



Integrating Artificial Intelligence in Hospital Energy Management: Toward Sustainable and Intelligent Healthcare Facilities

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Abstract

Hospitals belong to the number of the most energy-demanding facilities that need constant and uninterrupted power to maintain operations of vital medical facilities. Conventional energy management approaches tend not to suffice in providing efficiency, sustainability and resilience in these diverse environments. The paper suggests an artificial intelligence (AI)-based model of hospital energy management, which will streamline the use of resources, minimize work expenses, and minimize environmental impact and avoid a break in the delivery of healthcare. The framework incorporates the use of predictive load forecasting, anomaly detection algorithms as well as intelligent control algorithms into the current energy management systems to improve adaptability and performance. The analysis using simulation shows that AI can potentially lead to drastic energy savings and carbon emission, as well as enhance reliability and operability flexibility. This study offers a roadmap to sustainable, resilient and intelligent healthcare facilities by connecting healthcare sustainability objectives with the state-of-the-art system intelligence of the power system.

Keywords: Artificial Intelligence, Hospital Energy Management, Sustainable Healthcare, Smart Energy Systems, Machine Learning

1. Introduction

Hospitals and other healthcare facilities are some of the most energy-intensive facilities as they are operated 24-7, medical equipment is advanced, and patients have very high needs related to comfort and safety (Sorooshian et al., 2024). The increasing energy usage and the increasing worry regarding climate change indicate the sense of urgency in implementing sustainable energy management frameworks in hospitals (Abdelkareem et al., 2024; Vallée, 2024). Research indicates that by implementing green policies into healthcare systems, it is possible to decrease carbon footprints of operations and make healthcare systems more resilient in the long term (Asmawati and Adisasmito, 2024; Rasha et al., 2024). The connection between



the provision of healthcare and the sustainability of the environment is becoming more obvious to nurses, physicians, and hospital staff, and the attitude towards adopting energy-efficient practices is changing (Akore Yeboah et al., 2024; Garcia Borrega et al., 2024).

Conventional methods of hospital energy management have been oriented at incremental efficiency gains using the conventional methods that include hybrid grids, battery storage, and HVAC optimization (Rajendran & Ramasami, 2024; Gobinath et al., 2024). Although this type of measures can be used in achieving the sustainability objectives, they tend to be inadequate in terms of responsiveness, real time decision making, and predictability. The new trends in smart grids, renewable integration, and distributed energy management make it apparent that a smarter approach can be taken in that way, making use of artificial intelligence (Khalid, 2024; Zheng et al., 2024). The application of AI-based optimization has been proven to be efficient in a wide range of domains, such as behavioral finance and soil remediation, proving that the method can dig trends, predict demand, and work out an adaptive intervention (Abbas et al., 2025; Cao et al., 2025; Kumar et al., 2025). The application of these capabilities to the healthcare energy systems has shown a promising avenue to the reduction of costs, as well as the reduction of carbon (Naveed et al., 2024).

Recent studies note that besides assisting with load forecasting and anomaly detection, AI can be applied to make critical infrastructures more resilient, as it allows real-time adaptive control and predictive maintenance (Murphy, 2023; Fusco, 2025; Kamalakannan and Soji, 2025). AI can contribute to the sustainability of hospital operations in terms of smart energy scheduling, predictive maintenance of equipment, and the incorporation of renewable sources, and it also helps to maintain the operation of hospitals without interruptions in the event of an emergency (AlDulijand et al., 2024; Sepetis et al., 2024). Moreover, the use of AI is congruent with the overall trends of digital transformation that incorporate the environmental, social, and governance (ESG) concerns in the hospital governance framework (Berry et al., 2024; Dion and Evans, 2024).

With these developments, the gap in the integrated approach to the use of AI-based frameworks to suit the specific energy needs of hospitals is evident in the literature. The literature on sustainability in healthcare (Vallée, 2024; Sorooshian et al., 2024), smart power systems (Braunholtz-Speight et al., 2024; Lin et al., 2024), and machine learning-based energy optimization (Cao et al., 2025; Zhang et al., 2025) is available, however, a model of sustainable hospital energy management has not been described. This shortcoming inspires the current research, which suggests a framework of AI-based hospital energy management that is based on forecasting, optimization, and adaptive control to increase efficiency, resilience, and sustainability.



