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The Role of Artificial Intelligence Technologies in Accelerating SustainableDevelopment in the Building Sector

Francesco Fabbrocino[1] **and Mariarosaria Angrisano**[1]

[1]*Pegaso University, Italy*

Abstract

The building sector plays a key role in the transition toward sustainability due to its significant impact on energy consumption, resource use, and greenhouse gas emissions. In this context, Artificial Intelligence (AI) has emerged as an important enabler for improving energy efficiency, environmental performance, and resilience in the built environment. The objective of this paper is to investigate how AI technologies can be systematically integrated across the building life cycle to support sustainable development in the construction sector.

The study is framed within major international and European policy frameworks, including the Sustainable Development Goals, the European Green Deal, and the New Urban Agenda. A review of recent scientific literature is conducted to analyze state-of-the-art AI applications in construction, focusing on BIM-based workflows, Digital Twin technologies, smart buildings, and AI-driven energy optimization systems. Based on the findings, the paper develops a conceptual framework and proposes guidelines for the effective adoption of AI in sustainable building design and operation, highlighting its potential to reduce environmental impacts and enhance long-term resilience.

Keywords: Sustainable development, green technology, renewable energy, nZEB buildings, AI-Driven Sustainable Design, Energy Management

1. INTRODUCTION

The built environment is widely recognized as one of the major contributors to urban pollution, due to the intensive use of materials, energy, and manufacturing technologies (Ramaglia et al, 2025). Across the entire building life cycle, from construction and operation to demolition, the European building stock is responsible, on average, for 36% of annual CO_2 emissions, 40% of total energy consumption, and approximately 50% of overall raw material extraction (Angrisano et al., 2024). However, the renovation of the existing built environment represents a significant opportunity to support the energy transition through energy efficiency interventions that integrate renewable energy technologies and the use of innovative materials, such as nanomaterials and biomaterials (Attia et al., 2021).

A further relevant aspect is that the existing building stock in Europe accounts for approximately 80– 90% of the buildings that are expected to still be in use by 2050, while the construction sector continues to account for about 40% of total energy consumption (Gravagnuolo et al., 2022).

Achieving sustainability in the building sector requires a holistic approach that considers the entire life cycle of buildings, from design and construction to operation and end-of-life (Nocca and Angrisano, 2022). Digital transformation, and AI in particular, is reshaping traditional construction paradigms by enabling data-driven decision-making, predictive analysis, and adaptive control systems. AI contributes to reducing environmental impacts, optimizing resource use, and enhancing occupant well-being, aligning the construction industry with global sustainability objectives.

The objective of this paper is to investigate how AI technologies can be systematically integrated across the building life cycle to support sustainable development in the construction sector.

The paper is framed within major international and European policy frameworks, including the Sustainable Development Goals, the European Green Deal, and the New Urban Agenda. A review of recent scientific literature is conducted to analyze state-of-the-art AI applications in construction, focusing on BIM-based workflows, Digital Twin technologies, smart buildings, and AI-driven energy optimization systems. Based on the findings, the paper develops a conceptual framework and proposes guidelines for the effective adoption of AI in sustainable building design and operation, highlighting its potential to reduce environmental impacts and enhance long-term resilience.

2. LITERATURE REVIEW

In the most recent studies published between 2024 and 2025, the scientific literature confirms the increasingly prominent role of Artificial Intelligence in the construction sector. Several review papers show that the application of AI algorithms can improve building energy efficiency, reduce operational costs, and enhance occupant comfort (Emedo et al., 2025; MDPI, 2025). Meta-analytical studies highlight energy savings ranging from 20% to 50% for AI-based energy management systems compared to traditional approaches (Bajwa et al., 2025), while recent conceptual frameworks illustrate the integration of AI with the Internet of Things (IoT) and regulatory tools such as the Smart Readiness Indicator to enhance the sustainability and adaptability of smart buildings (Buildings, 2025). Finally, the literature identifies both progress and persistent challenges in the widespread adoption of AI across the entire building life cycle (Ehtsham, 2025; Ekanayaka Gunasinghalge et al., 2025).

