, cybersecurity, data privacy, organizational readiness, and regulatory conditions. Moreover, the environmental footprint of AI itself should be considered when evaluating its

contribution to sustainability. Therefore, AI should be implemented within an integrated framework that combines technological, environmental, economic, organizational, and regulatory considerations.

Future research should focus on developing integrated AI-based frameworks for the simultaneous assessment of environmental, energy, economic, and social performance. Further attention should be given to standardized indicators for evaluating AI contributions to the SDGs, interoperability between AI and building information systems, and the long-term environmental and economic effects of AI-enabled buildings.

In conclusion, AI should be regarded primarily as an enabling technology for environmental sustainability, rather than as an isolated technological solution. Its integration with sustainable construction principles and digital technologies can support the development of more energy-efficient, resource-efficient, adaptive, and environmentally responsible buildings and represents an important pathway toward a more sustainable built environment.

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