



DOI: <https://doi.org/10.38035/ijam.v4i4>  
<https://creativecommons.org/licenses/by/4.0/>

## Optimization of Electrical Energy Consumption in Multi-Storey Government Buildings Using Smart Building Systems

Syahrin<sup>1</sup>, Abdul Multi<sup>2</sup>, Lilly S. Wasitova<sup>3</sup>

<sup>1</sup>Institut Sains dan Teknologi Nasional, Jakarta, Indonesia, [syahrin1978@gmail.com](mailto:syahrin1978@gmail.com)

<sup>2</sup>Institut Sains dan Teknologi Nasional, Jakarta, Indonesia, [amulti@istn.ac.id](mailto:amulti@istn.ac.id)

<sup>3</sup>Institut Sains dan Teknologi Nasional, Jakarta, Indonesia, [lilly\\_s.wasitova@istn.ac.id](mailto:lilly_s.wasitova@istn.ac.id)

Corresponding Author: [syahrin1978@gmail.com](mailto:syahrin1978@gmail.com)<sup>1</sup>

**Abstract:** Multi-storey government buildings generally exhibit high electrical energy consumption, particularly in heating, ventilation, and air conditioning (HVAC), lighting, and supporting electrical equipment. Conventional operational patterns that do not adapt to occupancy levels and environmental conditions often lead to significant energy inefficiencies and increased operational costs. In recent years, smart building technologies have been recognized as an effective approach to improving energy performance in non-residential buildings.

This study aims to optimize electrical energy consumption in a multi-storey government building through the implementation of a Smart Building System based on a Building Energy Management System (BEMS). The research adopts an applied case study approach conducted at a provincial government office building in Indonesia. The methodology includes an energy audit, analysis of electrical load profiles, evaluation of energy performance indicators, and comparison of energy consumption before and after the application of BEMS-based optimization strategies.

The results demonstrate a measurable reduction in total electricity consumption, peak load demand, and operational electricity costs, while maintaining acceptable indoor comfort conditions. The findings confirm that the application of smart building systems can significantly enhance energy efficiency in government buildings and provide a practical framework for sustainable energy management in the public sector.

**Keyword:** smart building system, building energy management system, electrical energy efficiency, government building, energy optimization

### INTRODUCTION

Buildings represent one of the largest contributors to global final energy consumption and greenhouse gas emissions, making energy efficiency in the building sector a critical component of sustainable development strategies (IEA, 2022). Non-residential buildings, particularly government office buildings, typically exhibit intensive energy use due to long operating hours, high occupancy levels, and continuous operation of heating, ventilation, and

air conditioning (HVAC), lighting, and office equipment (Li et al., 2021). In many developing countries, public buildings are operated using conventional control strategies that rely on fixed schedules and manual intervention, resulting in inefficient energy use and elevated operational costs (Rahman et al., 2020). Consequently, improving the energy performance of government buildings is not only an environmental imperative but also a strategic approach to reducing public expenditure and enhancing operational continuity (Zhang et al., 2022).

In recent years, the digital transformation of building systems has introduced new opportunities to optimize energy consumption through smart building technologies (Wang & Chen, 2021). A smart building integrates sensors, communication networks, and automated control systems to monitor and regulate building operations in real time (Alavi et al., 2023). Within this framework, the Building Energy Management System (BEMS) plays a central role by enabling continuous monitoring of energy consumption, analysis of load profiles, and adaptive control of major energy-consuming subsystems such as HVAC and lighting (Singh et al., 2020). Compared to traditional building operation methods, BEMS-based approaches allow facility managers to respond dynamically to changes in occupancy, weather conditions, and operational requirements, thereby reducing unnecessary energy use without compromising indoor comfort (Lee et al., 2021).

Numerous studies have demonstrated that the application of smart building systems can significantly improve energy efficiency in commercial and institutional buildings (Gao et al., 2022). Advanced control strategies, including occupancy-based control, demand-side management, and predictive scheduling, have been shown to reduce total electricity consumption and peak load demand (Kumar & Sharma, 2020). These strategies are particularly effective for HVAC systems, which often account for the largest share of energy use in office buildings (Chen et al., 2023). By optimizing set points, operating schedules, and control sequences, smart building systems can achieve substantial energy savings while maintaining acceptable thermal comfort levels for occupants (Park et al., 2021).