Systematic reviews published in 2025 indicate that the adoption of machine learning, deep learning, and reinforcement learning techniques in smart buildings enables significantly more efficient energy management compared to conventional control systems. These approaches allow for the prediction of energy loads, optimization of HVAC (**H**eating, **V**entilation and **A**ir **C**onditioning) system operation, and dynamic adaptation of building behavior to climatic conditions, occupancy patterns, and renewable energy availability, resulting in measurable reductions in energy consumption and CO_2 emissions (Wei et al., 2019; Li et al., 2021; Springer Review, 2025).

In parallel, several contributions from 2024 and 2025 emphasize the strategic role of integrating AI and the Internet of Things (IoT) in the development of nearly zero-energy and net-zero energy buildings. In this context, AI acts as a coordinating layer among sensor networks, monitoring platforms, and control systems, enabling a holistic approach to building life-cycle management. Recent conceptual frameworks demonstrate how this integration can overcome challenges related to data fragmentation and system interoperability, making predictive and adaptive building performance management possible(Sustainability, 2025; MDPI, 2025).

Another important research stream focuses on the application of AI to the energy retrofit of existing building stock, which represents the dominant share of buildings expected to remain in use over the coming decades. Recent studies propose the use of Explainable Artificial Intelligence (XAI) models to support retrofit decision-making even in the presence of incomplete or heterogeneous data. These approaches enhance the transparency of predictive models and promote the acceptance of AI-based solutions among designers, public decision-makers, and investors (arXiv, 2025).

The most recent literature also highlights the emergence of new application areas for AI, including the discovery and optimization of sustainable building materials and the use of large language models (LLMs) to support building energy modeling. These technologies accelerate simulation and environmental performance assessment processes, reducing time, costs, and decision-making uncertainty (Nature Scientific Reports, 2025; arXiv, 2024).

Overall, contributions converge in recognizing Artificial Intelligence as a key enabler for the transition of the construction sector toward more sustainable, resilient, and user-centered models. AI not only contributes to reducing environmental impacts and optimizing resource use, but also improves indoor environmental quality and occupant well-being, thereby supporting the achievement of global sustainability goals. However, the literature emphasizes the need to address remaining challenges, such as process standardization, data governance, and the development of interdisciplinary skills, in order to fully exploit the potential of AI at scale (IEA, 2023; Sustainability, 2025).

The integration of AI with established digital technologies such as Building Information Modeling (BIM), the Internet of Things (IoT), and Digital Twin systems enables the collection, processing, and interpretation of large volumes of heterogeneous data across the different phases of the building life cycle. These capabilities support evidence-based decision-making processes, improving the accuracy of design, operational, and energy performance predictions (Volk et al., 2014; Boje et al., 2020).

One of the main contributions of AI lies in predictive analytics applied to energy management, maintenance, and indoor comfort. Through machine learning algorithms, it is possible to anticipate energy demand, predict system failures or inefficiencies, and optimize the real-time operation of HVAC, lighting, and ventilation systems. These approaches enable significant reductions in energy consumption and greenhouse gas emissions, contributing to the achievement of climate neutrality targets (IEA, 2023; Wei et al., 2019).

At the same time, AI-based adaptive control systems allow buildings to dynamically respond to external environmental conditions, occupant behavior, and renewable energy availability. This aspect is particularly relevant in the context of smart buildings and smart grids, where demand-side flexibility represents a key factor for the large-scale integration of renewable energy sources (Li et al., 2021).

Beyond environmental and energy benefits, AI significantly contributes to occupant well-being by improving Indoor Environmental Quality (IEQ). Continuous analysis of parameters such as temperature, humidity, air quality, and lighting enables the creation of healthier and more comfortable indoor environments, with positive effects on health, productivity, and quality of life (Pisello et al., 2020).