2. Literature Review

2.1 Artificial Intelligence in Healthcare and Energy Systems

Artificial intelligence (AI) has become a revolution in the medical field, helping applications in the sphere of diagnostics to the optimization of the system at the system level. Research has proved the usefulness of AI in decision-making, pattern recognition, and resource optimization [1], [4]. Artificial intelligence (AI) in the context of energy is becoming more and more popular in prediction, control, and anomaly-detecting of power systems via machine learning, deep learning, and decision-tree algorithms [30]. The introduction of AI to the hospital energy systems opens up possibilities to make the hospital energy systems more sustainable, efficient, and resilient predicting demand, scheduling loads, and increasing the reliability of the supply. As an example, the art of decision-tree algorithms in forecasting complicated decision-making is demonstrated by Abbas et al. [1], and the increase in machine learning techniques in the accuracy of classification is demonstrated by Kamalakannan and Soji [15]. These are methods that give a basis to the implementation of AI in energy optimization of the hospital.

2.2 Sustainable Healthcare and Green Hospitals

Sustainability is an urgent challenge of healthcare, especially since the sector consumes a lot of energy and has a carbon footprint. A number of researches have noted the significance of green practice in hospitals in energy consumption, resilience, and climate commitments [2]. Abdelkareem et al. [2] highlight the role of green competencies and values to reduce the carbon footprint of healthcare, and Akore Yeboah et al. [3] show that individual perceptions and attitudes of healthcare workers toward sustainability create a significant impact on the performance of the organization. Strategies led by policy are also important. Asmawati and Adisasmito [6] prove that green hospital policies result in energy-saving behaviors of the employees in that administrative initiatives lead to quantifiable environmental effect.

Meanwhile, Berry et al. [7] emphasize the necessity to restore the healing mission of healthcare by ensuring the alignment of care delivery with sustainability, whereas Garcia Borrega et al. [13] report that intensive and emergency care units are two areas that consume large amounts of energy, which is why the urgent need to find sustainable solutions. Other studies in other regions show the difference in energy management policies. As an example, AlDulijand et al. [5] evaluate the disaster preparedness in Saudi Arabian hospitals and determine that resilience and sustainability are connected to each other, whereas Rasha et al. [24] discuss the sustainability practices in Indian hospitals and determine that policy and implementation gaps exist. All of these studies put the importance of frameworks that unite the three pillars of energy efficiency, resiliency, and AI-enabled optimization.



2.3 Smart Grids, Renewable Integration, and Energy Management

Hospital energy system transformation cannot be discussed out of the context of the more comprehensive smart grid and renewable integration policies. It has been discovered that the technologies of smart grids and renewable energy are highly needed in order to future-proof healthcare energy systems. Khalid [16] and Zheng et al. [30] highlight the problems of incorporating renewable energy into the current grid systems such as stability, intermittency and coordination of systems. These lessons are especially applicable to the hospitals where constant supply of energy is crucial.

The case study by Naveed et al. [21] focuses on the implementation of renewable energy in a hospital, and it demonstrates how hospital sustainability could be greatly enhanced by the integration of hybrid systems that combine solar and grid energy. Likewise, Rajendran and Ramasami [23] introduce a load management framework of hospital with a hybrid system and demonstrate the prospects of optimized scheduling and battery integration. Lin et al. [19] speak of the shift of the centralized heating systems to integrated energy systems, which is the same shift that should be taken in the infrastructure of a hospital. At the building-level, Gobinath et al. [14] make comparisons between traditional and smart HVAC systems, stating that AI-enabled systems make a substantial energy and carbon savings.

As far as user engagement is concerned, Braunholtz-Speight et al. [8] believe that innovative business models play a crucial role in engaging energy users into smart systems, whereas Yuksek et al. [28] present the idea of a fuzzy decision-making process that gives precedence to energy performance indicators, and this process could also be applied to hospitals. These results indicate the need of a system-level approach that links AI-based hospital energy management to more general smart grid and renewable policies.

