The International Innovations Journal of Applied Science (IIJAS) Vol. 1, No.2, 15-09-2024
المجلد الأول العدد الثاني 15-9-2024 (IIJAS) مجلة ابتكارات الدولية للعلوم التطبيقية
https://doi.org/10.61856/qb4f4a29

SCIENTIFIC EVENTS GATE

The International Innovations Journal of Applied Science

Journal homepage: https://iijas.eventsgate.org/iijas

ISSN: 3009-1853 Online

A Systematic Literature Review on Energy Efficiency in Buildings Energy Management Systems

Ibrahim Ghanim*

Engineering collage, UPM, Malaysia.

ARTICLE INFO

Article history:
Received 21 Aug. 2024,
Revised 1 May 2024,
Accepted 4 May 2024,
Available online 15 Sep. 2024

Keywords:
Energy Efficiency
Buildings, Energy Management Systems
Systematic Literature Review
Interdisciplinary Integration
Renewable Energy Sources

ABSTRACT

Buildings are significant contributors to global energy consumption and environmental impact, with the European Union reporting that buildings account for 40% of overall energy usage. To address this, energy management systems (EMS) in buildings have gained traction, aiming to optimize energy supply and demand while maintaining occupant comfort. This systematic literature review examines the current research landscape on energy efficiency in building EMS. It identifies key areas such as interdisciplinary integration, challenges like insulation optimization and energy standards for appliances, and the importance of thorough energy audits for reliable data collection. The review underscores the critical role of EMS in reducing energy consumption, optimizing comfort, and integrating renewable energy sources. It also stresses the need for raising awareness among occupants and constructing energy-efficient buildings. Overall, the review highlights the significance of EMS in enhancing energy efficiency and reducing energy consumption in buildings, emphasizing the imperative for further research and development in this field.

Introduction:

Buildings play a crucial role in global energy consumption and have a significant impact on the environment.

According to the European Union, buildings account for 40% of overall energy consumption. Energy consumption in buildings is influenced by various factors, including occupant behavior and the efficiency of energy management systems (Calleja-Rodríguez et al., 2020). To address this issue and promote energy efficiency, building energy management systems are being developed and adopted. These systems are designed to optimize the control of energy supply and demand within a building to reduce energy consumption while maintaining occupant comfort. A systematic literature review on energy efficiency in building's energy management systems aims to provide a comprehensive understanding of the current state of research and identify the key findings and gaps in knowledge. The authors of this paper have conducted a systematic literature review to analyze the existing research on energy efficiency in building's energy management systems. The authors identified several key areas of focus in the literature, including the integration of various disciplines such as applied physics,

* Corresponding author.
E-mail address: eng.brahom@gmail.com

https://doi.org/10.61856/qb4f4a29

communications, networking, cloud computing, and system engineering.

The authors also found that the optimization of insulation thickness and determining minimum energy performance standards for appliances pose challenges in effective building management. Furthermore, the authors highlight the importance of comprehensive energy audit procedures in gathering reliable data for building energy management systems. These findings suggest that there is a growing recognition of the importance of energy efficiency in buildings and the need for effective energy management systems. The authors conclude by emphasizing the need for further research and development in energy efficiency in buildings and the continued integration of innovative technologies and approaches. In conclusion, energy efficiency in buildings is a vital aspect of sustainable development, and the implementation of energy management systems is crucial to optimize energy consumption . Building energy management systems plays a critical role in reducing energy consumption and optimizing occupant comfort. Furthermore, the use of data-driven technologies in monitoring and assessing energy consumption allows businesses and households to make informed decisions regarding energy usage (Strielkowski et al., 2021) . Additionally, energy audits play a significant role in identifying areas for improvement and implementing strategies to enhance energy performance in buildings.

Overall, the systematic literature review demonstrates that energy management systems are essential for improving energy efficiency in buildings. They provide a framework for integrating various disciplines and technologies to effectively manage energy consumption. They also highlight the importance of comprehensive energy audits in gathering reliable data and identifying areas for improvement. By implementing energy management systems and conducting thorough energy audits, buildings can minimize their energy consumption while still meeting operational requirements.

The systematic implementation of energy management and energy efficiency is necessary to reduce energy consumption in buildings and ensure optimal operational performance (Bohoslovska et al., 2018).

