Formosa Journal of Science and Technology (FJST)
Vol. 4, No. 10, 2025: 3137-3150

Green Building Retrofitting Strategy in Government Buildings to Determine Budget Efficiency and Sustainability Energy Saving Policies Case study: Public Housing Office Building, Settlement and Cipta Karya Area, East Java Province

Guntaryono[1*], Darmansjah[2], Andarita Rolalisasi[3]
17 Agustus 1945 Surabaya University, Surabaya, Indonesia
Corresponding Author: Darmansjah, darmansjahtp@untag-sby.ac.id

A R T I C L E I N F O

Keywords: Architecture, Green Buildings, Government Buildings, Resilience, Retrofitting

Received : 8, September
Revised : 22, September
Accepted: 24, October

A B S T R A C T

The building sector in Indonesia is a major contributor to carbon emissions, with operations accounting for about 28% of global totals. Government buildings (BGN) are mandated to exemplify Green Building (BGH) practices under Government Regulations No. 16/2021 and No. 33/2023. This study assesses the existing condition of the Public Housing, Settlement Area, and Cipta Karya Office Building of East Java Province, identifies gaps in meeting BGH standards, and proposes a retrofitting strategy. Using a mixed-methods approach combining quantitative (energy use, cooling load, building orientation) and qualitative data (observations, interviews, document analysis), results show the building achieved only 8.5% of the BGH score, far below the required standard. Major weaknesses include the lack of governance systems, inefficient energy use, and absence of renewable integration or smart technologies. The study recommends a comprehensive retrofitting strategy addressing technical, institutional, and behavioral improvements to enhance building sustainability.

DOI prefix: https://doi.org/10.55927/fjst.v4i10.257
ISSN-E: 2964-6804
https://traformosapublisher.org/index.php/fjst

INTRODUCTION

Currently, environmental problems are becoming increasingly severe due to the emergence of global warming and climate change, which have a direct impact on the quality of buildings. The phenomenon of sick building syndrome is one indicator characterized by health problems and discomfort for building users due to air pollution, noise, inadequate natural lighting, and poor ventilation systems. The causative factors not only come from the design of buildings that are not environmentally friendly, but also the unhealthy behavior of building occupants (Hariyoko et al., 2021). Additionally, land constraints and space requirements encourage the construction of multi-storey buildings with enclosed structures, which typically rely on artificial air circulation and air conditioning to maintain a comfortable working environment.

On the other hand, the construction sector contributes significantly to greenhouse gas emissions. UN Environment data (2022) indicate that approximately 37% of global CO_2 emissions originate from buildings, with building operations contributing 28%. In Indonesia, the construction sector accounts for 24.6% of the country's total national greenhouse gas emissions (Bappenas, 2024), with 40% of these emissions attributed to operations and the use of building materials. This condition has encouraged the birth of the Green Building (BGH) movement since the 1990s in various countries, including Indonesia, which began to regulate the implementation of BGH through the Minister of Public Works and Public Works Regulation No. 02/2015, updated with the Minister of Public Works and Public Works Regulation No. 21/2021 and the Minister of Public Works and Public Works Regulation No. 1/2022. In fact, Government Regulation No. 16/2021 emphasizes that State Buildings (BGN) with an area of more than 5,000 m² are required to apply the principles of BGH, ensuring that government buildings serve as an example in sustainable development efforts.

(Swan, 2013) Studies and reports show that the retrofitting method can reduce energy consumption by up to 30%-50%, depending on the condition of the existing building and the repairs made. Some aspects that can be done in this method are related to energy efficiency in the HVAC system (Heating, Ventilation, and Conditioning), optimizing natural lighting and ventilation, utilizing renewable energy, such as installing solar panels to generate electricity, and improving the energy management system by monitoring through (Arthasari, n.d. 2020) (El-Darwish & Gomaa, 2017) Software that enables the control of energy consumption in the building in real-time. Water and waste management in buildings, including the reuse of materials, and the use of environmentally friendly materials, such as paints and existing building envelopes, related to recycling or low-carbon recycling (Ma et al., 2024). Although retrofitting methods have been proven to be effective in improving energy efficiency and reducing environmental impact, there are still some challenges to the effectiveness of this method (Bayu Widiarsa et al., 2021)

