Artificial Intelligence for Sustainable Climate Action: Mitigation, Adaptation, Resilience, and Green Innovation.

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Abstract: This paper discusses how Artificial Intelligence (AI) can make a difference by driving climate action in mitigation, adaptation, resilience and green innovation. It examines the impact of artificial Intelligence on improving the reliability of climate modeling and on optimizing energy-consuming systems while also investigating the environmental costs and ethical issues to be considered. This has a wide range of potential applications, such as predictive analytics for greenhouse gas reduction, renewable energy integration, disaster risk management and planning for urban and agricultural development that is resilient to climate change. The paper also analyzes the role of artificial intelligence in green innovation and circular economy solutions, as well as the behavioral solutions needed to promote sustainable consumption. Issues of computational carbon footprint, data gaps, opaque algorithms, and access disparities are critically discussed. Lastly, the paper suggests future directions with a focus on interdisciplinary cooperation, energy-efficient algorithms for AI systems, and governance frameworks to benefit from AI applications for equitable and sustainable climate solutions..,

Keywords: Collaborating with an industry leader like this is a fantastic opportunity to gain insight into their innovative solutions. Working with a leading company like that is a great chance to learn about their cutting-edge solutions

Introduction

This paper explores the dual nature of machine learning to improve the precision of climate models and to optimize energy-intensive systems, and discusses the trade-offs between computational burden and the environmental benefits associated with these models (Cowls et al., 2021). This review summarizes the latest publications on AI's influence on the integration of renewable energy and disaster risk management, as well as on the mitigation of the carbon footprint and the ethical governance issues of high-performance computing (HPC) (Eze et al., 2025; Handa, 2025).

Transparent and energy-efficient solutions are needed to align the increasing number of algorithmic solutions with global sustainability requirements (Chen et al., 2023; Tiwari et al., 2025). In addition to these operational issues, this research investigates the “Green AI” paradigm, which aims to minimize the environmental impact of AI model use by leveraging model compression and pruning.This research also covers the paradigm of “Green AI,” which seeks to reduce the environmental footprint of AI models by leveraging model compression and pruning. This synthesis also explores the potential of AI-powered predictive analytics and data-driven decision support systems to support systemic resilience (strategic shifts) in key sectors including agriculture, water resource management, and urban planning (Fayemi, 2025; N et al., 2025). Lastly, this review outlines key regional differences in technology adoption and suggests a pathway towards enabling interdisciplinary partnerships focused on equity in access to climate-resilient AI technologies (Ayadi et al., 2025).

Use Artificial Intelligence To Combat Climate Change

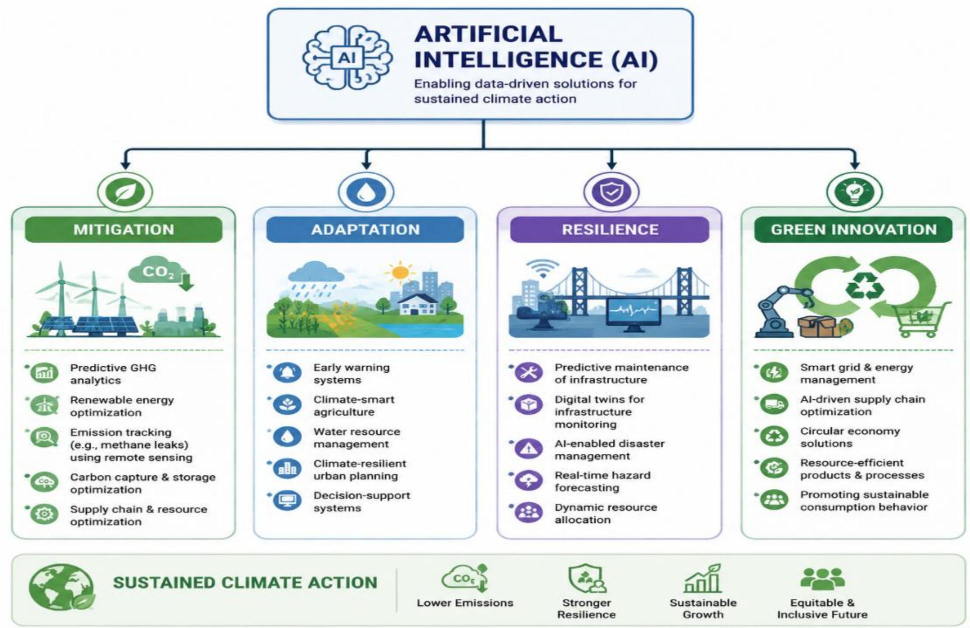
AI for Sustainable Design

Using AI as a key enabler in system-wide optimization and predictive modeling will be a critical opportunity to lower global greenhouse gas emissions, as described in this article (Lu, 2024). The computational tools help to achieve more accurate environmental forecast, and support the shift to decentralized, low-carbon infrastructure (Adegbite et al., 2024; Eze et al., 2025). Currently, machine learning algorithms are used to optimize the integration of renewable energy and the management of the energy grid as a result of which 30-50% of energy waste can be saved in industry and carbon emissions can be reduced by this amount (Chen et al., 2023).