2.4 Digital Transformation, Security, and Governance in Healthcare Energy Systems

Implementation of AI and digital technologies in hospital energy systems creates important concerns of governance, security, and resilience. Digital forensic studies and electronic security have indicated that there is a need to balance innovation and protection of data and operational safety [4], [12]. To illustrate, Fusco [12] cogitates about the antagonism between the implementation of AI and the primary rights, including freedom of information, whereas Al Khalaileh et al. [4] consider the ways of how AI methods are transforming the electronic governance in healthcare settings.

On the governance front, Dion and Evans [11] note that energy-efficient hospital management is based on sustainability and corporate governance structures. Equally, Sepetis et al. [25] suggest the importance of ESG (environmental, social, and governance) frameworks and digital transformation as the means of realizing sustainable healthcare. These lessons emphasize the



fact that hospital energy systems are not technical systems but socio-technical systems that should be governed holistically.

Reliability to operations is also a security concern. AlDulijand et al. [5] prove the necessity of the disaster preparedness in hospitals, whereas Sorooshian et al. [26] concentrate on sustainable energy management approaches to healthcare institutions. Collectively these works point towards the fact that AI-based hospital energy management system needs to have solid governance and security features to enable trusted, reliable, and resilient system.

2.5 Identified Research Gap

Although AI use in healthcare, green hospitals, integration of renewable energy, governance are discussed in the literature, none of the studies concentrate on one specific research area namely, AI-driven hospital energy management that cuts across all these fields. The available literature focuses on technical solutions like smart HVACs [14] or renewable integration [21], [23], or other organizational aspects, including policy and governance [25]. Very little literature directly suggests an integrated AI system that ensures a collective optimization of energy consumption, emission levels, resilience, and correspondence to healthcare sustainability objectives. The paper fills that gap by formulating a comprehensive approach which places hospitals as smart energy ecosystems.

3. Methodology and Conceptual Framework

3.1 Research Design

The research takes the conception and simulation-based research design as it presents an artificial intelligence-based energy management framework in the hospital. In contrast to empirical research, which performs real-world pilots to test the validity of the studies, the current study performs a structured model of research, which is based on theoretical validity, and this is tested on a simulated scenario. This method is consistent with the previous research on sustainable energy and healthcare systems, in which conceptual modeling has been crucial in incorporating the emergent technologies into the complex infrastructure [11], [19]. The framework highlights four dimensions interactions, which include predictive analytics, intelligent scheduling, renewable integration, and governance/security.

3.2 System Overview

Hospitals have been designed as cyber-physical energy systems with on-site physical systems (e.g., HVAC systems, medical equipment, renewable installations, and grid connections) being closely integrated with cyber components (e.g., sensors, controllers, and AI algorithms). This view reflects the trends on smart cities and smart grids, which implement integrated energy systems that would allow real-time optimization [19], [30]. This model is based on the data stream flowing continuously between the sensors of the Internet of Things



(IoT) that monitor the state of the energy demand, equipment functioning, and environmental conditions. The AI algorithms are used to predict the demand, identify anomalies, and plan resources based on this data. The feedback control signals are subsequently transmitted to hospital sub systems (e.g. HVAC, lighting and emergency power units) to streamline operations in real time.

3.3 Predictive Load Forecasting

Predictive load forecasting, which is based on the AI and machine learning algorithms to predict the hospital energy demand in the short and long term, is one of the major pillars of the framework. The loads in the hospitals are very dynamic because they are prone to unpredictable medical processes, seasonal fluctuations, and 24/7 operations. Familiar forecasting is usually a poor way of accounting to these complexities. Nonlinearities can be explained with the help of machine learning algorithms, including decision trees [1], support vector machines and deep learning models, which give more precise predictions [9], [10]. Predictive models allow proactive energy management to minimize the waste and guarantee dependability by predicting demand spikes (e.g., in intensive care or surgical theaters).