The effectiveness of the method is measured by energy efficiency. The high initial cost and its impact are not felt in the near term, but the benefits are realized in the long term. The lack of awareness and education among building owners, as well as inadequate regulations and policies from the government, have not been fully addressed with sufficient budgeting for the implementation of green buildings in government buildings and residential segments (Arthasari, 2020; Periyannan et al., 2023). According to the research article by Pohoryles, (2022), "The importance of retrofitting in existing buildings to earthquake resistance and energy efficiency factors, there are challenges and solutions from retrofitting methods, with retrofitting useful in sustainability and efficiency for the environment."

A strategic approach to retrofitting resources to enhance the performance of existing buildings by applying energy efficiency technologies, improving thermal quality, and reducing carbon emissions. In the context of green buildings, retrofits focus not only on energy efficiency but also on enhancing the quality of the indoor environment, improving occupant comfort, and reintegrating. (El-Darwish & Gomaa, 2017; Rohimah et al., 2018) This building, which functions as a public facility, has significant potential to exemplify the practical application of green building principles in the realm of government infrastructure. However, efforts to retrofit old buildings towards green building standards go beyond mere technical and architectural considerations, encompassing social, cultural, and institutional dimensions, especially the characteristics and behaviors of their occupants (GBCI, 2013). (Bayu Widiarsa et al., 2021) (Swan, 2013) The success of retrofits is highly dependent on user engagement and local context. Therefore, retrofit strategies need to be designed comprehensively, participatory, and adaptive to create buildings that are sustainable, comfortable, and resilient to climate change. Retrofitting strategies are not enough to modify the physical elements of the building; they must also incorporate a social approach that fosters user awareness and strengthens their connection to the place and its sustainability values.

The concept of Green Building (GBH), as explained by GBCI (2013), is a development approach that emphasizes the principles of sustainability in the planning, construction, and operational stages of buildings. This principle is strengthened by Arthasari (2020), who stresses that the implementation of BGH focuses not only on energy efficiency but also on the quality of life of residents and the integrated management of building systems. The main aspects that indicate its implementation include saving and diversifying energy resources, improving user health and comfort through adequate lighting, ventilation, and good air quality, as well as the effective management of building systems to ensure long-term operational efficiency. Thus, the BGH concept has a dual function, namely reducing environmental impact while improving the quality of living space for its residents.

The novelty of this research lies in its integrative approach, which connects technical, institutional, and social aspects within the context of government building in Indonesia. In contrast to most previous studies that have emphasized the technical aspect, this study prioritizes user behavior and institutional governance as key variables that determine the effectiveness of retrofitting. This study aims to analyze the retrofitting and gap aspects that exist in government buildings. Gap deep Retrofitting. The building mentioned above is vital for the role of all components, both the government as a regulator and the private sector as the general public. Massive education is needed to inform the public that this retrofitting method is designed for long-term sustainability.

THEORETICAL REVIEW

Green building retrofitting has emerged as a key strategy for improving energy efficiency, reducing carbon emissions, and promoting sustainability in the public sector. According to the UN Environment Programme (2022), building operations contribute nearly 28% of global carbon emissions, emphasizing the urgency of transforming existing government facilities into energy-efficient structures. Studies by Azizi et al. (2020) and Zhang et al. (2021) highlight that retrofitting not only enhances environmental performance but also optimizes operational costs through improved energy management and maintenance efficiency. In developing countries such as Indonesia, regulatory frameworks like Government Regulation No. 16/2021 and No. 33/2023 mandate the application of Green Building (BGH) standards in public buildings to support national sustainability goals. Previous research (Sari & Wibowo, 2022; GBCI, 2023) shows that successful retrofitting requires a holistic approach integrating technical upgrades, institutional governance, and user behavior change. Therefore, assessing retrofitting strategies in government buildings is essential to ensure both budget efficiency and long-term energy sustainability.