In addition, the detection of methane leaks and industrial emissions in near real time has been made possible by computer vision and remote sensing technologies, thereby dramatically shortening the time for environmental interventions (Ullah et al., 2025). These models are also crucial for the management of operating renewable energy resources beyond emission tracking, as they can predict variations in both demand and supply to balance smart grids (Adefemi et al., 2023; Tasha, 2025). At the same time, machine learning models are being incorporated in CCs to optimize the sequestration process, and high-resolution geophysical data analysis is being used to monitor the integrity of the geology, through machine learning models (N et al., 2025; Qamar, 2024). AI's role in optimizing supply chains and resource utilization for more precise management is proving effective in reducing emissions across various carbon-intensive industries, building on these technical strengths (Fayemi, 2025).

The Role of AI In Climate Adaptation

As per Jain et al. (2023) adaptation strategies would be defined as the pro-active changes that are made in ecological, social or economic systems in response to current and anticipated climatic stimuli, to reduce the impacts or capitalise on the opportunities. AI can complement these approaches by incorporating vast amounts of data on environmental and socioeconomic factors, enabling predictive analytics and decision-support tools that adapt to changing weather conditions (Shah & Jhanjhi, 2025). Additionally, AI has helped significantly in creating complex climate models and early warning systems, by analyzing multidimensional datasets and predicting extreme weather events with unprecedented accuracy to enable more proactive resource management (Chen et al., 2023; Pavapanunkul et al., 2024).



Flowchart : AI Applications in Climate Action

In the agricultural sector, the AI algorithms are used to facilitate resource management in order to ensure drought and flood resilience, and in the urban sector policy makers are using these algorithms to design resilient infrastructure for climate change including sea-level rise and temperature changes (Evangeline, 2025; Verma et al., 2024). The adoption of these technologies, however, can be challenging if there is a significant disparity in data availability, especially given the need for region-specific ethical guidelines and frameworks to ensure equitable outcomes (Ayadi et al., 2025; Srivastava & Maity, 2023). Moving beyond theory to practice, AI has been applied globally in various water resource management scenarios, including the use of reinforcement learning to address complex water resource allocation trade-offs (Cheong et al., 2022; Eze et al., 2025).

Sustainable Resilient Building using Artificial Intelligence (AI)

The paper reviews how AI can enhance the resilience of complex systems to systemic shocks through predictive maintenance of critical infrastructure (Ayadi et al., 2025; Rane et al., 2024) and data-driven disaster management, highlighting AI's transformative power in managing complex systems. Moreover, the use of real-time sensor streams and digital twins can support the shift towards self-correcting networks that can predict hazards self-servicing and allocate resources dynamically (Ajayi et al., 2025), (Vinayakan et al., 2025). Furthermore, the use of AI powered digital twins can also simulate the deterioration of assets continuously, as opposed to the traditional inspection cycles, and generate strategies based on that deterioration that will adapt to mitigate the effects of stressors on aging urban utilities due to climate change (Argyroudis et al., 2021; Rane et al., 2024).

In addition to asset maintenance, these smart systems can be used for community planning, integrating multidimensional data to promote equitable urban resilience to the growing threats posed by climate change (Chen et al., 2023; Ramkissoon et al., 2026). While all these developments have taken place, research on participatory planning has often ignored important human and organizational aspects, including algorithmic bias of decision-support technologies (Praharaj, 2026). In addition, the lack of coordination among current resilience frameworks results in more complex situations in which such technologies cannot be seamlessly adopted without adopting more holistic frameworks that integrate technical monitoring and the institutional capacity dimension (Afolabi et al., 2025).

Aerospace and Green Innovation (AI)

One of the key factors of fulfilling the United Nations Sustainable Development Goals by integrating artificial intelligence into the industrial systems is optimizing resource utilization and monitoring the environment at a large scale (Emon & Khan, 2025; Kayyali, 2025). These technologies can be used in smart grids and complex supply chains to manage them with predictive algorithms, thus reducing waste and energy use in the operation of these systems (Potdar, 2026). In addition, these computational breakthroughs improve recycling accuracy and provide real-time data to regulate and reduce pollution levels, supporting the circular economy (Subrahmanyam, 2025; Tariq, 2025).