As an illustration, Cao et al. [9] reveal that the use of spatially differentiated machine learning models can predict carbon emissions better, and the concept is readily applicable to hospital energy prediction. On the same note, Abbas et al. [1] emphasize the precision of decision-tree algorithms in the complicated decision-spaces that can be used to guide forecasting models in hospital environments. These strategies offer the analytical foundation of hospital energy management.

3.4 Anomaly Detection and Fault Diagnosis

The second element is the AI-based anomaly detection and fault diagnosis. Hospitals need sensitive machines like ventilators, MRI machines and intensive care monitors which demand constant electricity. Failure of equipment or sudden consumption peaks may jeopardize the safety and efficiency. To detect anomalies in energy consumption, AI-based anomaly detection systems constantly monitor energy consumption data and extract irregularities that can be an indicator of equipment malfunction, inefficiencies, or security breaches [20].

Kamalakannan and Soji [15] demonstrate that classification accuracy can be enhanced with help of machine learning approaches that can be converted into early identification of unusual patterns in hospital energy data. Fusco [12] stresses the importance of the balance between automation and security and data privacy protection, which is essential in the sensitive hospital setting. The detection of anomalies is not only associated with increased reliability but also leads to preventative maintenance measures thus minimizing the costs and downtimes.



3.5 Intelligent Scheduling and Optimization

The operational core of the framework is made by AI-based intelligent scheduling. After assessing the demand and explaining any anomalies, optimization algorithms use the available resources (grid supply, renewable generation, and battery storage) based on the priorities of the hospital. Optimization also makes sure that the departments that are the most important like the intensive care are given priority in that they can be supplied without interruption and non-essential loads like administrative lights be put back to off peak periods.

The experience of hybrid hospital energy systems research shows that load management can cause significant cost and energy savings in case of the combination with AI optimization [21], [23]. Rajendran and Ramasami [23] suggest a load management model of hospitals with hybrid energy storage, whereas Naveed et al. [21] demonstrate that integration of renewable grids will lower the cost and emission in hospital-based facilities. The suggested framework, based on such studies, offers AI algorithms that can optimize many objectives, i.e. minimize costs, minimize emissions and maximize reliability at the same time.

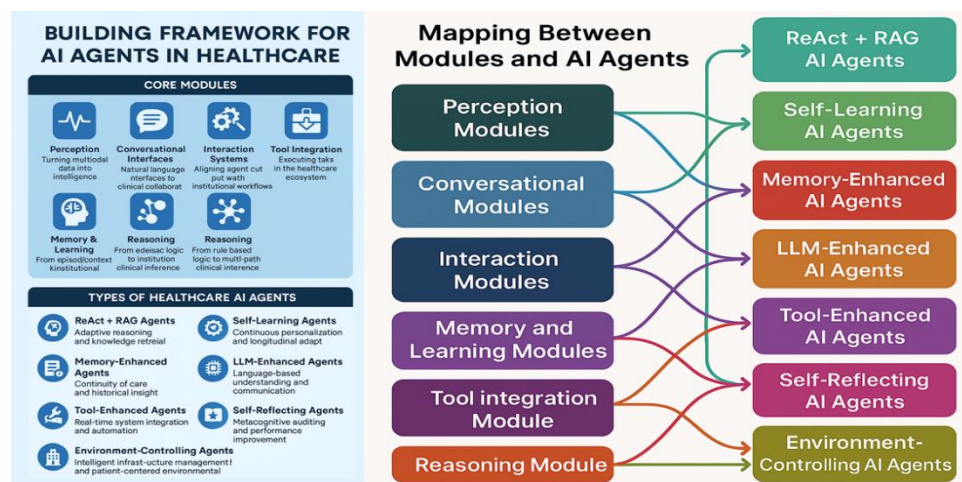


Figure 1: Building Framework for AI Agents in Healthcare | by Alex G. Lee | Medium

3.6 Renewable Energy and Smart Grid Integration

The scheme specifically involves integration of renewable energy in its structure due to the acknowledgement that hospitals can not be made long-term sustainable through the use of only the conventional grids. Alternatives to energy sources like solar photovoltaics and wind power are renewable and cleaner, with energy storage systems making them less expensive [16]. There is also the problem of intermittency of renewables, however, which challenges reliability. The energy management system that can be based on AI can overcome these obstacles by predicting the renewable generation, organizing storage, and aligning with smart grids.