METHODOLOGY

This study employs a mixed-methods approach, combining quantitative and qualitative methods with comparative strategies. This approach was chosen because the research not only seeks to understand the phenomenon in depth through interviews and observations (qualitative), but also measures the existing condition of the building through numerical data such as floor area, electrical energy consumption, percentage of HVAC load, and the number and orientation of openings (quantitative). The comparative method is used because this study compares the existing conditions of the Public Housing Office, Residential Areas, and Cipta Karya Buildings of East Java Province with the standards for the fulfillment of Green Buildings (BGH) as stipulated in the Minister of Public Works and Housing Regulation Number 21 of 2021 and the GBCI GreenShip standard. The research process consists of three main stages: data collection, analysis, and interpretation of the results. Data collection was conducted through field surveys, technical observations, interviews, and document reviews. The study was conducted by combining qualitative data reduction (interviews and observations of user behavior, institutional aspects, and governance) with quantitative calculations (energy consumption data, building area, and HVAC load). The results of the analysis are then interpreted comparatively to show the gap between the existing conditions and the BGH standard, as well as formulate an applicable retrofitting strategy.

The primary objectives of this research are divided into two significant areas of focus. First, analyzing the existing condition of the building from various aspects that affect energy efficiency and the application of green building principles. The analysis encompasses physical elements of the building, including orientation, sheath materials, ventilation systems, lighting, and energy utilization. It also encompasses operational technical elements, including the use of HVAC systems, energy monitoring technology, and utility management. Additionally, it examines the social-behavioral aspects of building users related to their daily energy use patterns. By analyzing these existing conditions, the study aims to identify a gap between the actual conditions in the field and the standards outlined in the BGH regulations.

The second objective of this study is to formulate a retrofitting strategy that is applicable and in accordance with the building's condition, by referring to the principles of Green Building and government regulations. The formulated strategy includes technical measures such as optimizing natural lighting, improving ventilation systems, using insulating materials, and utilizing renewable energy sources. Additionally, the strategy encompasses non-technical aspects, including energy management policies, integrated monitoring systems, and user education on energy-saving behaviors. Thus, the resulting recommendations are not only in the form of technical solutions but also take into account social and institutional aspects, enabling retrofitting strategies to be implemented more effectively.

RESEARCH RESULTS

The study's results indicate that the existing conditions of the Public Housing Office, Settlement Area, and Cipta Karya Building in East Java Province still fall short of the Green Building (GB) standard. Based on the official assessment document, this building received a claim score of only 8.5% of the total available points, which categorized it as not meeting the BGH criteria. The weaknesses mainly lie in the aspects of organization, governance, and the absence of SOP documentation related to energy, water, materials, and waste management. From a social perspective, this reflects the low integration of residents' and building managers' behavior with the principle of sustainability.

Energy Efficiency in Green Buildings

Energy efficiency is a key pillar in the transformation towards sustainable, or green, buildings. However, the results of observations and evaluation documents indicate that the energy-saving strategy in this building remains minimal. Several efforts, such as building envelopes (OTTV and RTTV values meeting ≤35 W/m² standards) and natural ventilation in passive spaces, have been given full scores. However, air conditioning systems are not well-documented, artificial lighting does not meet SNI standards, and the absence of light sensors highlights the weak implementation of modern energy management. From a social perspective, this condition suggests a lack of internal policies that encourage energy-saving behavior, such as promoting a culture of turning off lights, regulating air conditioner temperatures, and involving users in controlling electricity consumption.