In addition to these operational improvements, AI innovation can enable the development of products that use resources more efficiently and have a positive impact on the environment, reducing the effects of environmental degradation and biodiversity loss (Adanma & Ogunbiyi, 2024). For instance, in the energy industry, machine learning models can optimize grid performance and help integrate renewable sources, balancing supply and demand (Potdar, 2026; Zaidi et al., 2025). In addition to infrastructure, AI-powered behavioral solutions, such as personalized digital platforms, can be used to promote consumers' more sustainable decisions, contributing to a system-level transformation toward more sustainable consumption (Ziemba et al., 2024). Furthermore, AI can help achieve multiple environmental SDGs through cross-sector synergies AI enhancing disaster preparedness, agricultural efficiency, and infrastructure resilience, among others (Khan et al., 2026).

Table 1: AI Impact Across Climate Domains

Climate Domain	AI Applications	Key Benefits
Mitigation	Renewable energy optimization, emission tracking, carbon capture	Reduce energy waste, lower GHG emissions
Adaptation	Predictive analytics, early warning systems, climate-smart urban planning	Enhanced resilience to floods, droughts, storms
Resilience	Digital twins, predictive maintenance, disaster management	Strengthened critical infrastructure, adaptive systems
Green Innovation	Smart grids, circular economy, sustainable product design	Energy efficiency, pollution reduction, responsible consumption

Challenges and Limitations

The technical challenges posed by black-box models are also a significant hurdle to deploying these technologies, particularly in translating laboratory research into practice, as interdisciplinary collaboration is often lacking (Debnath et al., 2023; Hamdan et al., 2024). The use of proprietary, resource-intensive architectures deepens geographical disparities, especially for smaller municipalities that may lack the computing resources and/or expertise needed to implement these analytical tools (Raftopoulos et al., 2024).

The opacity of these algorithms makes it difficult to assess the risks of climate change because decision makers are not able to understand the output of the algorithms without a clear explanation of the algorithm they use (Ayadi et al., 2025), (Marasinghe et al., 2024).

This inbuilt opacity is eventually detrimental to trust of stakeholders and makes it difficult to develop evidence-based adaptation strategies in a highly sensitive sociopolitical setting (Jain et al., 2023; Mohammed et al., 2023).

To fill this gap, it is crucial to put in place mechanisms for the ethical audit and contestation of the parameters of optimisation, in order to guarantee that the results of algorithms are in line with the socio-economic priorities in the local context (Cowls et al., 2021).

In addition, policymakers should explicitly include multi-hazard risk modeling that goes beyond climate risk to enable a more comprehensive resilience planning strategy (Fayemi, 2025).

Future Directions

The fusion of artificial intelligence, Internet of Things sensors, and remote sensing with blockchain technology provides a promising opportunity for a transformative approach to environmental decision making and emissions monitoring as the world moves towards achieving its net-zero goals (Olawade et al., 2024; Raman et al., 2024). These distributed systems enable precise carbon accounting at a finer level through satellite imagery and real-time IoT sensory streams, as well as optimization of supply chain logistics (Chen et al., 2023; Fayemi, 2025). Moreover, blockchain technology enhances the integrity and transparency of these datasets, creating an unalterable record of verified emissions, such as verified emissions reductions (Ibrahim et al., 2025). The governance frameworks need to adapt to realize these cross-sectoral synergies, enabling interdisciplinary collaborations between environmental policymakers and computational scientists, and to facilitate the interoperability between the different data sets and data ecosystems.To achieve the full potential of these cross-sectoral synergies, governance frameworks should be adapted to enable interdisciplinary collaboration between environmental policymakers and computational scientists and to facilitate interoperability across different data sets and data ecosystems (Khan et al., 2026; Kojo et al., 2024). To tackle these challenges, it is essential to carefully calculate the life-cycle carbon footprint of systems that rely heavily on computing to enable AI to help combat climate change, while not inadvertently worsen its effects. (Cowls et al., 2021) The need for small-data methods such as transfer learning and few-shot learning becomes even more crucial as energy usage for training large models continues to rise, with no substantial new technological breakthroughs to reduce the energy footprint of model training (Handa, 2025; May, 2025).

Conclusion

Although AI can transform how energy systems are optimized and how the climate is modeled, there are many ethical issues, data quality concerns, and the AI technology's own high carbon footprint that limit its deployment (Cowls et al., 2021; Olawade et al., 2024). However, the concept of "Green AI" frameworks brings about a new conundrum: how to shift the entire technology lifecycle toward computational efficiency and energy-efficient hardware architectures.To resolve these paradoxes, a paradigm shift toward computational efficiency and energy-aware hardware architectures across the entire technology lifecycle is now required (Chen et al., 2023; Raman et al., 2024). Additionally, closing the digital divide is critical, as unequal access to technological resources and skills could trigger the marginalization of areas most vulnerable to climate change (Pandey, 2025). Therefore, a multidisciplinary approach with collaboration between climate scientists, policymakers, and industry representatives is key to unlocking the potential benefits of these digital solutions and creating a transparent governance framework that will prevent unintended consequences of technological advances from worsening reliance on unsustainable carbon-intensive practices (Handa, 2025; Pavapanunkul et al., 2024).

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