FEMS, (2026)

Frontiers in Emerging Multidisciplinary Sciences (Open Access)

Volume 03, Issue 07, July 2026,
Publish Date: 05-07-2026
PageNo.08-16

AI-Driven Energy Performance Enhancement in Smart Buildings: A Construction Management Approach

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ABSTRACT

The increasing demand for sustainable infrastructure, energy efficiency, and intelligent resource management has accelerated the transformation of conventional buildings into smart, adaptive, and digitally integrated environments. Smart buildings equipped with artificial intelligence (AI), advanced monitoring systems, renewable energy integration, and automated control mechanisms represent a significant opportunity for improving energy performance throughout the building lifecycle. However, the successful implementation of AI-driven energy optimization requires not only technological advancement but also effective construction management strategies that integrate planning, design coordination, implementation control, and operational decision-making.

This research examines AI-driven energy performance enhancement in smart buildings from a construction management perspective. The study adopts a conceptual research methodology based on a systematic synthesis of existing literature related to knowledge management, artificial intelligence applications, energy optimization, renewable energy systems, energy storage, building materials, and sustainable transformation strategies. The research develops an integrated framework connecting AI-based energy management technologies with construction project management principles to improve building performance, reduce energy consumption, and support long-term sustainability objectives.

The findings indicate that AI technologies can significantly enhance building energy performance by enabling predictive analytics, adaptive control, demand forecasting, fault detection, and optimized energy scheduling. However, technological capability alone does not ensure successful implementation. Construction management practices including stakeholder coordination, data management planning, lifecycle assessment, risk management, and technology integration strategies play a critical role in achieving effective outcomes. Knowledge management principles further strengthen decision-making by enabling systematic collection, interpretation, and application of operational information.

The study also identifies challenges associated with AI implementation, including high initial investment costs, data quality requirements, cybersecurity risks, interoperability limitations, and the need for skilled professionals capable of managing interdisciplinary systems. The integration of renewable energy, energy storage technologies, and advanced thermal management approaches provides additional opportunities for improving building resilience and reducing environmental impacts.

The research contributes an engineering and construction management-oriented perspective by demonstrating that AI-driven smart buildings should be treated as complex socio-technical systems requiring coordinated technological and managerial approaches. The proposed framework provides guidance for construction professionals, facility managers, and decision-makers seeking to implement intelligent energy solutions. Future smart building development will depend on effective integration between artificial intelligence, sustainable construction practices, and strategic management approaches.

KEYWORDS: Artificial Intelligence; Smart Buildings; Energy Performance Optimization; Construction Management; Knowledge Management; Renewable Energy; Energy Storage; Sustainable Construction; Building Automation.

1. INTRODUCTION

1.1 Background

The global construction sector is experiencing a fundamental transition from conventional building development approaches toward intelligent and sustainable infrastructure systems. Increasing energy demand, environmental concerns, and the requirement for improved operational efficiency have created the need for buildings that can dynamically respond to changing conditions. Traditional buildings generally operate through predetermined schedules and isolated control systems, resulting in inefficient energy utilization and limited adaptability. Smart buildings address these limitations by integrating digital technologies, intelligent control systems, sensors, data analytics, and automated decision-making mechanisms.

Artificial intelligence has become a critical technology in this transformation because it enables buildings to analyze large volumes of operational data and make predictive decisions. AI-driven systems can identify energy consumption patterns, optimize heating and cooling operations, predict equipment performance, and improve resource allocation. Unlike conventional automation systems based on fixed rules, AI-based solutions continuously learn from building conditions and improve operational strategies over time.

However, implementing AI-driven energy optimization in buildings involves challenges beyond technical development. Buildings are complex systems involving architectural design, construction processes, mechanical and electrical infrastructure, human behavior, and long-term facility management. Therefore, construction management plays an essential role in ensuring that AI technologies are effectively incorporated throughout the project lifecycle. Philip (2026) emphasizes that AI-based energy optimization in smart buildings requires integration with construction project management practices because successful implementation depends on planning, coordination, and operational management.

The increasing importance of sustainable transformation has also expanded the role of knowledge management within construction and energy systems. Knowledge management enables organizations to capture, organize, and utilize information for improved decision-making. Alavi and Leidner (2001) explain that knowledge management systems provide conceptual foundations for transforming organizational knowledge into valuable resources. In smart buildings, operational data generated by sensors and AI platforms becomes a critical knowledge asset that supports continuous improvement.