Overall, AI-driven digital transformation aligns the construction sector with global sustainability objectives by supporting environmental impact reduction, efficient resource use, and the development of resilient and user-centered buildings. Nevertheless, the full adoption of these technologies requires further efforts in terms of standardization, interoperability, data governance, and interdisciplinary skillsdevelopment.

2.1 Theoretical Frameworks for Sustainable Construction

Artificial Intelligence–based applications in the construction sector represent a strategic enabler for achieving multiple Sustainable Development Goals (SDGs) by addressing key energy, environmental, and urban challenges of the built environment (Angrisano et al, 2025c). Through intelligent design tools, advanced energy management systems, and digital infrastructures, AI supports the transition toward more efficient, resilient, and sustainable building models. In particular, AI contributes to SDG 7 by optimizing energy production and consumption and facilitating renewable energy integration, while supporting SDG 9 through technological innovation enabled by BIM, Digital Twin technologies, and the Internet of Things. AI-driven solutions also foster SDG 11 by improving indoor comfort, reducing environmental impacts, and supporting urban regeneration, while contributing to SDG 12 and SDG 13 through life-cycle-based resource efficiency, emissions reduction, and climate adaptation strategies (united Nations, 2015). These objectives are reinforced by major policy frameworks such as the New Urban Agenda (NUA) and the European Green Deal. The NUA promotes an integrated and inclusive approach to urban development, emphasizing compact cities, adaptive reuse, environmental sustainability, resilience, and the role of digital innovation (United Nations, 2016). Similarly, the European Green Deal places the construction sector at the centre of climate neutrality strategies through building decarbonisation, circular economy principles, climate resilience, and digitalisation (European Commission, 2019) (Angrisano et al, 2025b). Together, these frameworks highlight AI as a key enabling technology for a sustainable, resilient, and socially inclusive built environment.

3. AI AND GREEN TECHNOLOGIES IN BUILDINGS

3.1 AI-Driven Sustainable Design

Artificial Intelligence is increasingly transforming architectural and engineering design processes through the adoption of generative design and simulation-based optimization techniques, enabling a shift from traditional intuition-driven workflows to data-driven and performance-oriented methodologies (Attia et al., 2020). This transformation is particularly relevant in the context of sustainable construction, where early design decisions strongly influence long-term energy performanceand environmental impacts.

AI-based generative design systems explore large solution spaces defined by climatic, geographic, regulatory, and functional constraints, including local climate data, solar radiation, site characteristics, building orientation, and occupancy profiles. By processing these variables simultaneously, AI algorithms generate multiple design alternatives that would be impractical to explore manually (Pisello& Cotana, 2014). Simulation-based optimization further enhances this process by integrating environmental and energy performance analyses directly into the design loop, allowing each design option to be evaluated in terms of energy demand, thermal comfort, daylight availability, material use, and carbon emissions (Angrisano et al, 2024).

These tools enable architects and engineers to compare numerous design scenarios at early project stages, when decisions have the greatest impact on long-term building performance. From a sustainability perspective, generative design supports the reduction of operational energy demand through climate-responsive forms, optimized envelopes, and passive strategies, while also contributing to lower embodied carbon by optimizing structural systems and material use

(Attia et al., 2020). Overall, AI-driven design methodologies provide a robust framework for developing high-performance buildings aligned with energy efficiency, resource efficiency, and climate resilience goals.

3.2 Intelligent Microclimate Management

Intelligent microclimate management represents a key application of Artificial Intelligence in the building sector, enabling continuous monitoring, prediction, and control of indoor and outdoor environmental conditions. Through the integration of sensor networks, Internet of Things (IoT) technologies, and AI-based algorithms, buildings can dynamically respond to changing climatic conditions and occupancy patterns, improving both energy efficiency and occupant comfort (Wei et al.,2019).

High-resolution data on temperature, humidity, solar radiation, wind speed, and air quality are processed by machine learning and predictive control models to enable adaptive and anticipatory system responses (Pisello et al., 2020). When integrated with nature-based solutions such as green roofs, vegetated façades, and water-sensitive design elements, AI-driven microclimate management enhances passive cooling, reduces cooling energy demand, and mitigates urban heat island effects (Santamouris, 2014; Speak et al., 2020).

