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A Review on AI & IOT in Green Buildings

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ABSTRACT-Artificial Intelligence (AI) and the Internet of Things (IoT) are increasingly being integrated into green buildings to enhance energy efficiency, sustainability, and intelligent building management. Rapid urbanization and industrial growth have increased pressure on natural resources, making energy-efficient construction practices essential. While green buildings reduce environmental impact through optimized resource usage, conventional building management systems often lack real-time adaptability, leading to inefficient energy consumption. The integration of AI and IoT enables real-time data collection through smart sensors and intelligent data analysis for automated control of lighting, ventilation, energy usage, and maintenance operations. The proposed system improves building performance, reduces energy consumption and carbon emissions, and supports sustainable development and smart city initiatives.

KEYWORDS: Artificial Intelligence, Internet of Things, Green Buildings, Smart Energy Management, Sustainability.

I. INTRODUCTION

The rapid growth of urbanization and increasing energy demand have made it essential to adopt intelligent and sustainable building solutions. Green buildings aim to reduce environmental impact by optimizing the use of energy and resources; however, conventional building management systems lack real-time monitoring and adaptive control, resulting in inefficient energy usage and increased operational costs.

The integration of Artificial Intelligence (AI) and the Internet of Things (IoT) has emerged as a powerful solution for smart green building management. IoT sensors enable continuous real-time data collection related to temperature, occupancy, lighting, and air quality, while AI algorithms analyze this data to enable automated control, predictive decision-making, and energy optimization. AI- and IoT-based systems improve building performance through adaptive lighting, ventilation, and energy management, while also supporting predictive maintenance. Thus, the application of AI and IoT in green buildings plays a crucial role in enhancing energy efficiency, sustainability, and intelligent infrastructure development.

II. CURRENT PROBLEMS

Despite the growing adoption of green buildings, the effective implementation of Artificial Intelligence (AI) and the Internet of Things (IoT) in building management systems faces several challenges. Most existing buildings still rely on conventional control systems that operate on fixed schedules and lack real-time adaptability, resulting in inefficient energy usage and underutilization of intelligent technologies. In many cases, IoT devices are installed without proper system integration, leading to fragmented data, poor interoperability, and limited optimization of building performance.

Another major issue is the high initial cost associated with AI- and IoT-based infrastructure, including sensors, communication networks, data platforms, and skilled manpower, which discourages widespread adoption, especially in developing regions. Data security and privacy concerns further limit implementation, as smart buildings continuously collect sensitive occupancy and operational data that are vulnerable to cyber threats. In addition, the absence of standardized protocols and regulatory frameworks creates compatibility issues between devices from different manufacturers, reducing system efficiency.

Furthermore, lack of technical expertise and awareness among building operators results in improper use and maintenance of AI- and IoT-enabled systems, preventing buildings from achieving their full energy-saving potential. As a result, many green buildings fail to fully benefit from intelligent automation, predictive maintenance, and real-time energy optimization, highlighting the need for improved integration, standardization, and capacity building in AI- and IoT-based green building management.

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III. NEGATIVE EFFECTS

Improper implementation of Artificial Intelligence (AI) and the Internet of Things (IoT) in green buildings can result in inefficient energy management due to inaccurate sensor data and poor system integration. Faulty AI decision-making may lead to increased energy consumption, higher operational costs, and reduced occupant comfort.

Cybersecurity and data privacy risks are major concerns, as AI- and IoT-based systems continuously collect and transmit sensitive building data. Additionally, frequent system failures, lack of skilled operators, and increased dependence on electronic devices can raise maintenance costs and contribute to electronic waste generation. These issues may reduce the overall sustainability benefits of smart green buildings.

IV. METHODS FOR ADDRESSING AI AND IoT CHALLENGES IN GREEN BUILDINGS

- The effective implementation of AI and IoT in green buildings requires proper system planning and integration, as smart building technologies consist of multiple sensors, communication networks, data platforms, and control systems that must work together seamlessly.
- Standardization and interoperability: – Adoption of standardized communication protocols and interoperable platforms is essential to ensure compatibility between IoT devices from different manufacturers and to enable efficient data exchange across building systems.
- Accurate data collection and sensor calibration: – Regular calibration and maintenance of IoT sensors are necessary to ensure accurate real-time data collection related to temperature, occupancy, lighting, and air quality, which directly affects AI-based decision-making.
- Secure data management and cybersecurity: – Implementation of strong cybersecurity measures such as data encryption, secure communication protocols, and access control systems is required to protect sensitive building and occupant data from cyber threats.
- AI-based optimization and predictive analytics: – Advanced AI algorithms should be used to analyze real-time and historical data for adaptive control of lighting, HVAC, and energy systems, as well as for predictive maintenance to detect faults before system failure.
- Training and skill development: – Proper training of building operators and facility managers is essential to ensure correct operation, monitoring, and maintenance of AI- and IoT-enabled systems.
- Lifecycle management of devices: – Sustainable disposal, upgrading, and recycling of outdated IoT devices and electronic components should be practiced to minimize electronic waste and maintain the environmental benefits of green buildings.