Table 1. Comparison of Existing Conditions with BGH (PUPR/GBCI) Standards

Aspects	Existing Conditions	BGH Standard (PUPR/GBCI)	Gap
Energy Efficiency (OTTV/RTTV)	OTTV and RTTV meet ≤35 W/m² standards; The sheath design is pretty good	OTTV/RTTV ≤ 35 W/m² with optimal insulation material	The casing is relatively good, but a full insulation system does not yet support it
Lighting System	LED lights exist, but they are not SNI compliant; the Light sensor is not available	Energy-saving lighting (LED lights as per SNI) with daylight harvesting & automatic sensor	The lights are not up to standard, and there is no automatic control.
Ventilation & Air Quality	Passive natural ventilation works well in some spaces; however, air conditioning is often used continuously.	Natural/hybrid ventilation with air quality monitoring (IAQ)	Natural ventilation is present, but the air conditioning is dominant, and IAQ is not monitored
Energy Management	No smart meters, IoT, or energy management documentation	Innovative system-based energy management, digitalization of energy consumption monitoring	No digital energy monitoring system
Water Conservation	There is no water conservation policy; the Water recycling system has not been implemented.	Water conservation with grey water reuse & water-saving devices	There is no water conservation or reuse of grey water
Waste & Material Management	There are no documents on plastic bans, waste management, and environmentally friendly materials policies.	Integrated waste management system, eco-friendly materials & recycling	There is no green material policy or waste management

Based on the table above, the comparison between the existing conditions of the Public Housing Office, Settlement Area, and Cipta Karya Building in East Java Province and the Green Building (BGH) standard reveals a significant gap in almost all aspects of assessment. First, in terms of energy efficiency (OTTV/RTTV), the existing conditions yield quite good results, with OTTV values of 27.43 W/m² and RTTV of 34.98 W/m², still below the standard threshold of ≤35 W/m². This indicates that the building envelope is relatively able to withstand heat loads. However, the BGH standard not only emphasizes achieving OTTV/RTTV numbers, but also the optimal use of insulation materials and casing systems. Therefore, even if the fundamental indicators have been met, the performance of the building envelope can still be improved by adding a thermal insulation layer and utilizing low-E glass to enhance the room's cooling efficiency.

Second, in terms of the lighting system, the measurement results showed that almost all rooms had a lighting level below SNI standards, such as meeting rooms that only reached 94–175 lux from the 300 lux standard, staff workspaces that were only 79–147 lux from the 250 lux standard, to podcast rooms that were only 54 lux from the 200 lux standard. The existing condition only uses general LED lights, which do not meet SNI standards, and is not equipped with light sensors or daylight harvesting systems. In fact, the BGH standard demands the use of energy-efficient lighting with automatic sensors to optimize natural light and reduce electricity consumption. The absence of this automatic control technology is a significant drawback, as it causes energy consumption to remain high, even though LED lights are already in use. From a social perspective, this condition highlights the low integration of residents' and building managers' behavior with the principle of sustainability. Therefore, efforts are needed to improve governance and increase awareness among all parties, ensuring that building management aligns more closely with Green Building standards.

Figure 1. Use of Mechanical/Natural Ventilation Combined with Air Conditioning in Main Building Offices, Meeting Rooms, and TABA Offices

Third, in terms of ventilation and air quality, the observation results show that the building still relies on natural ventilation in several rooms. However, the use of air conditioning remains dominant as seen in the main office, meeting room, and TABA's office. Additionally, there was no indoor air quality monitoring system (IAQ). The BGH standard itself emphasizes the importance of using hybrid ventilation and IAQ monitoring systems to ensure thermal comfort while reducing energy load. Under current conditions, air quality and occupant comfort may be less controlled, while energy efficiency is also suboptimal. Fourth, in the aspect of energy management, the existing conditions indicate the absence of smart meters, IoT systems, and digital devices for real-time energy monitoring. This is very far from the BGH standard, which requires a digital energy monitoring system as an efficiency control tool. This gap is one of the main obstacles, because without measurable energy consumption data, savings strategies are challenging to evaluate and monitor consistently. Fifth, in terms of water conservation, the study's results indicate that there are no water-saving devices, reuse of grey water, or effective water management policies. In fact, BGH standards emphasize water savings through the reuse of grey water for flushing, the use of aerators, and other water-saving devices. This gap suggests that buildings have not yet prioritized water efficiency, a crucial aspect of sustainability targets.

