Artificial Intelligence and Energy Efficiency in Smart Buildings

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Abstract

This study provides an analysis of papers related to Home Energy Management (HEM) methodology and its potential for optimizing energy consumption in IoT-enabled smart homes. Innovative solutions such as machine learning algorithms, thermal imaging, and IoT sensors are discussed as strategies to improve energy efficiency, reduce waste, and improve security. The importance of sustainable energy systems and cloud-based infrastructures is emphasized, and the need for further development is discussed. The potential of these technologies to reduce carbon emissions and improve energy efficiency while maintaining user comfort levels is highlighted.

Keywords

Artificial intelligence, Energy, IoT, Smart buildings

1. Introduction

The technology known as Artificial Intelligence is transforming many aspects of our lives at an unparalleled rate, including the way we interact with the world, work, and live. One area where this technology is having a significant impact is in the energy sector. As we move towards more sustainable energy sources and seek to improve energy efficiency, this technology is playing a crucial role in making this transition possible. Its ability to analyze vast amounts of data and provide insights and predictions is enabling AI algorithms to optimize energy usage, reduce waste, and increase the use of renewable energy sources [6]. From smart energy grids to predictive maintenance of energy systems. It is revolutionizing the way we generate, distribute, and consume energy.

In today's era of climate change and sustainability, the intersection of AI and energy has never been more important. The integration of this technology with the Industrial Internet of Things (IoT) has resulted in significant advancements in smart buildings, showcasing the potential of IoT when combined with AI. The research will analyze the risks and challenges associated with using IoT devices in smart buildings, as well as the opportunities they present. By doing so, this study seeks to contribute to a better understanding of the potential of IoT and AI in improving energy efficiency and sustainability in smart buildings.

2. Methodology

Our study adhered to the Prisma Checklist [21] and involved querying four databases –

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IEEEXplore [17], ACM Digital Library [18], ScienceDirect [20], and SpringerLink [19] to gather information on the intersection of Artificial Intelligence and Energy, limited to conference papers published in the past 5 years. This initial search yielded a vast number of articles: 20,155 results in IEEE, 68,317 results in ACM Digital Library, 3,224 results in SpringerLink, and 41,509 results in ScienceDirect. After a careful examination of a few of the research titles, we identified a paper titled "Energy Efficiency in Smart Buildings: IoT Approaches" that drew our attention and prompted us to expand our search criteria by adding the keywords "IoT" and "smart buildings". This led to changes in the number of results retrieved from each database: 46 results in IEEE, 67 in ACM Digital Library, 125 in SpringerLink, and 663 in ScienceDirect, as shown in Figure 1.

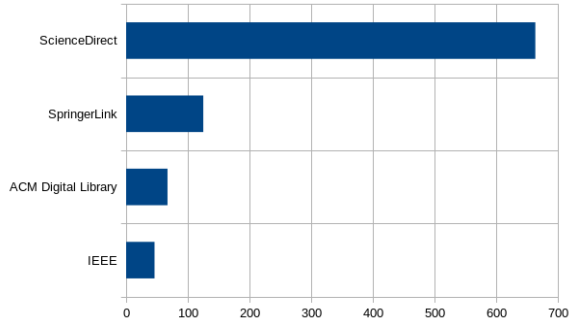

Figure 1. Results of the query search in libraries

From these papers, by performing a first pass and then re-analyzing them, we selected 33 papers that piqued our interest for closer inspection. After a thorough review and reading the papers, we selected and analyzed 16 papers that best met our inclusion criteria in terms of their content quality and relevance to the intersection of Artificial Intelligence, IoT, and energy efficiency in smart buildings.

3. State of the art

The Home Energy Management (HEM) methodology offers a new approach to managing energy consumption in IoT-enabled smart homes [1]. In addition to traditional methods used in energy fields, the HEM methodology aims at optimizing the scheduling of home appliances and improving energy exchange [3].

As we strive towards a future with renewable energy and Artificial Intelligence, researchers have proposed new ways to optimize energy systems with sophisticated machine learning algorithms and cloud-based infrastructures [4]. One such proposed system is the SETS system, which aims to enhance security for IoT-based smart homes by detecting energy theft activities with an accuracy of 99.96% using machine learning and statistical models [2]. However, to truly optimize energy usage, we need to consider the intersection of software development and hardware creation. For example, an IoT device was developed to reduce electricity waste, resulting in lower consumption during a pilot project, and optimized electricity graphs were displayed through a web interface [5]. In addition, researchers have proposed using thermal imaging with a specific camera and an Android Smartphone to identify insulation issues in buildings with an accuracy of 75% [6]. Real-time monitoring of building structures can also be achieved using cost-effective resistance sensors implanted during construction to measure moisture content [7].

Moreover, building occupants' behavior can impact energy efficiency. Therefore, a model using 5 or 8 sensors that collect data every 15 or 20 minutes has been developed to predict occupancy patterns with 90% accuracy [8]. In the event of a fire outbreak, a smart IoT system with various components can swiftly predict, monitor, and respond by activating alarms, sprinklers, and air exchange systems and notifying relevant personnel in real-time [9].

By utilizing these innovative technologies, we can work towards a more sustainable future while ensuring the security and efficiency of our energy systems. As we continue to rely more heavily on IoT devices, the energy consumption of smart buildings continues to increase, leading to toxic pollution from electronic waste [11]. Inefficient energy management in buildings can also contribute to a significant amount of global carbon emissions, accounting for around 30% of these emissions [12]. To address these challenges, researchers have proposed various innovative solutions. For example, a framework incorporating an algorithm to balance energy consumption and CO2 emissions was developed, reducing emissions by 45-59% while maintaining user comfort levels within a 3% reduction [14]. Another study addressed the challenge of energy optimization in building management with a transfer learning scheme that utilizes a deep

learning model trained on the ImageNet dataset to count people in a room, allowing for more efficient energy usage [13]. Additionally, an edge-based IoT system was proposed to minimize the daily energy costs of in-home appliances by using a reinforcement learning algorithm, which assists in making appropriate decisions for load scheduling [15]. Furthermore, comparing various machine learning algorithms resulted in a higher average accuracy of 0.97% and a performance of 0.058% in predicting indoor temperature in smart buildings [16]. We can see from Table 1, all analyzed papers and their characteristics.

Table 1. Characteristics of analyzed papers

References	Characteristic	Description
[1], [16]	AI and ML	Intelligent machines transforming fields, but with ethical concerns.
[2], [11]	Renewable energy	Eco-friendly climate solution
[3], [5], [14]	Energy efficient	Saving energy, money, and the planet
[6], [8], [13]	IoT system	Connected objects, transform but raise privacy/security concerns
[7], [9], [10]	Smart Buildings/ Environments	Thermal Imaging, sensor selection, fire safety, smart solution
[15], [16]	Energy management	Optimizing energy usage to reduce costs and environmental impact

4. Conclusion

While the existing energy management systems are inefficient in their task, Artificial Intelligence has significant potential to optimize energy usage and improve sustainability in IoT-enabled smart buildings. Some highlights of this potential include machine learning optimization algorithms, thermal imaging, IoT sensors, and other strategies to enhance energy efficiency, reduce waste, and improve security. The importance of further development in sustainable energy systems and cloud-based energy infrastructures cannot be overstated. These innovative solutions offer a promising outlook for the future of energy optimization in smart buildings, with the potential to reduce carbon emissions and improve energy efficiency while ensuring that user comfort levels are maintained. As it is crucial to continue exploring the implementation of these technologies, a more thorough literature review will be conducted in the future.

5. References

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