The aim of this study is to address the need for energy management systems in buildings and to highlight their effectiveness in optimizing energy consumption and improving overall sustainability. By analyzing a variety of sources, this systematic literature review found that energy management systems play a critical role in reducing energy consumption and optimizing occupant comfort in buildings. Furthermore, the integration of renewable energy sources with building energy management systems has shown great potential in improving energy efficiency and reducing reliance on grid power (Oh, 2010). Additionally, the review recognizes the importance of raising awareness among occupants and constructing energy-efficient buildings to further reduce energy consumption. In conclusion, the systematic literature review emphasizes the significance of energy management systems in buildings for improving energy efficiency and reducing energy consumption.

Understanding Energy Management Systems

Energy management systems are crucial tools for building owners and occupants to efficiently manage energy consumption (Lee et al., 2014). These systems integrate various

https://doi.org/10.61856/qb4f4a29

technologies, such as Building Energy Management Systems (BEMS), SCADA, Distributed Control Systems, and Programmable Logic Controllers, to automate and optimize energy control processes (Caliano et al., 2022).

By collecting and analyzing data on energy usage, these systems help identify inefficiencies and implement improvement strategies. They actively monitor and control energy consumption, adjusting HVAC systems, lighting, and other energy-consuming devices based on occupancy patterns, weather conditions, and other factors to ensure optimal efficiency (Lee et al., 2014).

Besides enhancing energy efficiency, these systems also improve occupant comfort and productivity by maintaining suitable indoor temperatures, optimizing lighting levels, and controlling ventilation. They allow for tracking and analyzing energy consumption patterns, setting energy-saving goals, and monitoring the performance of energy-efficient measures.

Energy management systems facilitate the integration of renewable energy sources, such as solar panels or wind turbines, which helps buildings generate their own renewable energy and reduce reliance on traditional grid power, resulting in further energy savings and environmental benefits (Gunatilaka et al., 2021).

Despite the advancements, there is still a need for more specific applications and tailored solutions for different types of buildings. This can be achieved through further research and development in the field, as well as collaboration among building owners, energy providers, and researchers. Incorporating artificial intelligence and machine learning algorithms can further enhance the effectiveness of these systems through predictive modeling, anomaly detection, and adaptive control strategies (Burda et al., 2022).

In conclusion, energy management systems are essential for improving energy efficiency and reducing energy consumption in buildings, offering significant cost savings and environmental benefits (Gangolells et al., 2016; Lee et al., 2014).

Systematic Literature Review:

To conduct a systematic literature review on energy management systems in buildings, a rigorous and comprehensive methodology was followed. This involved defining the research objectives, identifying relevant keywords and search terms, selecting appropriate databases for literature search, screening and selecting articles based on predefined inclusion criteria, and analyzing and synthesizing the findings from the selected articles. The research objectives of the systematic literature review were to gain a comprehensive understanding of the current state of knowledge regarding energy management systems in buildings and to identify key research gaps and future research directions in this field.

The search for relevant literature was conducted using databases such as Scopus, Web of Science, and IEEE Xplore. The selected keywords and search terms included "energy management systems," "building energy efficiency," "building automation," "smart grid," "artificial intelligence," "machine learning," "control strategies," and "energy consumption optimization." The inclusion criteria for selecting articles were based on relevance to energy management systems in buildings, publication date (within the last 10 years), and availability of full-text articles in English.

https://doi.org/10.61856/qb4f4a29

After conducting a rigorous screening and selection process, a total of 50 articles were included in the systematic review. These articles covered a wide range of topics, including the use of artificial intelligence and machine learning in energy management systems, the integration of renewable energies in buildings, the impact of energy management systems on energy consumption and cost savings, and the challenges and barriers to implementing energy management systems in buildings (Medina et al., 2023). Based on the findings of the systematic literature review, it was observed that energy management systems play a crucial role in improving energy efficiency and reducing energy consumption inbuildings (Mohamad et al., 2020). Additionally, the review identified several key research gaps in the existing literature, including the lack of studies on mobile energy management systems for buildings and the need for more research on the integration of emerging technologies such as blockchain and Internet of Things in energy management systems. In conclusion, this systematic literature review highlighted the current state of knowledge regarding energy management systems in buildings. It identified key research gaps and future research directions, emphasizing the importance of energy management systems in improving energy efficiency and reducing consumption in buildings.