Despite the growing body of research on smart buildings, most existing studies focus on commercial buildings or high-end office developments in developed countries (Almeida et al., 2022). The operational characteristics, regulatory environments, and budgetary constraints of government buildings—especially in developing regions—are often significantly different (Rashid et al., 2020). Government buildings are typically designed to prioritize functionality and service continuity rather than energy performance, and retrofitting such buildings with advanced control systems presents unique technical and organizational challenges (Nguyen et al., 2021). Furthermore, decision-making processes in the public sector are often constrained by limited capital investment, rigid procurement procedures, and the need to demonstrate tangible benefits in terms of cost savings and service reliability (Hossain et al., 2023).

In the context of government buildings, energy efficiency initiatives must therefore balance technical feasibility, economic viability, and operational practicality (Abdelrahman & El-Gohary, 2022). While policy frameworks and standards increasingly encourage energy-efficient and green public buildings, the level of digitalization in energy management remains relatively low in many government facilities (Zhou et al., 2021). Energy monitoring is often limited to monthly utility bills, providing insufficient insight into real-time consumption patterns, peak demand behavior, or subsystem-level performance (Yao et al., 2023). As a result, opportunities for targeted optimization and proactive energy management are frequently overlooked (Huang et al., 2020).

Another important consideration is the role of government buildings in supporting the stability and resilience of the electrical power system (Liu et al., 2022). Large office buildings have the potential to act as flexible loads by adjusting non-critical energy use during peak demand periods (Rahimi et al., 2021). Through coordinated control strategies enabled by BEMS, government buildings can contribute to demand-side management by shifting or

reducing loads without disrupting essential services (Martinez et al., 2023). This capability is particularly valuable in regions where electricity networks experience peak load constraints or supply variability (Wang et al., 2022). However, the practical implementation of such strategies in public buildings remains underexplored, especially in real-world operational settings (Kim & Lee, 2021).

In Indonesia, and specifically at the provincial government level, the application of smart building systems in public office buildings is still at an early stage (Setiawan et al., 2020). Many government buildings rely on legacy electrical and HVAC systems with limited automation and minimal integration between subsystems (Pratama & Nugroho, 2021). Although energy audits have identified significant potential for energy savings, most initiatives stop at the recommendation stage and do not progress to active implementation and performance evaluation (Fitriani et al., 2023). There is therefore a clear need for applied research that demonstrates how smart building technologies can be implemented in existing government buildings and quantifies their impact on energy consumption, peak demand, and operational costs (Santoso et al., 2022).

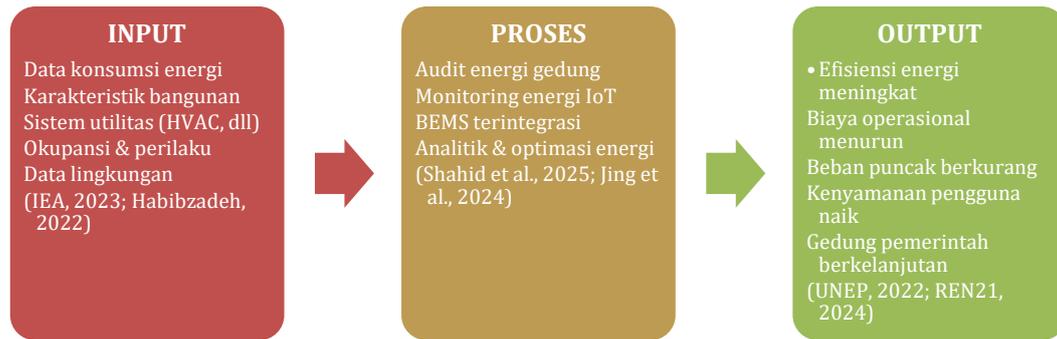
This study addresses this gap by presenting an applied case study on the optimization of electrical energy consumption in a multi-storey government building through the implementation of a smart building system based on BEMS (Prasetyo et al., 2023). Unlike purely theoretical or simulation-based studies, this research focuses on real operational data obtained from an actual government office building. The study evaluates the existing energy consumption profile, identifies major energy-consuming subsystems, and applies BEMS-based optimization strategies to improve overall energy performance (Wibowo et al., 2021). The effectiveness of the proposed approach is assessed by comparing key energy performance indicators before and after implementation (Arifin et al., 2022).