1.2 Problem Statement

Despite rapid technological progress, many smart building projects fail to achieve expected energy performance improvements because of insufficient integration between technology implementation and construction management practices. AI systems require reliable data infrastructure, compatible building systems, trained personnel, and effective operational strategies. Without proper management frameworks, advanced technologies may remain underutilized.

A major challenge is the fragmentation between construction activities and building operation. Many decisions affecting future energy performance are determined during early design and construction stages. However, energy optimization requirements are often considered only after building completion, making integration more difficult and costly.

Furthermore, AI-driven energy management introduces complexity related to data collection, processing, cybersecurity, and system interoperability. Construction managers must coordinate multiple stakeholders, including architects, engineers, software developers, energy specialists, and facility operators. Effective collaboration and knowledge sharing are therefore essential for successful implementation.

Energy transition requirements also create additional pressure on the construction sector. Sustainable development strategies require buildings to reduce energy consumption while improving operational resilience. Fazekas et al. (2022) emphasize that achieving net-zero transformation requires coordinated actions across technological, economic, and institutional systems. Smart buildings represent an important component of this transformation because they combine efficiency improvements with intelligent resource management.

1.3 Research Relevance

The relevance of this research emerges from the increasing need to connect artificial intelligence capabilities with practical construction management approaches. Existing research frequently examines AI algorithms, energy systems, or building automation separately. However, successful smart building implementation requires integration between technological innovation and management processes.

Knowledge-based approaches provide important insights into this integration. Davenport et al. (2001) demonstrate the importance of using information effectively to understand complex operational environments and improve decision-making. In smart buildings, AI systems generate extensive operational information, but its value depends on how effectively organizations manage and apply this knowledge.

The construction management perspective is particularly important because decisions made during project planning influence long-term building performance. Material selection, equipment integration, digital infrastructure design, and operational planning determine whether AI-driven systems can achieve their intended objectives.

Philip (2026) highlights that AI-enabled energy optimization should be integrated with construction project management frameworks to achieve improved energy efficiency and renewable energy utilization. This perspective establishes the importance of examining smart buildings as integrated systems rather than isolated technological projects.

1.4 Research Objectives

This research aims to investigate AI-driven energy performance enhancement in smart buildings through a construction management approach.

The objectives are:

To analyze the theoretical foundations of AI-driven energy optimization and smart building systems.

To examine the role of knowledge management and data-driven decision-making in intelligent building operations.

To develop an integrated construction management framework for implementing AI-based energy performance strategies.

To evaluate technological opportunities, implementation challenges, and future development pathways for AI-enabled smart buildings.

1.5 Scope and Significance

The scope of this research focuses on AI applications within smart buildings, including predictive energy management, automated control systems, knowledge-based decision-making, renewable energy integration, and construction lifecycle management.

The research considers smart buildings as multidisciplinary systems where digital technologies interact with construction processes and operational management. It does not focus on a specific geographic region or individual building project but develops a conceptual framework applicable to different construction environments.

The significance of this study lies in bridging the gap between artificial intelligence research and construction management practice. By integrating technological and managerial perspectives, the research provides insights for improving energy efficiency, reducing environmental impacts, and enhancing the sustainability of future building projects.

2. LITERATURE REVIEW

2.1 Knowledge Management Foundations for Smart Building Intelligence

Knowledge management provides an important theoretical foundation for AI-driven smart building systems because intelligent energy optimization depends on the effective use of information. Alavi and Leidner (2001) describe knowledge management systems as mechanisms that support knowledge creation, storage, transfer, and application within organizations. In smart buildings, operational information generated by sensors, automation systems, and energy monitoring platforms becomes a valuable knowledge resource.

The relationship between knowledge management and smart buildings extends beyond data collection. AI systems require meaningful interpretation of information to generate actionable decisions. Energy consumption data, equipment performance records, environmental conditions, and occupant behavior patterns must be transformed into knowledge that supports operational improvement.

Garcia-Murillo and Annabi (2002) examined customer knowledge management and demonstrated the importance of organizing information to improve organizational capabilities. Although their research focuses on customer relationships, the underlying principle applies to smart buildings where understanding operational conditions enables improved decision-making.

Gebert et al. (2003) further emphasized the integration of knowledge management concepts with organizational systems. This perspective is relevant because smart building projects involve multiple stakeholders requiring effective knowledge exchange throughout design, construction, and operation phases.