Several studies demonstrate that AI-supported green infrastructure can significantly reduce surface and air temperatures in dense urban areas, improving outdoor thermal comfort and reducing heat stress during extreme weather events (Santamouris et al., 2018; Bowler et al., 2010). By coordinating natural ventilation, shading, and mechanical systems based on real-time microclimatic conditions, AI-based control strategies achieve improved thermal comfort with reduced energy input, supporting climate- adaptive and resilient built environments (Pisello & Cotana, 2014; IEA, 2023).

4. AI AND RENEWABLE ENERGY SYSTEMS

4.1 Forecasting and Energy Management

Artificial Intelligence plays a central role in integrating renewable energy systems within buildings through advanced forecasting and energy management capabilities. AI-based models use historical operational data, real-time measurements, and weather forecasts to predict energy generation from solar and wind sources with high accuracy, outperforming traditional statistical approaches (Voyant et al., 2017; Ahmed et al., 2020).

Reliable forecasting enables optimized energy storage, increased self-consumption, and reduced dependence on external energy supply. AI-driven energy management systems determine optimal charging and discharging strategies for batteries and thermal storage, aligning energy demand with renewable availability and minimizing reliance on fossil fuel–based electricity (Lund et al., 2015; Li et al., 2021). These capabilities support intelligent interaction with the power grid through demand- response and flexibility mechanisms, contributing to grid stability in systems with high shares of variable renewable energy (Siano, 2014; IEA, 2023).

From a sustainability perspective, AI-based forecasting combined with optimized energy management reduces greenhouse gas emissions and operational costs at both building and district scales (Vázquez- Canteli & Nagy, 2019; Ekanayaka Gunasinghalge et al., 2025).

4.2 Smart Buildings and Smart Grids

AI-enabled smart buildings act as active nodes within smart grids, dynamically adjusting energy consumption in response to real-time grid conditions, renewable availability, and pricing signals. Through AI-based demand-response strategies, buildings optimize HVAC, lighting, and storage systemsto reduce peak demand and smooth load profiles without compromising occupant comfort (Wei et al., 2019; Li et al., 2021).

This flexibility enhances grid stability and supports higher penetration of renewable energy sources, reducing curtailment and improving system resilience (IEA, 2023; Gellings & Samotyj, 2020). AI- driven coordination between on-site renewable generation, energy storage, and grid interaction further enables buildings to operate as prosumers within decentralized energy systems, aligning economic performance with environmental objectives (Vázquez-Canteli & Nagy, 2019).

5. AI-ENABLED BUILDING OPERATION AND NET-ZERO STRATEGIES

5.1 Smart Buildings and Building Management Systems (BMS)

AI-powered Building Management Systems represent a major advancement in building operation, enabling predictive and adaptive control of HVAC, lighting, and energy systems. By processing data from sensors and smart devices, AI-driven BMS anticipate building behavior, optimize system operation, and balance energy efficiency with occupant comfort (Wei et al., 2019; Pisello et al., 2020). Studies show that AI-enabled BMS can achieve energy savings ranging from 10% to over 30% compared to conventional control systems, while also enhancing operational reliability through predictive maintenance (IEA, 2023; Ekanayaka Gunasinghalge et al., 2025). These systems reduce downtime, extend equipment lifespan, and facilitate integration with smart grids and renewable energysources (Volk et al., 2014; Boje et al., 2020).

5.2 Digital Twins in Sustainable Construction

AI-enhanced Digital Twins provide dynamic virtual representations of buildings by integrating real-time data from sensors, BMS, and IoT devices. These systems support continuous performance monitoring, predictive maintenance, and scenario analysis, enabling proactive building management (Boje et al., 2020; Tao et al., 2019).