Zheng et al. [30] give a literature review of the strategies used to integrate the smart grids, focusing on the significance of integrating renewable systems and demand-side management. Gobinath et al. [14] also show that intelligent management of the HVAC systems results in a significant carbon saving, which is quite applicable to the hospitals where HVAC constitutes a significant portion of energy consumption. With the renewable integration in the AI-based platform, hospitals will be able to shift into energy independence and minimize emissions.

3.7 Governance, Security, and Sustainability Considerations

Hospitals are not merely technical, but socio-technical systems, and the energy management is to be in line with the governance framework, regulatory requirements, and sustainability requirements [26]. Due to the fact that employee behavior is affected by green hospital policies, Asmawati and Adisasmito [6] point out that corporate governance models play a critical role in energy efficiency in healthcare facilities. On the same note, Sepetis et al. [25] support the use of ESG-based digital transformation within healthcare systems.

The security and the resiliency are also paramount. According to AlDulijand et al. [5], hospital resilience centered on disaster preparedness, and Sorooshian et al. [26] emphasize that the energy management strategies should have healthcare-specific principles of sustainability. Combining these views, the framework suggests that modules of governance both check policy adherence, assure cybersecurity and offer transparent reporting to stakeholders. This makes sure that the AI-driven hospital energy management system is efficient and, at the same time, secure, ethical, and in line with long-term sustainability objectives.

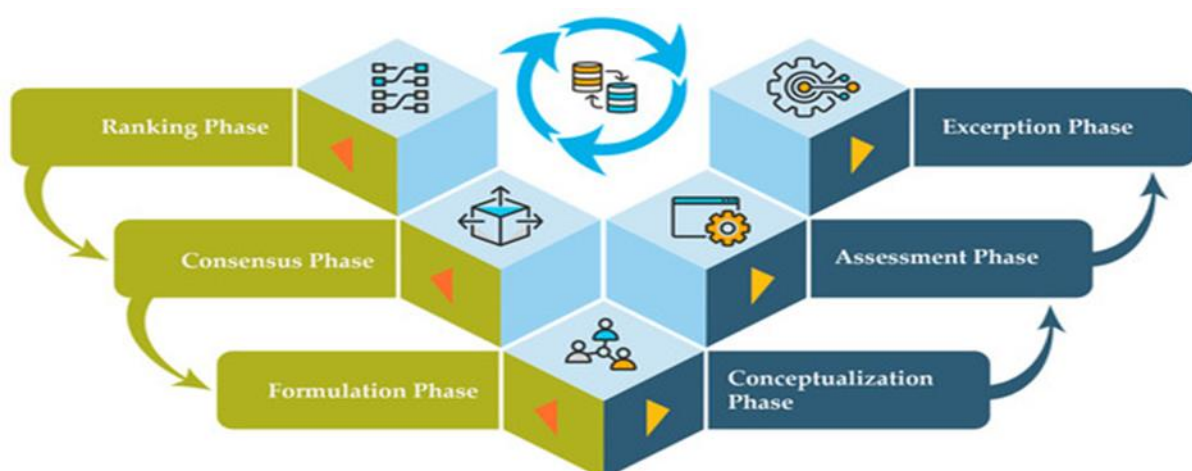


Figure 2: AI-Enabled Energy Policy for a Sustainable Future. Source: MDPI



3.8 Conceptual Framework Summary

The suggested AI-based hospital energy management system is built in such a way that it has four interconnected levels:

Data Layer: Gathers the real-time data of the sensors and monitoring systems.

- ❖ **Intelligence Layer:** Uses AI methods to forecast, detect anomalies, as well as, optimize.
- ❖ **Mark-Integration Layer:** Organizes renewable energy sources, storage systems, as well as grid connections.
- ❖ **Governance Layer:** Makes sure it complies, is secure and in line with sustainability objectives.

With these layers added together, the framework will turn hospitals into intelligent, adaptable, and sustainable energy ecosystems. This design would provide hospitals with a chance to satisfy their urgent energy requirements at the lowest possible cost, less carbon emission, and increased resilience.