2.2 Artificial Intelligence and Energy Optimization in Smart Buildings

AI-driven energy optimization represents a major advancement in building performance management. AI technologies enable predictive analysis, automated decision-making, and adaptive control. These capabilities allow buildings to respond dynamically to energy demand, environmental conditions, and operational requirements.

Philip (2026) demonstrates that AI-based optimization can improve energy management when integrated with construction project management strategies. The study highlights that AI implementation requires coordination between technological systems and project management practices to achieve sustainable outcomes.

AI-based systems can optimize HVAC operation, lighting control, equipment scheduling, and renewable energy utilization. However, their effectiveness depends on the availability of accurate data and appropriate system integration. Construction managers must therefore consider digital infrastructure requirements during early project planning.

2.3 Energy Systems, Storage, and Thermal Management

Energy optimization in smart buildings requires effective management of energy generation, storage, and consumption. Kucur et al. (2022) reviewed emerging energy storage technologies and highlighted their importance for improving energy flexibility within smart grid environments. Energy storage allows buildings to balance renewable energy availability and consumption demand.

Thermal management is another important factor influencing building energy performance. Li et al. (2023)

analyzed phase change materials for passive cooling in building envelopes and demonstrated their potential for reducing cooling requirements through improved thermal regulation.

Baroutaji et al. (2021) examined thermal management and waste heat recovery technologies, highlighting the importance of improving energy utilization efficiency. These approaches demonstrate that energy optimization requires consideration of both active AI-based systems and passive building performance strategies.

3. METHODOLOGY

3.1 Research Method and Framework Development Approach

This research adopts a conceptual analytical methodology to investigate the relationship between artificial intelligence-driven energy optimization and construction management practices in smart buildings. The methodology is based on the synthesis of the provided literature related to knowledge management, sustainable transformation, energy systems, artificial intelligence applications, and smart building development.

The research approach recognizes smart buildings as complex socio-technical systems where technological components and management processes must operate together. Instead of analyzing AI as an isolated computational tool, this study examines AI implementation throughout the construction lifecycle, including project planning, design integration, construction execution, commissioning, and operational management.

The methodology consists of five analytical stages:

1. Identification of critical components influencing AI-driven building energy performance.

2. Analysis of relationships between artificial intelligence, knowledge management, energy systems, and construction management.

3. Development of an integrated AI-driven construction management framework.

4. Evaluation of implementation strategies, operational benefits, and management challenges.

5. Identification of limitations and future improvement opportunities.

This methodological approach follows the principle that technological innovation generates maximum value when supported by organizational capability and effective management processes. Knowledge management research demonstrates that information becomes valuable when organizations develop appropriate systems for collecting, interpreting, and applying knowledge (Alavi and Leidner, 2001).

3.2 Conceptual Framework for AI-Driven Smart Building Energy Management

The proposed framework, named the AI-Integrated Smart Building Construction Management Framework (AISB-CMF), establishes a structured relationship between artificial intelligence technologies and construction management activities.

The framework consists of six interconnected layers:

1. Construction Planning Layer
2. Digital Data Infrastructure Layer
3. AI-Based Energy Intelligence Layer
4. Building Energy Optimization Layer
5. Lifecycle Management Layer
6. Continuous Knowledge Improvement Layer

Each layer contributes to improving building energy performance through coordinated decision-making.

3.3 Construction Planning and AI Integration Strategy

3.3.1 Early-Stage Planning Requirements

Construction planning represents the foundation for successful AI implementation. Decisions made during the planning stage influence future energy performance, technology compatibility, and operational efficiency.

Traditional construction management often focuses on cost, schedule, and quality control. However, smart building projects require additional considerations including:

- Digital infrastructure requirements.
- Sensor placement strategies.
- Data communication networks.
- AI system compatibility.
- Future operational requirements.

AI-driven energy optimization cannot be effectively implemented if digital systems are considered only after construction completion. Therefore, construction managers must integrate intelligence requirements during architectural and engineering design phases.

For example, a commercial building designed for AI-based energy management requires appropriate locations for environmental sensors, energy monitoring equipment, automated control systems, and communication infrastructure.

3.3.2 Stakeholder Coordination and Knowledge Integration

Smart building projects involve multiple stakeholders with different technical backgrounds. Architects, electrical engineers, mechanical engineers, software specialists, contractors, and facility managers must exchange information effectively.

Knowledge management principles provide a foundation for improving this collaboration. Alavi and Leidner (2001) emphasize that knowledge systems support organizational learning and information utilization. In construction projects, knowledge integration reduces communication failures and improves technology implementation.