By linking operational data with life-cycle assessment information, digital twins support resource-efficient operation, retrofit planning, and long-term sustainability strategies (Lu et al., 2020; Ehtsham, 2025). At district and urban scales, interconnected digital twins enhance resilience by enabling coordinated responses to climate-related and operational challenges (Batty, 2018; IEA, 2023).

5.3 Net-Zero Energy Buildings

Net-zero energy buildings rely on the integration of high-performance envelopes, renewable energy systems, and AI-driven control strategies. While envelope efficiency reduces baseline energy demand, AI optimizes the balance between energy production and consumption under dynamic climatic and occupancy conditions (Attia et al., 2020) (Angrisano et al, 2025).

Through predictive control, demand-response strategies, and intelligent energy flexibility management, AI enables buildings to maximize renewable self-consumption, reduce peak demand, and interact effectively with smart grids (Vázquez-Canteli & Nagy, 2019; Li et al., 2021). Recent studies demonstrate that AI-driven optimization significantly improves net-zero performance compared to rule- based control strategies, while maintaining high levels of occupant comfort (Pisello et al., 2020; Ekanayaka Gunasinghalge et al., 2025). As a result, AI-driven net-zero buildings represent a key pathway toward climate-neutral and resilient built environments.

6. ANALYSIS OF RESULTS

6.1 Catalogue of AI Technologies in the Construction Sector Linked to the SDGs, the European Green Deal, and the New Urban Agenda

AI adoption in sustainable construction offers significant benefits, including emission reductions, cost optimization, and improved environmental quality. The convergence of AI, Internet of Things (IoT), and renewable energy technologies will lead to increasingly autonomous, adaptive, and resilient buildings.

However, challenges remain, such as data availability, interoperability, cybersecurity, and the need for interdisciplinary skills. Addressing these barriers is essential for widespread implementation. As part of the results analysis, the study develops a comprehensive mapping of the most widely adopted AI-based technologies in the construction sector, systematically linking each solution to the objectives of the 2030 Agenda, the New Urban Agenda, and the European Green Deal (Table 1).

Table 1. *Catalogue of AI Technologies in the Construction Sector Linked to the SDGs, the European Green Deal, and the New Urban Agenda.*

Domain	AI Technologies	Main Applications	UN SDG	European Green Deal	New Urban Agenda (NUA)	References
Design and Planning	Generative Design, Evolutionary Algorithms, Machine Learning	Energy and morphological optimization, multi-criteria simulations	SDG 9 SDG 11 SDG 12	Efficient use of resources; Circular economy	Integrated urban planning; efficient land use	Azhar et al., 2011; Wong & Zhou, 2015
Advanced BIM and Digital Twin	Machine Learning, Semantic AI, Data Fusion	Dynamic life-cycle management, predictive simulations	SDG 9, SDG 11, SDG 13	Digitalisation as an enabler; Climate neutrality	Data-driven urban governance; resilience	Volk et al., 2014; Boje et al., 2020
Construction Site Management	Computer Vision, Deep Learning, Robotics	Work monitoring, safety management, logistics optimization	SDG 8 SDG 9, SDG 12	Sustainable industry; waste reduction	Safe and sustainable construction sites	Emedo et al., 2025; Bajwa et al., 2025
Energy Management and Smart Buildings	Reinforcement Learning, Predictive Analytics, Edge AI	Adaptive HVAC control, demand-response strategies	SDG 7 (Energy), SDG 11, SDG 13	Renovation Wave; Energy efficiency	Efficient and resilient buildings	Wei et al., 2019; Li et al., 2021; IEA, 2023
Predictive Maintenance	Machine Learning, Anomaly Detection, Time-Series Analysis	Failure prediction, maintenance optimization	SDG 9, SDG 11, SDG 12	Resource efficiency; durability	Sustainable management of the building stock	Pisello et al., 2020; Springer Review, 2025
Sustainable Materials and Circular Construction	AI for materials discovery, predictive models	Low-carbon material selection, durability optimization	SDG 9, SDG 12, SDG 13	Circular Economy Action Plan	Reduction of resource consumption; urban regeneration	Zhang et al., 2025; ISO 14040–44
Environmental Assessment	Big Data Analytics,	Automated LCA, ESG	SDG 12, SDG 13,	Sustainable finance; EU	Transparent and	ISO 14040–44; Ehtsham,