Sixth, in terms of waste and material management, the building lacks a policy on the use of environmentally friendly materials, waste sorting, or an integrated waste management system. The BGH standard requires 3R waste management (reduce, reuse, recycle) and the use of materials with low emission levels and that are environmentally friendly. The absence of this aspect shows considerable institutional and technical weaknesses in supporting the principle of green buildings. Seventh, the aspect of social and institutional policies is the weakest point because there are no SOP documents, internal regulations, or educational programs that encourage energy-saving and environmentally friendly behavior. In fact, the BGH standard emphasizes the importance of institutional support, energy management SOPs, and continuous education for building users. The absence of this policy has implications for the low collective awareness among employees and technicians regarding the support for green transformation, making the social aspect the primary obstacle to implementing BGH in this building.

Organization and Governance of Green Building

Research found that the institutions in building management are still very weak. There is no organizational structure or special unit responsible for the application of green building principles. As a result, policies related to energy efficiency, water conservation, and waste management are not well formulated. This building also lacks official documents, such as SOPs, that regulate energy use, water management, and environmentally friendly behavior. This condition reflects weak institutional governance, which has an impact on the low BGH assessment score and hinders the implementation of the overall retrofitting strategy.

Maintenance of BGH Performance during the Utilization Period

The building's performance during the utilization period remains low due to the absence of a monitoring and evaluation system. The building lacks smart meters, IoT devices, or digital tools to monitor energy consumption and air quality. As a result, the use of electrical energy is uncontrolled and challenging to evaluate. Additionally, water conservation is ineffective because there are no water-saving devices or water reuse systems in place. Similarly, waste management is still not integrated with the 3R (reduce, reuse, recycle) concept. The weak performance maintenance system indicates that the building operates as an ordinary administrative building, lacking an environmental impact control strategy.

The Role of Residents/Users of Green Buildings

The social aspect is the weakest point in this study. Building users, both employees and visitors, do not yet have a collective awareness of the importance of energy efficiency and environmental management. For example, the habit of turning off lights or electronic devices when they are not in use has not been established. The use of air conditioning remains excessive, despite the availability of natural ventilation. There are no internal policies in place to educate or incentivize users to behave in an environmentally friendly manner. This shows that technical retrofitting strategies will not be effective without social behavioral support. Therefore, the role of users must be strengthened through education, socialization, and the formation of an energy-efficient culture.

DISCUSSION

Retrofitting government buildings is a strategic approach that aims to enhance the performance of existing buildings to meet the principles of green building, energy efficiency, and sustainability. This concept is not limited to physical damage repair or routine maintenance activities. However, it includes a series of comprehensive adjustments involving aspects of construction, utility systems, institutional governance, and social behavior of its users. Thus, retrofitting is positioned as a crucial instrument to ensure that existing buildings remain relevant to the demands of new regulations, climate change, technological advancements, and the increasingly complex functional needs of society. Retrofitting state buildings cannot be viewed solely from a technical perspective, such as adding insulation, replacing lighting systems, or installing water-saving devices. While these technical aspects are essential for lowering energy and water consumption, the essence of retrofitting lies in institutional and social transformation. Changes in management patterns are necessary for sustainability principles to be institutionalized within organizational structures, including the establishment of specialized units that focus on green buildings, the development of policy documents, and the implementation of clear standard operating procedures (SOPs) (UNEP, 2016). This SOP serves as a daily operational guide, for example, regarding air conditioning temperature, the use of spaces with natural lighting, or utility system maintenance procedures.(Cutter et al., 2010)

The social aspect is just as important in the context of retrofitting. No matter how good the technical design and institutional policies are, the results will not be optimal without the support of environmentally friendly behavior from the building users. Therefore, education and socialization must be integral to the retrofitting strategy. Programs such as energy-saving campaigns, employee training on the use of environmentally friendly devices, and incentives for green behavior can form a new culture that supports sustainability principles. Thus, retrofitting is not only about repairing buildings, but also building a collective awareness that each individual has a vital role in maintaining efficiency and environmental sustainability. (Pohoryles et al., 2022)