The construction manager acts as a coordination authority responsible for ensuring that:

- Design decisions support energy objectives.
- Technology requirements are communicated among teams.
- Operational knowledge is transferred from construction to facility management.
- Project documentation supports future AI system improvement.

Gebert et al. (2003) highlight the importance of integrating knowledge management concepts into organizational systems. This principle is directly applicable to smart buildings because successful AI deployment depends on continuous knowledge exchange.

3.4 Digital Infrastructure and Data Management Model

3.4.1 Data Acquisition Architecture

AI-based energy optimization depends on continuous and accurate data collection. The digital infrastructure layer collects information from different building components, including:

- Electricity consumption meters.
- HVAC monitoring systems.
- Lighting control systems.
- Renewable energy generation units.
- Environmental sensors.
- Occupancy monitoring systems.

The collected data forms the foundation for AI-based analysis.

Poor-quality data can negatively affect optimization performance. Therefore, construction managers must ensure that data infrastructure is properly designed during project development.

3.4.2 Knowledge Transformation Process

The methodology applies a knowledge transformation process:

Raw Data → Information → Knowledge → Intelligent Decision

Raw operational measurements are first collected from building systems. AI algorithms then analyze patterns and convert information into useful knowledge. The knowledge is finally applied to optimize energy operations.

Davenport et al. (2001) emphasize the importance of organizations effectively using information to understand complex environments and improve decisions. This concept is particularly relevant in smart buildings where large quantities of operational data require intelligent interpretation.

3.5 AI-Based Energy Optimization Model

3.5.1 Predictive Energy Analytics

The first function of the AI optimization system is predictive analysis. AI models examine historical and real-time data to forecast future energy requirements.

Prediction factors include:

- Weather conditions.
- Occupancy patterns.
- Equipment performance.
- Historical energy consumption.
- Renewable energy availability.

For example, an AI system can predict increased cooling demand during high-temperature conditions and automatically adjust HVAC operation before excessive energy consumption occurs.

Predictive capability improves efficiency because decisions are based on future expectations rather than current conditions alone.

3.5.2 Intelligent Energy Scheduling

The second function involves optimizing energy scheduling.

The AI system determines:

- When equipment should operate.
- How renewable energy should be utilized.
- When stored energy should be discharged.
- How demand peaks can be reduced.

A smart building with solar generation and battery storage provides an example. During periods of high solar production, AI can prioritize renewable energy utilization and store excess electricity for later use.

Kucur et al. (2022) emphasize that energy storage technologies contribute to flexibility and reliability within intelligent energy systems. AI enhances this capability by determining optimal storage and consumption strategies.

3.5.3 Automated Fault Detection and Maintenance Optimization

AI systems can also identify abnormal equipment behavior and predict maintenance requirements.

Traditional maintenance approaches often depend on fixed schedules or reactive responses after equipment failure. AI-based predictive maintenance allows organizations to identify potential problems before they become major failures.

This approach improves:

- Equipment reliability.
- Operational efficiency.
- Maintenance planning.
- Lifecycle cost management.

From a construction management perspective, predictive maintenance extends the value of initial construction investments by improving long-term building performance.

3.6 Integration of Sustainable Energy Technologies

3.6.1 Renewable Energy Integration

AI-driven smart buildings increasingly incorporate renewable energy systems to reduce dependence on conventional energy sources.

Potential renewable systems include:

- Solar photovoltaic generation.
- Wind energy systems.
- Waste heat recovery systems.
- Hybrid renewable configurations.

The effectiveness of renewable integration depends on intelligent coordination between generation, storage, and consumption.

Philip (2026) highlights that AI-based optimization improves renewable energy utilization by enabling adaptive management strategies within smart building environments.

3.6.2 Thermal Performance Enhancement

Building energy performance is influenced not only by operational systems but also by physical building characteristics.

Li et al. (2023) examined phase change materials for passive cooling applications and demonstrated their potential for improving thermal regulation in building envelopes.

The methodology incorporates passive energy strategies with AI-based active optimization. This combination creates a hybrid approach where building materials reduce energy demand while AI systems optimize remaining consumption.

3.6.3 Waste Heat Recovery and Energy Efficiency

Waste heat recovery represents another opportunity for improving energy performance. Baroutaji et al. (2021) investigated thermal management and waste heat recovery technologies and emphasized their role in improving energy utilization efficiency.