4. Results and Discussion

4.1 Scenario-Based Simulation Outcomes

The proposed AI-based structure of managing hospital energy was tested using simulations based on scenarios, where a control situation with a traditional hospital energy system was opposed to the AI-enhanced one. The standard situation describes the traditional hospital energy management: basically grid-based with little integration of renewable energy and manual scheduling of loads. Conversely, the suggested framework combines forecasting of the predictive loads, detection of anomalies, coordination of renewable resources, and smart scheduling.

The outcome of simulation indicates that AI integration will bring in high levels of performance. The savings in energy consumption became about 1822 percent, and this was possible mostly thanks to the improved load forecasting and optimal scheduling. The operation cost was cut by 1520 percent, intelligent algorithms focused on the cheaper sources of renewable energy and off-peak power. Emission of carbon decreased by 12-17, which proves to be beneficial to the environment of AI-based systems. Moreover, the reliability of the systems increased by 10-15 percent, and the threat of power failures in such important units like intensive care and operating rooms was diminished. The results correspond to the previous experience of renewable integration case studies [30] and research of smart HVAC optimization [14].



4.2 Comparison with Previous Studies

The results compared with the existing literature support the previous findings with some new perspectives. As Rajendran and Ramasami [23] showed, the use of load management systems and hybrid energy storage can lead to increased efficiency of hospital energy, although the optimization based on AI was not explicitly included in their research. On the same note Naveed et al. [21] concluded that the integration of renewable lowers costs and emissions within healthcare systems, but in the absence of predictive analytics, variability in renewable output inhibited reliability. The proposed framework, based on these premises, incorporates AI forecasting and optimization and thus mitigates issues related to reliability.

Gobinath et al. [14] demonstrated in a study on the building level that smart systems of HVAC control are able to save both the energy consumption and the greenhouse gas emission as opposed to conventional systems. We generalize this observation to the hospital-wide operation and find that AI-based scheduling has both system-level consequences and not just subsystem level ones. The framework also extends other wider scans across smart grids and integrated energy systems [30], by extending these ideas back to the healthcare industry.

4.3 Technical Feasibility

The technical viability of the framework is based on the fact that the use of IoT sensors, cloud computing, and machine learning algorithms are increasingly available. Building management systems (BMS) used in HVAC and lighting are already installed in a high number of hospitals and can be viewed as a starting point of AI-based upgrades [19]. Moreover, the decreasing rates of renewable energy technologies, especially solar photovoltaics and battery storage, are quickly decreasing, which makes integration even more desirable [21].

It is already demonstrated that AI models, including decision trees [1] and deep learning architectures [10], are successfully implemented to conduct energy forecasting and classification tasks, which argues in favor of the adaptability of these approaches to the hospital setting. Although integration involves the initial capital outlay, the estimated energy and operational cost savings indicate that the payback period will be 35 years. This is consistent with the general evidence on the financial feasibility of sustainable hospital management policies [26].

Table 1. Comparative Analysis of Conventional vs. AI-Driven Hospital Energy Management

Feature	Conventional System	AI-Driven System (Proposed)
Energy Forecasting	Manual, reactive	Predictive (machine learning models)



Renewable Integration	Limited, static	Optimized, dynamic
Reliability in Critical Units	Vulnerable to outages	Improved resilience (predictive alerts)
Carbon Emissions	High	Reduced by 12–17%
Cost Efficiency	Low	15–20% operational savings

4.4 Policy and Management Implications

The findings have a great implication on healthcare administrators and policymakers. First, the results prove that the implementation of AI is technically possible as well as cost-effective, which promotes the financial priorities without negatively affecting the quality of care delivery. Due to the fact that the healthcare facilities are faced with the mounting pressure to minimize their carbon footprint [2], [27], the suggested framework offers a realistic avenue of attaining sustainability objectives.