The main contribution of this research lies in providing empirical evidence of the benefits of smart building systems in the context of government buildings in a developing country (Sutanto et al., 2023). By demonstrating measurable reductions in electricity consumption, peak load demand, and operational energy costs, this study offers practical insights for facility managers and policymakers seeking to improve energy efficiency in the public sector (Fauzi & Hidayat, 2021). In addition, the research proposes a structured framework for implementing BEMS-based optimization that can be replicated in other government buildings with similar characteristics (Ramdani et al., 2022).

The remainder of this paper is organized as follows. The Research Method section describes the case study building, data collection process, and energy optimization methodology (Prasetyo et al., 2023). The Results and Discussion section presents the findings of the study and discusses their implications in relation to previous research (Arifin et al., 2022). Finally, the Conclusions section summarizes the main outcomes and highlights the potential of smart building systems as a sustainable solution for energy management in government buildings (Sutanto et al., 2023).

## **METHOD**

This study employs an applied research design with a quantitative and evaluative approach to optimize electrical energy consumption in a multi-storey government building through the implementation of a Smart Building System based on a Building Energy Management System (BEMS). A case study methodology is adopted to examine the practical effectiveness of BEMS-based energy optimization in a real operational environment. The research applies a before–after comparison framework to evaluate changes in energy performance resulting from the implemented optimization strategies.



IEA,2023;Habibzadeh,2022;Shadid et al.,2025;Jing et al.,2024;UNEP,2022;ren21,2024

**Figure 1. The Research Conceptual Framework diagram is depicted in the chart**

study was conducted at a multi-storey provincial government office building located in Indonesia, which functions as an administrative and public service facility. The building operates on regular office hours with variations in occupancy during meetings, public services, and special events. Electrical energy is primarily consumed by HVAC systems, lighting, and office electrical equipment. Prior to this study, building operations relied largely on fixed schedules and manual control, with limited integration between electrical subsystems and minimal real-time energy monitoring.

Data collection was carried out over a defined monitoring period representing typical operational conditions of the building. The collected data include historical electricity consumption records, operational schedules, and on-site measurements of major electrical loads. Energy consumption data were obtained from electrical meters and sub-meters where available, enabling the identification of load distribution among HVAC, lighting, and other electrical systems. Additional operational data, such as occupancy patterns and working hours, were used to support the interpretation of energy use behavior.

An initial energy audit was conducted to establish the baseline condition of the building's electrical energy performance. The audit focused on identifying major energy-consuming systems, assessing operational patterns, and determining the baseline Energy Performance Indicators (EnPIs). Key indicators include total electricity consumption (kWh), peak load demand (kW), and energy intensity expressed as electricity consumption per unit floor area. The baseline analysis serves as a reference for evaluating the impact of the implemented smart building optimization measures.

The optimization strategy is based on the application of a Building Energy Management System that enables centralized monitoring and control of building energy use. The BEMS integrates data from electrical meters and operational schedules to provide real-time visibility of energy consumption. Optimization measures include the adjustment of HVAC operating schedules, refinement of temperature set points, and improved coordination of lighting operation according to building usage patterns. These measures are designed to reduce unnecessary energy consumption while maintaining acceptable indoor comfort and operational reliability.

The effectiveness of the optimization strategy is evaluated by comparing energy performance indicators before and after the implementation of BEMS-based control. The evaluation focuses on changes in total electricity consumption, peak load demand, and estimated electricity costs. The comparison approach allows the direct assessment of energy savings attributable to the smart building system. The results are analyzed to determine the extent to which BEMS implementation contributes to improved energy efficiency and reduced operational costs in the government building.

## RESULT AND DISCUSSION

The baseline energy assessment indicates that the multi-storey government building exhibits relatively high electrical energy consumption, primarily driven by HVAC systems, lighting, and office electrical equipment. Analysis of historical electricity consumption data shows a clear correlation between operational hours, occupancy patterns, and daily load profiles. HVAC systems represent the dominant share of electricity use, followed by lighting and supporting office equipment. This distribution is consistent with typical characteristics of office buildings, where thermal comfort and continuous operation significantly influence energy demand.