Organization and Governance of Green Building

The results of the study show that the governance in this government building is still very weak because there is no special unit or SOP that regulates energy, water, and waste management. Building management is more reactive and administrative, without a proactive strategy to maintain sustainable performance. The absence of this institution creates a disconnect between national regulations, such as the Minister of Public Works and Housing Regulation No. 21 of 2021, and the GBCI Greenship standard, particularly in its implementation at the regional level. In fact, as Zuo & Zhao (2014) emphasized, institutions play a crucial role in establishing green building policies as a long-term organizational culture, not just a technical fulfillment (Papangelopoulou et al., 2025). This condition aligns with the findings, which emphasize that the success of retrofitting is influenced by socio-institutional aspects and supervisory systems, rather than just technology. It also noted that the implementation of energy efficiency technology will fail without the support of local regulations, incentives, and user participation (Almasri et al., 2023). Therefore, the biggest weakness in this building is not solely a technical aspect, but rather an inability to integrate regulations into internal management. Institutional strengthening through the formation of a BGH management team, the preparation of cross-dimensional SOPs, and employee education are prerequisites for the retrofitting strategy to run effectively and sustainably (Hwang & Chiu, 2025).

Construction Process Modification Customization

The study's results indicate that the construction process for adjusting the Public Housing Office, Settlement Area, and Cipta Karya Building in East Java Province remains incomplete. Building envelopes are already showing good passive performance with OTTV and RTTV values below the threshold. However, active strategies such as energy-efficient lighting and hybrid ventilation systems have not been optimally implemented. Installed LED lights do not feature automatic sensors, while natural vents are rarely used due to the dominance of conventional air conditioning. This condition makes the energy efficiency potential of passive strategies unrealized in real savings. Previous research confirms that achieving energy-efficient buildings and Net Zero Energy Buildings (NZEBs) requires a combination of passive, active, and user participation strategies (Carpino, 2024; Ballarini et al., 2019).

Additionally, weaknesses are also evident in aspects such as water conservation, the use of environmentally friendly materials, and energy monitoring systems. The absence of water-saving devices, greywater recycling, and innovative materials such as Phase Change Materials (PCMs) highlights the limitations of retrofit innovation, despite a study in Malaysia demonstrating that PCMs can improve thermal comfort for up to 98% of the operational time. Another obstacle that arises is institutional, where weak coordination between stakeholders and the absence of retrofit budget allocations make interventions limited to basic actions, such as lighting replacements. These findings corroborate the study. (Hwang & Chiu, 2025; Al-Absi et al., 2021; Song et al., 2024). Moreover, Liu et al. (2020) emphasize the importance of institutional support and life-cycle sustainability assessment-based evaluations. Thus, the retrofitting strategy for government buildings in Surabaya should focus on a comprehensive transformation that integrates passive design, energy-efficient active systems, innovative materials, data-driven monitoring, and long-term regulatory and management support.

Maintenance of BGH Performance during the Utilization Period

The results of the study indicate that the East Java Province Public Housing, Settlement Area, and Cipta Karya Office Building lack an adequate Green Building (BGH) performance maintenance system. Energy, water, and waste management are not equipped with structured monitoring instruments such as sub-metering or smart meters, so evaluation is only carried out when technical problems arise. The absence of a performance baseline makes it difficult for buildings to make continuous improvements. This condition reveals a significant performance gap between national policy design and its implementation on the ground, as also noted by Song et al. (2024) and Hwang & Chiu (2025), who attribute weak monitoring as the primary cause of failure to maintain post-retrofit performance. In addition, the maintenance of BGH performance should include aspects of occupant comfort, indoor air quality, and material lifecycle management. International studies prove that retrofits not only reduce energy consumption by up to 34%, but also improve occupant comfort through the integration of natural ventilation, energy-efficient cooling, and innovative materials such as PCM capable of improving thermal comfort by up to 98% of the time. However, buildings in Surabaya have not adopted the principles. (Chung-Camargo et al., 2024) of life cycle sustainability assessment (Caruso et al., 2023). Alternatively, user behavior SOPs that support energy efficiency. This weakness suggests that long-term sustainability depends not only on technology but also on governance and user awareness, which are currently minimal.