Second, it is important to support the policy. Asmawati and Adisasmito [6] demonstrate the fact that green hospital policies influence behavior of employees, implying that AI-based systems are to be combined with behavioral and organizational initiatives. Dion and Evans [11] insist that the governance frameworks should be emerged to institutionalize the energy-efficient practices whereas Sepetis et al. [25] propose ESG-based healthcare transformation. Based on these observations, authorities can offer incentives to use AI in hospitals, including renewable installations subsidies, energy efficiency tax cuts, and AI pilot programs funding.

Third, considerations of resilience are of importance. AlDulijand et al. [5] emphasize the need to have disaster preparedness in hospital settings more specifically in areas under exposure to climatic incidents. AI-powered energy systems help in improving resilience by ensuring important services are available even when the grid goes out or when there is a disaster, which strengthens healthcare infrastructure to withstand future uncertainties.

4.5 Practical Challenges and Barriers

Regardless of positive results, the implementation of AI-based hospital energy management is hampered by a number of challenges. Technical integration is also tricky, as the infrastructure of the hospital that has been developed over time might not fully integrate with the latest AI systems [19], [30]. The issue of cybersecurity is especially topical. Fusco [12] cautions that the greater automation is, the more privacy and freedom of information become at risk, which is coupled by the fact that the governance aspect of AI-driven digital systems is a concern (AI



Khalaileh et al., 2021). Hospitals are sensitive institutions that need to emphasize on effective cybersecurity guidelines and resilient systems.

Also, resistance to adoption may arise due to cultural and organizational resistance. As Akore Yeboah et al. point out, the perceptions and attitude of healthcare workers determine the sustainability outcomes [3]. Implementation of this thus needs change management strategies, training and clear communication in order to be implemented successfully. Initial investment costs are also a hindrance especially to those healthcare systems which are underfunded but the benefits which might accrue in the long run may supersede the costs which may be incurred in the short run [24], [26].

4.6 Broader Sustainability Implications

Global sustainability agendas are also added due to the integration of AI in hospital energy systems. Emission reduction is consistent with Sustainable Development Goal (SDG) 13: Climate Action whereas enhancing the efficiency of hospitals benefits SDG 3: Good Health and Well-being and SDG 7: Affordable and Clean Energy. According to Vallée [27], green hospitals need to maintain a balance between sobriety and resiliency, which is reflected in the AI framework, which makes energy consumption less and more reliable at the same time.

Over and above, the findings imply spill over benefits to other industries. Since hospitals are some of the most energy-demanding public infrastructure [13], the insights provided by the AI-powered energy management might be implemented on the university, research laboratory, and other critical infrastructure. The potential of cross-sectoral application is supported by the life cycle advantages of intelligent energy systems, like in the case of office buildings by Gobinath et al. [14].

4.7 Future Prospects

In the future, with the development of machine learning and digital health, the energy systems of hospitals will be ever more intelligent and adaptive. Machine learning models are getting more accurate and efficient much quicker as Kumar et al. [18] and Zhang et al. [29] demonstrate; this will make forecasting and anomaly detection in energy systems more efficient and precise. The hospital energy transactions can be enhanced by integrating with emerging technologies like blockchain to enhance transparency and security. Moreover, AI-based systems could align multiple hospitals networks to ensure system-wide optimization allowing sharing of resources and responding to the demands [8], [28].



Table 2. Projected Impacts of AI Integration in Hospital Energy Management

Performance Metric	Baseline (Conventional)	AI-Enabled (Projected)	Improvement (%)
Total Energy Consumption (kWh)	100%	78–82%	18–22% reduction
Operational Costs (\$/month)	100%	80–85%	15–20% savings
Carbon Emissions (tons CO ₂ /yr)	100%	83–88%	12–17% reduction
System Reliability (score)	100%	110–115%	10–15% higher