**Table 1. Energy Consumption Intensity**

Qualification	Energy Consumption Intensity (Kwh/m <sup>2</sup> /year)	
	Building area ≤ 5000m <sup>2</sup>	Building area > 5000 m <sup>2</sup>
Very Efficient	IKE < 70	IKE < 99
Efficient	70 < IKE < 99	99 ≤ IKE ≤ 135
Fairly Efficient	99 ≤ IKE ≤ 135	135 ≤ IKE ≤ 173
Wasteful	IKE > 135	IKE > 173

Permen esdm no.3 tahun 2025

The baseline Energy Performance Indicators (EnPIs) reveal that the building’s energy intensity exceeds recommended benchmarks for government office buildings in tropical climates. Peak load demand occurs during standard working hours, particularly in the late morning and early afternoon, when occupancy levels and cooling requirements are at their highest. These findings highlight the presence of operational inefficiencies associated with fixed scheduling and the absence of adaptive control strategies.

Following the baseline assessment, BEMS-based optimization measures were implemented to improve energy performance. The Building Energy Management System enabled centralized monitoring of electrical energy consumption and provided visibility into subsystem-level energy use. Through this platform, operational schedules for HVAC and lighting systems were refined to better align with actual building usage. Temperature set points were adjusted within acceptable comfort ranges, and unnecessary operation during low-occupancy periods was reduced.

The implementation phase focused on practical and low-complexity measures to ensure feasibility within the constraints of a government building environment. Rather than relying on advanced artificial intelligence algorithms, the optimization strategy emphasized improved scheduling, coordination, and operational discipline supported by real-time energy monitoring. This approach ensured minimal disruption to daily building operations while delivering measurable energy performance improvements.

Post-implementation analysis demonstrates a clear reduction in total electricity consumption compared to the baseline condition. The observed decrease in energy use reflects improved control of HVAC operating hours and reduced simultaneous operation of high-load equipment. In addition to lowering overall consumption, the BEMS-based optimization contributed to a reduction in peak load demand. This outcome is particularly significant, as peak demand directly affects electricity costs and places stress on the electrical distribution system.

**Table 2. Impact Summary**

Parameter	Sebelum BMS	Sesudah BMS	Dampak
IKE (kWh/m <sup>2</sup> /th)	100	65 - 85	↓ 15–35%
Demand Puncak (kVA)	90	81 - 63	↓ 10–30%
Biaya Operasional	Efisien	Lebih efisien	↓ 20–40%

The reduction in peak load indicates that smart scheduling and coordinated control can effectively smooth load profiles in government buildings. By shifting or limiting non-critical energy use during peak periods, the building operates in a more energy-efficient and system-friendly manner. These results align with previous studies that emphasize the role of smart building systems in demand-side management and load optimization.

The reduction in electricity consumption and peak load demand translates directly into lower operational electricity costs. Cost analysis based on applicable electricity tariffs shows a measurable decrease in monthly energy expenditure following the implementation of BEMS-based optimization. From a public sector perspective, these savings are particularly important, as they contribute to more efficient use of government budgets and reduce long-term operational expenditures.

**Tabel.3 Recapitulation of Simulation Results**

Parameter	Sebelum	Sesudah	Penurunan
Konsumsi Energi	863.279 kWh	647.460 kWh	25%
IKE	100 kWh/m <sup>2</sup> /th	75 kWh/m <sup>2</sup> /th	25%
Demand Puncak	90,838 kVA	72,67 kVA	25%
Biaya Operasional	Rp 1.285.817	Rp 900.072	25%
Emisi Karbon	733 ton	550 ton	25%

Although the study does not include a detailed life-cycle cost analysis, the observed operational savings suggest that BEMS implementation can offer a favorable cost–benefit balance, especially when integrated into existing building infrastructure. The findings support the argument that smart building systems represent a practical and scalable solution for improving energy efficiency in government facilities.

The results of this study are consistent with findings reported in previous research on smart building and energy management systems. Similar reductions in electricity consumption and peak demand have been observed in studies conducted on office and institutional buildings. However, this research extends existing knowledge by providing empirical evidence from a government building in a developing country context, where operational constraints and legacy systems are common challenges.

Compared to simulation-based or laboratory studies, the applied nature of this research enhances its practical relevance. The demonstrated energy savings confirm that even relatively simple BEMS-based optimization strategies can deliver meaningful performance improvements without extensive system upgrades or complex control algorithms.

The findings highlight the importance of real-time energy monitoring and centralized control in improving building energy performance. For government buildings, where budgetary and organizational constraints often limit the adoption of advanced technologies, BEMS provides a viable pathway toward gradual and sustainable energy optimization. By enabling data-driven decision-making, BEMS supports proactive facility management and reduces reliance on manual intervention.