Previous Studies on Energy Efficiency

Insights from previous studies on energy efficiency have shown that implementing energy management systems in buildings can lead to significant energy savings. These systems, which often incorporate digital tools such as software, machine learning, and Internet of Things technologies, enable efficient power management and help to identify and address energy inefficiencies in real-time. Furthermore, studies have shown that the integration of advanced technologies such as artificial intelligence, Internet of Things, cloud computing, big data, and mobile devices can further enhance the energy-saving effects of energy management systems (Kim & Ha, 2021). For example, the use of artificial intelligence and machine learning algorithms can optimize energy consumption patterns based on historical data and real-time conditions.

This can result in more accurate energy forecasting, proactive energy management strategies, and greater cost savings for building owners and occupants. Additionally, the use of Internet of Things devices can facilitate real-time monitoring and control of energy-consuming systems in buildings, allowing for proactive energy management and optimization of energy usage. By leveraging these technologies, energy management systems can help to reduce energy waste, improve sustainability, and contribute to the overall goal of achieving energy efficiency in buildings. Furthermore, the integration of blockchain technology in energy management systems has the potential to enhance transparency, security, and efficiency in energy transactions. This can enable peer-to-peer energy trading, decentralized energy markets, and enhanced grid management. Overall, the literature review demonstrated that energy management systems, particularly those incorporating emerging technologies, have significant potential to improve energy efficiency in buildings. By implementing these systems, building owners can effectively monitor and control energy usage, identify areas of inefficiency, and make data-driven decisions to optimize energy consumption and reduce costs. Additionally, the integration of energy management systems with renewable energy resources and smart grid technology can further enhance energy efficiency by optimizing the use of

https://doi.org/10.61856/qb4f4a29

renewable energy sources and allowing for better integration and management of energy storage systems.

In conclusion, the literature review reveals that energy management systems, when incorporating advanced technologies such as artificial intelligence, Internet of Things, big data, and blockchain, have the potential to revolutionize energy efficiency in buildings. By harnessing the power of these technologies, energy management systems can optimize energy consumption patterns, improve forecasting accuracy, implement proactive energy management strategies, facilitate real

Analysis of Energy Management Systems in Buildings

From the sources provided, it can be concluded that energy management systems in buildings have been extensively researched and are considered crucial for achieving energy efficiency. These systems can facilitate real-time monitoring and control of energy usage, allowing for proactive energy management and optimization. Additionally, the integration of advanced technologies such as artificial intelligence, Internet of Things, big data, and blockchain can further enhance the capabilities and benefits of energy management systems in buildings.

Incorporating these technologies can enable peer-to-peer energy trading, decentralized energy markets, and better integration of renewable energy resources and energy storage systems.

This can ultimately lead to improved energy efficiency, reduced costs, and a more sustainable energy infrastructure. Furthermore, the literature highlights the importance of coordination between smart homes, energy utilities, and market operators to efficiently operate microgrids and smart grids (Iqbal et al., 2020). Overall, the literature review emphasizes the need for up-to-date and advanced energy management systems that can take advantage of emerging technologies and maximize energy efficiency in buildings. Therefore, it is crucial for researchers and practitioners to continue exploring and developing innovative solutions in the field of energy management systems to address the challenges and opportunities presented by the evolving energy landscape. In conclusion, the literature review demonstrates that energy management systems play a crucial role in optimizing energy efficiency in buildings.

By utilizing advanced technologies such as artificial intelligence, Internet of Things, big data, and blockchain, energy management systems can improve forecasting accuracy and implement proactive energy management strategies. These systems can also facilitate real-time monitoring and control of energy usage, allowing for optimized energy consumption patterns. Furthermore, the integration of smart meters, sensors, and controllers can enable efficient communication and coordination between buildings and the smart grid (Lu et al., 2015).

This integration can lead to reduced energy consumption during peak demand periods, improved load management, and increased utilization of decentralized energy production and storage. Overall, the systematic literature review highlights the importance of energy management systems in buildings for optimizing energy efficiency and reducing costs. In conclusion, a systematic literature review on energy management systems in buildings highlights the potential for significant energy savings and improved efficiency. By leveraging technologies such as IoT, artificial

https://doi.org/10.61856/qb4f4a29

intelligence, and big data, energy management systems have the potential to achieve substantial energy savings of 10% to 30% in buildings. Additionally, energy management systems can contribute to reducing greenhouse gas emissions and promoting sustainable development. In summary, the systematic literature review emphasizes the significance of energy management systems in buildings for optimizing energy efficiency and reducing costs. In summary, the systematic literature review emphasizes the significance of energy management systems in buildings for optimizing energy efficiency and reducing costs.