(LCA, ESG)	Explainable AI	reporting	SDG 17	taxonomy	inclusive decision-making	2025
Human–Building Interaction and Well-being	User behavior modeling, NLP, Adaptive control	Personalized comfort, IEQ, health	SDG 3 SDG 11	Healthy buildings; social inclusion	People-centered design and quality of life	Pisello et al., 2020; Sustainability, 202
Domain	AI Technologies	Main Applications	UN SDGs	European Green Deal	New Urban Agenda (NUA)	References
Design and Planning	Generative Design, Evolutionary Algorithms, Machine Learning	Energy and morphological optimization, multi-criteria simulations	SDG 9 SDG 12	Efficient use of resources; Circular economy	Integrated urban planning; efficient land use	Azhar et al., 2011; Wong & Zhou, 2015

6.2 Guidelines for the Application of Artificial Intelligence in Sustainable Building Design

The integration of Artificial Intelligence into building design processes represents a concrete opportunity to reduce environmental impacts throughout the entire building life cycle. However, in order to fully exploit the potential of AI, it is essential to adopt design guidelines that steer its application in a conscious, systemic, and sustainability-oriented manner.

First, AI should be integrated from the earliest design stages, when decisions related to building form, orientation, envelope configuration, and passive strategies have the greatest influence on energy and environmental performance. The use of generative design tools and advanced simulation techniques allows designers to explore a wide range of design solutions, simultaneously evaluating energy performance, indoor comfort, material use, and carbon emissions. In this way, the design process becomes iterative and evidence-based rather than driven by intuition alone.

A second guideline concerns the adoption of a life-cycle-oriented approach. AI models should be used not only to optimize operational performance, but also to reduce the environmental impacts associated with materials and construction processes. Integrating AI with Life Cycle Assessment (LCA) tools supports the selection of low-carbon materials, the optimization of material quantities, and the evaluation of alternative scenarios related to durability, maintenance, and end-of-life, thereby contributing to the implementation of circular economy principles.

Another key aspect is the integration of AI with Building Information Modeling (BIM) and Digital Twin technologies, which ensures information continuity across design, construction, and operational phases. The use of interoperable digital models allows design assumptions to be updated based on real operational data, progressively improving simulation accuracy and supporting adaptive optimization strategies. This approach is particularly effective in reducing the performance gap between designed and actual building performance.

From an energy perspective, design guidelines should promote the use of AI to maximize renewable energy integration and demand-side flexibility. Predictive models can support optimal system sizing, energy storage management, and interaction with smart grids, reducing reliance on fossil fuels and operational emissions. In this context, AI plays a central role in coordinating building envelopes, technical systems, and occupant behavior.

Specific attention should also be given to indoor environmental quality and occupant well-being, recognizing that environmental and social sustainability are closely interconnected. AI can support the design of healthier and more comfortable indoor environments through predictive analysis of microclimatic conditions and occupancy patterns, avoiding solutions that reduce energy consumption at the expense of user comfort.

Finally, the application of AI in sustainable building design requires adherence to principles of transparency, interoperability, and data governance. The adoption of Explainable AI models, open standards, and interdisciplinary skills is essential to ensure the reliability of results, promote acceptanceamong designers and public decision-makers, and enable large-scale implementation. Overall, these guidelines outline an operational framework in which Artificial Intelligence is not conceived as an isolated tool, but as an enabling technology integrated within a design process oriented toward environmental impact reduction, climate resilience, and the quality of the built environment, in line with the objectives of the 2030 Agenda, the New Urban Agenda, and the European Green Deal (Table 2).