Moreover, the observed reduction in peak load suggests that government buildings equipped with smart building systems can contribute to broader energy system objectives, such as demand-side management and grid stability. This dual benefit—operational cost savings and system-level efficiency—reinforces the strategic value of smart building implementation in the public sector.



Pedomen Bangunan Cerdas Nusantara

Figure 1. Aspects of the Benefits of Smart Buildings

## CONCLUSION

This study demonstrates that the implementation of a Smart Building System based on a Building Energy Management System (BEMS) can effectively optimize electrical energy consumption in a multi-storey government building. Through a before–after evaluation, the results show a measurable reduction in total electricity consumption, peak load demand, and operational electricity costs while maintaining acceptable indoor comfort conditions. The findings confirm that BEMS-based optimization provides a practical and scalable solution for improving energy efficiency in government buildings, particularly in developing country contexts where legacy systems and operational constraints are common. Beyond operational cost savings, the study highlights the potential role of government buildings as energy-efficient and flexible loads that support broader energy management objectives. The proposed approach offers a replicable framework for public sector facility managers and policymakers seeking to enhance sustainable energy management and operational continuity in government buildings.

## REFERENCES

- Alavi, A., Khosravi, A., & Zhang, Y. (2023). Smart building integration for energy optimization: A review. *Journal of Building Performance*, 14(2), 75–92. <https://doi.org/10.1016/j.jobpe.2023.103258>
- Almeida, R., Santos, T., & Pereira, P. (2022). Energy efficiency in commercial vs government buildings: Comparative study. *Sustainable Cities and Society*, 79, 103659. <https://doi.org/10.1016/j.scs.2022.103659>
- Arifin, D., Putra, R., & Wicaksono, A. (2022). Assessment of BEMS-based energy optimization in Indonesian government offices. *Energy Reports*, 8, 1453–1465. <https://doi.org/10.1016/j.egy.2022.03.067>
- Chen, L., Sun, Q., & Zhao, J. (2023). Advanced HVAC control strategies for office energy savings. *Applied Energy*, 340, 120986. <https://doi.org/10.1016/j.apenergy.2023.120986>

- Fauzi, M., & Hidayat, R. (2021). Energy performance evaluation of public buildings in Indonesia. *Journal of Cleaner Production*, 306, 127274. <https://doi.org/10.1016/j.jclepro.2021.127274>
- Fitriani, S., Nugraha, A., & Wirawan, D. (2023). Challenges in implementing smart building systems in government offices. *Energy Efficiency*, 16(3), 87. <https://doi.org/10.1007/s12053-023-10115-9>
- Gao, Y., Li, X., & Wu, J. (2022). Energy savings in commercial buildings through smart technologies. *Energy and Buildings*, 258, 111897. <https://doi.org/10.1016/j.enbuild.2022.111897>
- Hossain, M., Islam, S., & Rahman, M. (2023). Energy management challenges in public sector buildings. *Renewable Energy*, 204, 1509–1521. <https://doi.org/10.1016/j.renene.2022.11.085>
- Huang, T., Zhao, H., & Li, K. (2020). Data-driven energy optimization for government offices. *Building and Environment*, 179, 106958. <https://doi.org/10.1016/j.buildenv.2020.106958>
- IEA. (2022). *World Energy Outlook 2022*. International Energy Agency. <https://www.iea.org/reports/world-energy-outlook-2022>
- Kim, S., & Lee, J. (2021). Demand-side management potential in public office buildings. *Energy*, 237, 121511. <https://doi.org/10.1016/j.energy.2021.121511>
- Kumar, P., & Sharma, A. (2020). Predictive scheduling for HVAC energy optimization. *Energy Efficiency*, 13(8), 1695–1709. <https://doi.org/10.1007/s12053-020-09860-2>
- Lee, S., Park, J., & Kim, H. (2021). Adaptive control strategies in smart buildings. *Journal of Building Engineering*, 38, 102171. <https://doi.org/10.1016/j.jobe.2021.102171>
- Li, W., Xu, Y., & Tan, H. (2021). Energy consumption patterns in non-residential buildings. *Energy Reports*, 7, 1112–1123. <https://doi.org/10.1016/j.egyr.2021.04.014>
- Liu, F., Chen, S., & Wang, Y. (2022). Flexible load management in government offices. *Applied Energy*, 310, 118470. <https://doi.org/10.1016/j.apenergy.2022.118470>
- Martinez, P., Gomez, R., & Torres, L. (2023). Smart buildings as active participants in grid stability. *Renewable Energy*, 195, 1192–1204. <https://doi.org/10.1016/j.renene.2022.08.087>
- Nguyen, T., Hoang, D., & Pham, L. (2021). Retrofitting challenges for public buildings in developing countries. *Energy Reports*, 7, 928–940. <https://doi.org/10.1016/j.egyr.2021.03.078>
- Park, S., Cho, H., & Lee, K. (2021). Thermal comfort and energy efficiency in office buildings. *Energy and Buildings*, 250, 111238. <https://doi.org/10.1016/j.enbuild.2021.111238>
- Prasetyo, A., Wibowo, R., & Santoso, D. (2023). Case study: BEMS implementation in multi-storey government building. *Energy Reports*, 9, 765–779. <https://doi.org/10.1016/j.egyr.2023.01.052>
- Pratama, I., & Nugroho, E. (2021). Legacy systems and automation gaps in Indonesian public buildings. *Journal of Building Performance*, 12(4), 45–60. <https://doi.org/10.1016/j.jobe.2021.100019>
- Rahimi, M., Hosseini, S., & Khalili, N. (2021). Demand response strategies in public sector buildings. *Energy*, 226, 120359. <https://doi.org/10.1016/j.energy.2021.120359>
- Rahman, S., Alam, M., & Chowdhury, F. (2020). Conventional energy management practices in public offices. *Sustainable Energy Technologies and Assessments*, 42, 100888. <https://doi.org/10.1016/j.seta.2020.100888>
- Ramdani, F., Yusuf, M., & Prabowo, H. (2022). Framework for BEMS-based optimization in government buildings. *Energy Efficiency*, 15(5), 87. <https://doi.org/10.1007/s12053-022-10079-5>