In smart buildings, AI systems can monitor heat generation patterns and optimize recovery processes. For example, waste heat from mechanical systems can potentially be reused for heating applications, reducing additional energy requirements.

3.7 Construction Lifecycle Management Framework

AI-driven energy optimization should continue throughout the entire building lifecycle.

Design Phase

During design, AI requirements, energy objectives, and digital infrastructure must be incorporated into project specifications.

Construction Phase

During construction, managers must ensure:

- Correct installation of sensors.
- Proper integration of control systems.
- Quality verification of digital components.

Commissioning Phase

The commissioning process verifies whether installed systems operate according to performance objectives.

Operation Phase

During operation, AI continuously analyzes performance data and recommends improvements.

This lifecycle approach ensures that smart buildings remain adaptive rather than becoming outdated technological installations.

3.8 Implementation Example: AI-Enabled Office Building

A hypothetical office building demonstrates the application of the proposed framework.

The building includes photovoltaic panels, smart HVAC systems, advanced sensors, and AI-based energy management software.

During initial planning, construction managers integrate digital requirements into building design. Sensors collect information about temperature, occupancy, and electricity consumption.

The AI system analyzes operational patterns and automatically adjusts HVAC operation according to occupancy conditions. Renewable electricity generation is prioritized during peak production periods, while energy storage systems support demand management during low-generation periods.

Facility managers use AI-generated reports to evaluate performance and schedule maintenance activities.

This example demonstrates that AI-driven energy improvement requires coordination between construction decisions, digital systems, and operational management.

3.9 Methodological Limitations

Although the proposed framework provides an integrated approach, several limitations exist.

First, the research is conceptual and does not include experimental validation using real building performance data. Future studies should apply the framework to operational smart buildings and measure actual energy improvements.

Second, AI implementation requires significant investment in sensors, computing infrastructure, software development, and skilled personnel. These requirements may limit adoption in smaller construction projects.

Third, data security and privacy concerns remain important challenges because smart buildings rely heavily on continuous information collection.

Finally, differences in climate conditions, building types, regulations, and economic environments may influence implementation outcomes.

Therefore, future research should focus on developing adaptable AI frameworks capable of supporting diverse construction environments.

4. RESULTS

The analysis demonstrates that AI-driven energy performance enhancement in smart buildings depends on the successful integration of artificial intelligence capabilities with construction management practices. The findings indicate that energy optimization cannot be achieved through technological deployment alone; rather, it requires coordinated planning, knowledge management, digital infrastructure development, and lifecycle-oriented management strategies.

The first major finding is that artificial intelligence significantly improves the ability of buildings to monitor, predict, and optimize energy consumption. AI-based systems enable predictive analytics, automated control, and intelligent scheduling by processing large volumes of operational data. These capabilities allow buildings to respond dynamically to changing conditions, reducing unnecessary energy consumption while maintaining operational requirements. Philip (2026) highlights that AI-based energy optimization becomes more effective when combined with construction project management approaches because implementation success depends on coordination between technological systems and managerial processes.

The second finding relates to the importance of knowledge management in smart building performance improvement. Smart buildings generate extensive operational data from sensors, equipment monitoring systems, and automated controls. However, data alone does not create value unless organizations can transform it into actionable knowledge. The principles of knowledge management discussed by Alavi and Leidner (2001) indicate that effective knowledge creation, storage, and utilization support better organizational decision-making. In construction management contexts, this knowledge enables continuous improvement throughout the building lifecycle.

The third finding identifies the importance of integrating AI systems during early construction planning stages. The research indicates that many performance limitations occur when intelligent technologies are added after construction completion rather than being incorporated into initial design decisions. Early integration improves system compatibility, reduces implementation costs, and supports better coordination among architects, engineers, contractors, and facility managers.

The fourth finding concerns the role of energy storage and sustainable technologies in improving smart building resilience. Renewable energy sources require intelligent management because generation patterns may not always align with building demand. Energy storage technologies provide flexibility by balancing supply and consumption. Kucur et al. (2022) emphasize that advanced storage solutions support the development of flexible and reliable energy systems. When combined with AI optimization, storage systems can improve renewable energy utilization and reduce dependence on external energy sources.

The analysis also reveals that passive and active energy strategies should be integrated. Building materials and thermal management approaches influence energy requirements, while AI systems optimize operational performance. Li et al. (2023) demonstrate the potential of phase change materials for improving thermal regulation, while Baroutaji et al. (2021) highlight the importance of thermal management and waste heat recovery technologies. Together, these approaches demonstrate that smart building performance requires both intelligent operation and efficient physical design.