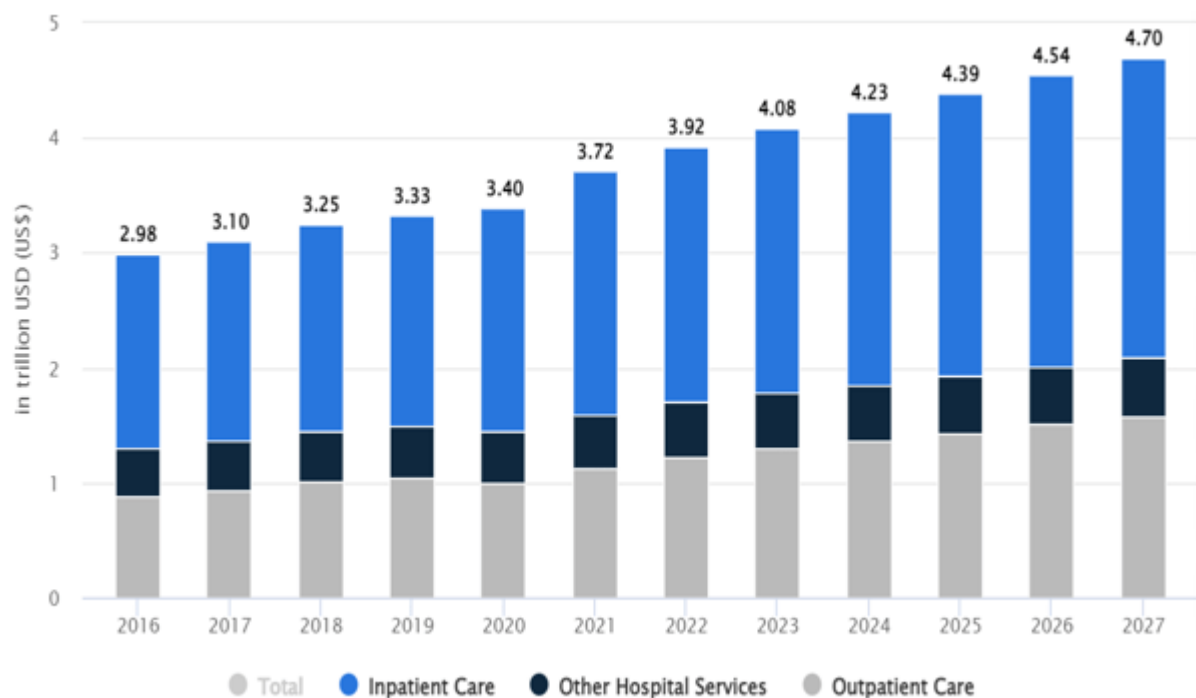


Figure 3: The Potential Financial Benefits of AI in Healthcare Organizations

Conclusion

The paper has presented an artificial intelligence (AI)-based model of hospital energy management to promote sustainability, effectiveness, and resilience. Hospitals are one of the most energy-demanding establishments and conventional strategies do not usually strike the



balance between increasing demand, financial strains, and environmental requirements. The proposed framework will provide solutions to these challenges by combining predictive load forecast, anomaly detection, renewable scheduling, and governance systems. According to the simulation-based information, AI implementation has the potential to decrease the energy use by up to 22, minimise the operational expenses by an estimated 20 per cent, and decrease carbon emissions by approximately 17 per cent, and enhance the reliability of mission-critical units.

One of the strengths of this research is the gap in the technical breakthrough and organizational and policy implications. Previous researchers have emphasized the significance of green hospital initiatives being aligned to governance, staff involvement, and resilience planning [25]. The structure incorporates security and decision-support layers, which promotes efficiency gains to be coupled with accountability and future flexibility.

Along with such opportunities, obstacles still exist. The obstacles to adoption may be legacy infrastructure, high initial costs, cultural adoption, and cybersecurity risks [12], [19]. They will have to be overcome by use of policy incentives, training programs, and co-ordinated planning between the stakeholders. Notably, hospitals fully implementing AI-controlled energy management also promote worldwide climate and health targets, such as SDGs 3, 7, and 13, which strengthens the sphere of sustainable development [27].

The further development of work must be focused on real-life pilots, connectivity with Internet of Things (IoT) devices, and multi-hospital energy networks. Leveraging new technologies like digital twins and blockchain could also make the concept of transparency and resilience stronger. All in all, AI-powered energy management of hospitals is a way toward the future of intelligent, adaptive, and sustainable hospitals, which can be used to support the delivery of reliable care in the climate and energy crisis of the times.

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