Table 2. *Guidelines for the Application of Artificial Intelligence in Sustainable Building Design.*

Design Domain	**AI-Based Strategies**	**Design Objectives**	**Environmental Benefits**	**Related Sustainability Frameworks**
Early-StageDesign and Planning	Generative design, evolutionary algorithms, parametric optimization	Exploration of climate-responsive forms and layouts	Reduced operational energydemand; optimizedland use	SDGs 9, 11, 12; European Green Deal; New UrbanAgenda
Building Envelope Optimization	Machine learning models, simulation-based optimization	Optimization of envelope performance (insulation, glazing, shading)	Lower heating and cooling loads; reduced carbon emissions	SDGs 7, 12, 13; European GreenDeal
Passive Design Strategies	AI-assisted environmental simulations	Enhancement of natural ventilation, daylighting, and solar control	Reduced reliance on mechanical systems; improved indoor comfort	SDGs 7, 11; New Urban Agenda
Energy Systems Integration	Predictive analytics, reinforcement learning	Optimization of renewable energy integration and storage	Increased self-consumption; reduced fossil fuel use	SDGs 7, 13; European GreenDeal
Indoor Environmental Quality (IEQ)	User behavior modeling, adaptive control systems	Personalized thermal, visual, andair quality comfort	Improved occupant well-being; energy-efficient comfort management	SDGs 3, 11; New Urban Agenda
Life-Cycle Environmental Assessment	Big data analytics, Explainable AI (XAI)	Automated and dynamic life-cycle impact evaluation	Reduced embodied carbon; informed material selection	SDGs 12, 13; European GreenDeal
Climate Resilience and Adaptation	Predictive climate modeling, AI-based scenario analysis	Design adaptationto future climate conditions	Enhanced resilience; reducedclimate-related risks	SDGs 11, 13; European Green Deal; New Urban Agenda
Design Decision Support	AI-driven multi-criteria decision-making tools	Evaluation of trade-offs betweenenergy, cost, and Environmental impact	Evidence-baseddesign choices;reduced environmental footprint	SDGs 9, 12; European GreenDeal
Design Domain	AI-Based Strategies	Design Objectives	Environmental Benefits	Related Sustainability Frameworks
Early-Stage Design and Planning	Generative design, evolutionary algorithms, parametric optimization	Exploration of climate-responsive forms and layouts	Reduced operational energy demand; optimized land use	SDGs 9, 11, 12; European Green Deal; New Urban Agenda

7. CONCLUSIONS

Artificial Intelligence technologies act as powerful accelerators of sustainable development in the building sector by enabling a paradigm shift toward data-driven, adaptive, and performance-oriented approaches across the entire building life cycle. Through the integration of AI with green technologies, nature-based solutions, and renewable energy systems, the construction industry can significantly reduce energy consumption, greenhouse gas emissions, and resource use, while enhancing operational efficiency, occupant well-being, and long-term resilience.

AI-driven tools such as generative design, intelligent microclimate management, smart Building Management Systems, Digital Twins, and predictive energy optimization support informed decision- making from early design stages to building operation and retrofit. These technologies facilitate the alignment of building performance with international and European sustainability frameworks, including the Sustainable Development Goals, the New Urban Agenda, and the European Green Deal, translating policy objectives into measurable and operational strategies.

Despite the significant benefits, the effective adoption of AI in the construction sector requires addressing key challenges related to data availability, interoperability, cybersecurity, and skills development. Overcoming these barriers is essential to fully unlock the potential of AI as an enabling technology for a low-carbon, resilient, and inclusive built environment. Overall, Artificial Intelligence emerges not only as a technological innovation, but as a strategic lever for steering the construction sector toward a sustainable and climate-resilient future.

Author Contributions

Conceptualization M.A., F.F, methodology F.F. and G.C.; formal analysis, M.A., F.F, investigation M.A., F.F., data curation, M.A., F.F.; writing—original draft preparation, M.A., writing, review and editing, M.A.F.F, supervision, F.F. Funding acquisition by Francesco Fabbrocino. All authors have read and agreed to the published version of the manuscript.

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