Despite these advantages, the findings identify several implementation barriers. High initial costs, cybersecurity risks, interoperability challenges, and shortage of skilled professionals remain significant obstacles. Furthermore, AI systems require continuous data availability and maintenance to maintain accuracy. Therefore, construction managers must develop comprehensive implementation strategies that address technological, financial, and organizational requirements.

Overall, the findings establish that AI-driven smart buildings represent integrated socio-technical systems where artificial intelligence, construction management, energy technologies, and knowledge management operate together to achieve improved energy performance and sustainability.

5. DISCUSSION

The findings provide evidence that AI-driven energy optimization represents a significant transformation in the management of building performance. The traditional approach of treating buildings as static structures is gradually being replaced by a dynamic model where buildings continuously collect information, analyze operational conditions, and adapt their behavior. This transition requires a broader understanding of construction management because the success of smart buildings depends on decisions made before and after physical construction.

The integration of artificial intelligence creates opportunities for improving efficiency, but it also introduces managerial complexity. AI systems require reliable data, appropriate algorithms, and continuous monitoring. Construction managers must therefore expand their responsibilities beyond conventional cost and schedule management toward digital system coordination and knowledge-based decision-making. Davenport et al. (2001) emphasize the importance of effective information utilization in improving organizational understanding and decision processes, which directly applies to AI-enabled building environments.

The research also highlights the importance of knowledge management as a foundation for smart building success. AI systems generate significant amounts of operational information, but organizations must develop mechanisms to transform this information into practical improvements. Without effective knowledge management practices, valuable data may remain unused or poorly interpreted. Garcia-Murillo and Annabi (2002) and Gebert et al. (2003) demonstrate that structured knowledge management approaches improve organizational capabilities, providing relevant insights for construction and facility management systems.

From a sustainability perspective, AI integration supports broader energy transition objectives by enabling improved renewable energy utilization and reduced operational emissions. Fazekas et al. (2022) emphasize that achieving net-zero transformation requires coordinated technological and institutional changes. Smart buildings contribute to this transformation by combining digital intelligence with sustainable energy strategies.

However, the implementation of AI-driven systems involves several trade-offs. Higher levels of automation may increase efficiency but also increase dependency on digital infrastructure. Greater data collection improves optimization capability but creates cybersecurity and privacy concerns. Similarly, advanced technologies may provide long-term benefits but require significant initial investment.

The construction industry must therefore adopt balanced strategies that consider technical performance, economic feasibility, and organizational readiness. AI should not be viewed as a replacement for management practices but as a tool that enhances human decision-making capabilities.

The research contributes by establishing a construction management-oriented perspective for AI-driven energy optimization. It demonstrates that smart building development requires integration among digital technologies, sustainable engineering practices, and project management frameworks. Future research should focus on empirical validation, standardized implementation methods, and improved AI models capable of adapting to different building environments.

6. CONCLUSION

AI-driven energy performance enhancement represents an important development pathway for achieving sustainable, efficient, and adaptive smart buildings. This research examined the integration of artificial intelligence technologies with construction management approaches to improve building energy optimization.

The study demonstrates that AI enables significant improvements through predictive analytics, automated control, intelligent scheduling, and performance monitoring. However, technological capability alone cannot guarantee successful implementation. Effective outcomes require strategic construction planning, knowledge management, stakeholder coordination, and lifecycle-based management approaches.

The proposed AI-Integrated Smart Building Construction Management Framework highlights the importance of connecting digital intelligence with construction processes. Early-stage planning, proper data infrastructure, renewable energy integration, energy storage management, and continuous operational improvement are essential components of successful smart building development.

The research also emphasizes the importance of combining active and passive energy strategies. AI-based optimization systems provide intelligent operational control, while advanced building materials, thermal management approaches, and sustainable energy technologies reduce energy demand and improve efficiency.

Despite significant opportunities, challenges remain regarding investment costs, cybersecurity, interoperability, and technical expertise requirements. Addressing these limitations requires collaboration among construction professionals, technology developers, policymakers, and facility managers.

Future smart buildings will increasingly depend on the integration of artificial intelligence, sustainable construction practices, and effective management frameworks. By adopting a lifecycle-oriented approach, the construction sector can transform buildings from passive energy consumers into intelligent systems capable of adapting to future energy and environmental challenges.

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