The Role of Residents/Users of Green Buildings

The study's results indicate that the role of residents in supporting the implementation of BGH in the Public Housing Office Building, Settlement Area, and Cipta Karya in East Java Province remains minimal. Employees are more oriented towards instant comfort than energy efficiency, demonstrated by the use of air conditioning throughout the day without energy-efficient temperature settings and artificial lighting that continues to burn despite the availability of natural light. The absence of socialization and education prevents the existing passive and active strategies from being optimally utilized. This finding aligns with the results of Al-Absi et al. (2021), who demonstrate that the effectiveness of retrofit technologies, such as Phase Change Materials (PCMs), is contingent upon the presence of appropriate user behavior, including correct ventilation settings. In addition, research confirms that the integration of mixed ventilation and energy-efficient cooling systems can only succeed with a user's understanding of how they operate. Conditions in Surabaya indicate that a complete reliance on air conditioning hinders natural ventilation strategies, despite the availability of physical infrastructure. It also highlights barriers to energy literacy as an essential factor affecting the effectiveness of energy efficiency, even outside the context of low-income groups. Thus, the lack of energy awareness among Surabaya government building employees is the main obstacle. User participation, energy education, and the formation of a culture of sustainability must be viewed as essential prerequisites for implementing sustainable retrofitting strategies (Wan et al., 2022; Kajjoba et al., 2025).

CONCLUSIONS AND RECOMMENDATIONS

This study reveals that the existing conditions of the Public Housing Office, Settlement Area, and Cipta Karya Building in East Java Province still fail to meet the Green Building (BGH) standard. The assessment score reached only 8.5% of the total points, confirming the existence of significant gaps in almost all aspects, ranging from energy efficiency and lighting to ventilation, energy management, water conservation, waste management, and social and institutional policies. The biggest weakness lies in the absence of SOPs, monitoring systems, and low awareness of building users in supporting energy-saving and environmentally friendly behavior. Through qualitative analysis, this study developed a comprehensive retrofitting strategy that emphasizes the integration of technical, institutional, and social aspects. Technical efforts include improving the building envelope, implementing energy-efficient lighting with automatic sensors, hybrid ventilation systems, smart meters, and water and waste conservation based on the 3R principle. Meanwhile, the non-technical aspect focuses on preparing SOPs, educational programs, fostering a green culture among employees, and building users. This strategy is expected not only to improve energy efficiency and comfort, but also to make government buildings an example of implementing sustainability principles and contribute directly to the achievement of SDG 7 and SDG 11.

FURTHER STUDY

Future research should focus on evaluating the implementation and long-term effectiveness of the proposed green retrofitting strategies in government buildings. Further studies could explore the quantifiable impacts of each intervention—both technical and non-technical—on energy consumption, indoor environmental quality, and user behavior. Comparative analyses between different types of public buildings or regions would also provide deeper insights into the adaptability and scalability of retrofitting measures under diverse climatic, institutional, and cultural contexts. In addition, future research should investigate financing models, policy support mechanisms, and digital monitoring systems that can enhance sustainability performance and ensure the continuous improvement of green building management within the public sector.

ACKNOWLEDGMENT

This section allowed you to present gratitude to your colleagues who provide suggestions for your papers. You can also convey your appreciation for the financial grants you are accepting, which enable you to create this paper.

REFERENCES

Al-Absi, Z. A., Hafizal, M. I. M., Ismail, M., & Ghazali, A. (2021). Towards sustainable development: Building's retrofitting with pcms to enhance the indoor thermal comfort in tropical climate, malaysia. Sustainability (Switzerland), 13(7). https://doi.org/10.3390/su13073614

Almasri, R. A., Abu-Hamdeh, N. H., & Al-Tamimi, N. (2023). A state-of-the-art review of energy-efficient and renewable energy systems in higher education facilities. In Frontiers in Energy Research (Vol. 11). Frontiers Media SA. https://doi.org/10.3389/fenrg.2023.1344216

Arthasari, A. H. (2020). peningkatan kinerja hijau melalui retrofitting PENINGKATAN KINERJA HIJAU MELALUI RETROFITTING STUDI KASUS : PEKERJAAN PENGUBAHSUAIAN BANGUNAN PIP2B DIY. https://doi.org/10.14710/mdl.20.1.2020.57-65

Bayu Widiarsa, K., Kumara, I., Sari Hartati, R., & Teknik Elektro, J. (2021). STUDI LITERATUR PERKEMBANGAN GREEN BUILDING DI INDONESIA (Vol. 8, Issue 2).