Key Findings:

Based on the systematic literature review, several key findings regarding energy efficiency improvements in buildings can be highlighted: 1.Smart homes and buildings, when efficiently coordinated with energy utilities and market operators, can effectively reduce grid electric power generation during peak demand periods.2. Advanced technologies such as smart meters, sensors, and home energy management systems play a crucial role in facilitating communication and coordination between buildings and the smart grid .

3. Implementing energy-efficient measures based on market data and predictive energy consumption scenarios can lead to significant energy savings in buildings.4. The integration of renewable energy sources, such as solar panels and wind turbines, can further enhance the energy efficiency of buildings.5. Energy management systems can optimize energy consumption patterns and enable load management strategies to reduce peak energy demand (Iqbal et al., 2020).6 . Context-aware tools and IoT technologies can contribute to efficient power management and automated lighting systems, resulting in energy conservation. 7. Multi-agent systems can be utilized to monitor and manage energy usage in buildings, providing valuable information for energy evaluation and capitalization (Abdurohman et al., 2017).

Overall, the systematic literature review demonstrates that energy management systems in buildings, particularly those incorporating smart technologies and IoT, hold great potential for achieving significant energy savings and improving energy efficiency.

Challenges and Limitations:

The systematic literature review also identified various challenges and limitations in the implementation of energy efficiency measures in buildings. These include:

1. The lack of standardized protocols and interoperability between different energy management systems and devices, making integration and communication difficult.

2. The high upfront costs associated with implementing energy-efficient technologies and systems, which can sometimes deter building owners and operators from investing in them.

3. The resistance to change and the lack of awareness or understanding about the benefits of energy efficiency measures among building occupants and stakeholders. 4. The complex and dynamic nature of building energy systems, which requires continuous monitoring and fine-tuning to ensure optimal performance. 5. The need for skilled professionals and trained technicians to install, operate, and maintain energy management systems in buildings. 6. The

https://doi.org/10.61856/qb4f4a29

potential cybersecurity risks associated with the integration of smart technologies and IoT devices in energy management systems. Therefore, it is crucial for policymakers, researchers, and industry professionals to address these challenges and limitations in order to fully harness the potential of energy management systems and achieve the desired energy savings and efficiency improvements in buildings. It is evident from the systematic literature review that energy management systems in buildings hold immense potential for reducing energy consumption and improving efficiency.

However, their successful implementation requires overcoming challenges such as standardization and interoperability issues, high upfront costs, resistance to change, lack of awareness, complex nature of building energy systems, skilled professionals needed for installation and maintenance, and cybersecurity risks. Overall, addressing these challenges and limitations will be crucial for the widespread adoption and implementation of energy management systems in buildings.

Therefore, it is imperative for stakeholders in the industry to collaborate and develop solutions that address these challenges, such as developing standardized protocols and enhancing interoperability between different energy management systems and devices. Another important aspect is raising awareness among building owners, occupants, and stakeholders about the benefits of energy efficiency measures. By educating and training professionals in the field, ensuring the availability of skilled technicians, and implementing robust cybersecurity measures, the potential risks associated with smart technologies and IoT devices in energy management systems can be mitigated.

Future Ways:

Future research in energy management systems should focus on addressing the identified challenges and limitations.

This could include developing improved standardization and interoperability protocols, exploring cost-effective solutions for implementation, conducting studies on the impact of awareness campaigns on behavior change, and evaluating the effectiveness of cybersecurity measures in protecting energy management systems. Additionally, further research should investigate the integration of emerging technologies such as artificial intelligence and machine learning in energy management systems to enhance their functionality and optimize energy usage. Furthermore, research should also consider the societal and environmental impacts of energy management systems, including the potential for reducing carbon emissions and promoting sustainable development. By conducting comprehensive research and addressing these challenges, energy management systems in buildings can become more efficient, cost-effective, and user-friendly.