V. IMPORTANCE OF AI AND IoT IN GREEN BUILDINGS

- Artificial Intelligence (AI) and the Internet of Things (IoT) play a crucial role in improving energy efficiency in green buildings by enabling real-time monitoring, automated control, and data-driven optimization of building systems.
- These technologies help reduce energy consumption, carbon emissions, and operational costs by intelligently managing lighting, heating, ventilation, and air conditioning based on occupancy and environmental conditions.
- AI- and IoT-enabled systems enhance indoor environmental quality by maintaining optimal temperature, air quality, and lighting levels, thereby improving occupant comfort, health, and productivity.
- Predictive maintenance supported by AI helps in early detection of equipment faults, reducing downtime, maintenance expenses, and extending the lifespan of building components.
- The integration of AI and IoT supports sustainable development and smart city initiatives by promoting efficient resource utilization, intelligent infrastructure, and environmentally responsible building management.
- Overall, the adoption of AI and IoT in green buildings represents a significant step toward achieving long-term sustainability, resilience, and improved quality of life.

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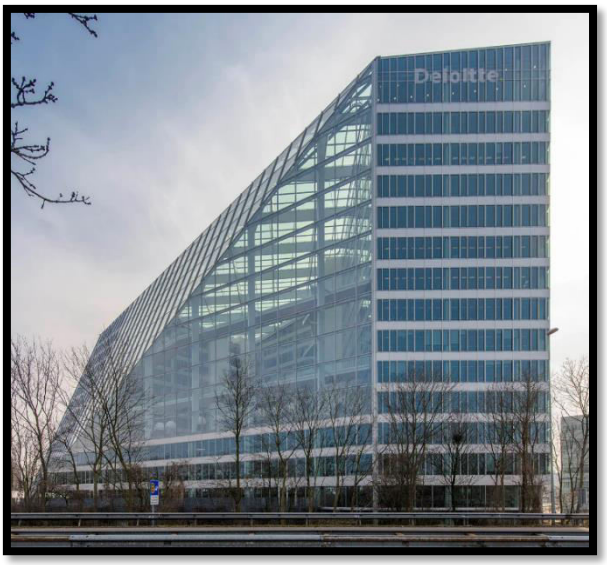
VI. CASE STUDY: THE EDGE, AMSTERDAM



Overview: The Edge is a world-renowned smart building that leverages AI and IoT to achieve exceptional energy efficiency and occupant comfort.

Key Features:

- Dynamic Lighting Systems – AI adjusts lighting intensity and color temperature based on occupancy and daylight availability.
- Adaptive HVAC Systems – Heating, cooling, and ventilation respond automatically to environmental conditions and occupancy patterns.
- Real-Time Occupancy Monitoring – Sensors track space usage to optimize lighting, climate control, and energy allocation.
- Renewable Energy Integration – Solar panels and energy storage are monitored and optimized by AI algorithms for maximum efficiency.
- Predictive Maintenance – AI predicts equipment failures before they occur, reducing downtime and maintenance costs.

Sustainability Outcomes: The building achieves significant reductions in energy consumption and carbon footprint while improving comfort and operational reliability

VII. CONCLUSION

The successful adoption of Artificial Intelligence (AI) and the Internet of Things (IoT) in green buildings requires a holistic approach that combines technological integration, skilled workforce development, data security, and supportive policies. Although AI- and IoT-based systems significantly improve energy efficiency, indoor environmental quality, and operational performance, challenges such as high initial costs, lack of standardization, cybersecurity risks, and improper system management limit their effectiveness. Proper awareness, training, and the use of cost-effective and scalable solutions are essential to ensure efficient implementation. By integrating intelligent technologies with conventional building practices and promoting sustainable lifecycle management of smart devices, green buildings can achieve long-term environmental benefits, reduced carbon emissions, and support sustainable urban development.

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