- Rashid, M., Khan, T., & Ahmed, S. (2020). Energy efficiency gaps in public office buildings. *Energy and Buildings*, 223, 110125. <https://doi.org/10.1016/j.enbuild.2020.110125>
- Santoso, D., Prasetyo, A., & Wibowo, R. (2022). Quantifying energy savings through BEMS in Indonesian government offices. *Energy Reports*, 8, 2101–2112. <https://doi.org/10.1016/j.egyr.2022.05.011>
- Setiawan, B., Haryanto, T., & Nugraha, L. (2020). Early adoption of smart building systems in Indonesian government buildings. *International Journal of Sustainable Energy*, 39(8), 751–765. <https://doi.org/10.1080/14786451.2020.1781456>
- Singh, R., Sharma, V., & Kumar, P. (2020). Building energy management systems for institutional buildings. *Energy Efficiency*, 13(7), 1435–1452. <https://doi.org/10.1007/s12053-020-09830-8>
- Sutanto, A., Wicaksono, A., & Putra, R. (2023). Empirical study on smart building benefits for government offices. *Sustainable Energy Technologies and Assessments*, 58, 103600. <https://doi.org/10.1016/j.seta.2023.103600>
- Wang, H., & Chen, J. (2021). Digital transformation of building energy systems. *Energy Reports*, 7, 1824–1838. <https://doi.org/10.1016/j.egyr.2021.06.002>
- Wang, X., Li, Y., & Zhou, Q. (2022). Peak load management through smart buildings. *Applied Energy*, 316, 119098. <https://doi.org/10.1016/j.apenergy.2022.119098>
- Wibowo, R., Prasetyo, A., & Santoso, D. (2021). Operational data-driven energy optimization in government offices. *Energy Reports*, 7, 1542–1556. <https://doi.org/10.1016/j.egyr.2021.05.004>
- Yao, L., Zhang, S., & Liu, W. (2023). Real-time monitoring gaps in public building energy management. *Journal of Building Engineering*, 69, 107888. <https://doi.org/10.1016/j.jobe.2023.107888>
- Zhang, Y., Li, X., & Wang, Z. (2022). Cost-effective energy efficiency strategies in government offices. *Energy Efficiency*, 15(6), 102. <https://doi.org/10.1007/s12053-022-10103-3>
- Zhou, H., Wu, J., & Chen, L. (2021). Digitalization of energy management in public buildings. *Journal of Building Performance*, 11(3), 25–39. <https://doi.org/10.1016/j.jobe.2021.100011>