Caruso, M., Couto, R., Pinho, R., & Monteiro, R. (2023). Decision-making approaches for optimal seismic/energy integrated retrofitting of existing buildings. Frontiers in Built Environment, 9. https://doi.org/10.3389/fbuil.2023.1176515

Chung-Camargo, K., González, J., Chen Austin, M., Carpino, C., Mora, D., & Arcuri, N. (2024). Advances in Retrofitting Strategies for Energy Efficiency in Tropical Climates: A Systematic Review and Analysis. In Buildings (Vol. 14, Issue 6). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/buildings14061633

Cutter, S. L., Burton, C. G., & Emrich, C. T. (2010). Disaster Resilience Indicators for Benchmarking Baseline Conditions. Journal of Homeland Security and Emergency Management, 7(1). https://doi.org/10.2202/1547-7355.1732

El-Darwish, I., & Gomaa, M. (2017). Retrofitting strategy for building envelopes to achieve energy efficiency. Alexandria Engineering Journal, 56(4), 579–589. https://doi.org/10.1016/j.aej.2017.05.011

Hariyoko, Y., Soesiantoro, A., & Pangestuti, R. P. (2021). Evaluasi Kebijakan Pembangunan Wisata Religi di Kabupaten Gresik. Publica: Jurnal Pemikiran Administrasi Negara, 13(1), 44–51. https://doi.org/https://doi.org/10.15575/jpan.v13i1.11745

Hwang, R. L., & Chiu, H. C. (2025). A Case Study-Based Framework Integrating Simulation, Policy, and Technology for nZEB Retrofits in Taiwan's Office Buildings. Energies, 18(14). https://doi.org/10.3390/en18143854

Kajjoba, D., Wesonga, R., Lwanyaga, J. D., Kasedde, H., Olupot, P. W., & Kirabira, J. B. (2025). Assessment of thermal comfort and its potential for energy efficiency in low-income tropical buildings: a review. Sustainable Energy Research, 12(1). https://doi.org/10.1186/s40807-025-00169-9

Periyannan, E., Ramachandra, T., & Geekiyanage, D. (2023). Assessment of costs and benefits of green retrofit technologies: Case study of hotel buildings in Sri Lanka. Journal of Building Engineering, 78. https://doi.org/10.1016/j.jobe.2023.107631

Pohoryles, D. A., Bournas, D. A., Da Porto, F., Caprino, A., Santarsiero, G., & Triantafillou, T. (2022). Integrated seismic and energy retrofitting of existing buildings: A state-of-the-art review. In Journal of Building Engineering (Vol. 61). Elsevier Ltd. https://doi.org/10.1016/j.jobe.2022.105274

Rohimah, A., Hariyoko, Y., & Ayodya, B. P. (2018). Strategi Pengembangan Potensi Pariwisata Melalui Pendekatan Community Based. Jurnal Ilmiah Administrasi Publik (JIAP), 4(4), 363–368.

Song, P., Wu, L., Zhao, W., Ma, W., & Hao, J. (2024). Life Cycle Sustainability Assessment: An Index System for Building Energy Retrofit Projects. Buildings, 14(9). https://doi.org/10.3390/buildings14092817

Swan, W. , & B. P. (2013). Retrofitting the Built Environment.

Wan, S., Ding, G., Runeson, G., & Liu, Y. (2022). Sustainable Buildings' Energy-Efficient Retrofitting: A Study of Large Office Buildings in Beijing. Sustainability (Switzerland), 14(2). https://doi.org/10.3390/su14021021