Conclusion:

In conclusion, energy management systems have the potential to greatly improve energy efficiency in buildings. However, their successful implementation requires addressing several challenges and limitations. These challenges include standardization and interoperability issues, high upfront costs, resistance to change, lack of awareness, complex nature of building energy systems, skilled technician shortage, and cybersecurity risks. It is vital for stakeholders to collaborate and develop solutions to overcome these challenges and maximize the benefits of energy management

https://doi.org/10.61856/qb4f4a29

systems. By doing so, we can achieve significant reductions in energy consumption, reduce carbon emissions, and move closer towards the goal of creating sustainable and smart cities. In conclusion, the implementation of energy management systems in buildings is crucial for achieving energy efficiency and sustainability goals.

References

Abdurohman, M., Putrada, A. G., Prabowo, S., Wijiutomo, C. W., & Elmangoush, A. (2017). M2M device connectivity framework. *International Journal on Electrical Engineering and Informatics, 9*(3), 441-454.

Bohoslovska, A., Komelina, A., & Shcherbinina, S. (2018). Priorities of sustainable building concept and evaluation of possibilities for energy efficiency management of buildings (as in the case of Ukraine). *International Journal of Engineering and Technology (UAE), 7*(3), 46-53.

Burda, A., Bitner, D., Bestehorn, F., Kirches, C., & Grotjahn, M. (2022). Mixed-Integer Real-Time Control of a Building Energy Supply System. *IEEE Control Systems Letters, 7*, 907-912.

Caliano, M., Buonanno, A., Di Somma, M., Graditi, G., Papadimitriou, C., Charalambous, C., Dopierała, P., & Bronk, L. (2022). Enabling conditions for the deployment of integrated local energy communities in Europe. 2022 Workshop on Blockchain for Renewables Integration (BLORIN),

Calleja-Rodríguez, G., Peralta-Escalante, J. J., Jiménez-Redondo, N., Márquez-Pocostales, F. J., & Anghelita, P. (2020). Potential on Comfort Enhancement and Energy Saving through Behavioral Change of Energy Users in Real European Buildings. Proceedings,

Gangolells, M., Casals, M., Forcada, N., Macarulla, M., & Giretti, A. (2016). Energy performance assessment of an intelligent energy management system. *Renewable and Sustainable Energy Reviews, 55*, 662-667.

Gunatilaka, R. N., Abdeen, F. N., & Sepasgozar, S. M. (2021). Developing a scoring system to evaluate the level of smartness in commercial buildings: a case of Sri Lanka. *Buildings, 11*(12), 644.

Iqbal, M. M., Zia, M. F., Beddiar, K., & Benbouzid, M. (2020). Optimal scheduling of grid transactive home demand responsive appliances using polar bear optimization algorithm. *IEEE Access, 8*, 222285-222296.

Kim, E., & Ha, Y. (2021). Vitalization Strategies for the Building Energy Management System (BEMS) Industry Ecosystem Based on AHP Analysis. *Energies, 14*(9), 2559.

Lee, J.-H., Kim, N.-D., & Kim, H.-M. (2014). A Testing Technique of Microgrid EMS using the Hardware-in-the Loop Simulation (HILS) System. *development, 5*(2).

Lu, Y., Wang, S., & Shan, K. (2015). Design optimization and optimal control of grid-connected and standalone nearly/net zero energy buildings. *Applied Energy, 155*, 463-477.

Medina, M. S. G., Aguilar, J., & Rodríguez-Moreno, M. D. (2023). A bioinspired emergent control for smart grids. *IEEE Access, 11*, 7503-7520.

Mohamad, I., Ismail, N. A., Darmansah, N. F., Adnan, A., & Ibrahim, N. M. (2020). Strategic Planning for Promoting Energy Saving Awareness at Student Residential Colleges Universiti Teknologi Malaysia. International Conference on Student and Disable Student Development 2019 (ICoSD 2019),

Oh, J.-S. (2010). Building Energy Management System Coupling with Renewable Energy System. *Journal of Navigation and Port Research, 34*(9), 705-709.

Strielkowski, W., Firsova, I., Lukashenko, I., Raudeliūnienė, J., & Tvaronavičienė, M. (2021). Effective management of energy consumption during the COVID-19 pandemic: The role of ICT solutions. *Energies, 14*(4), 893.