

**Analysis of the Implementation of Green Building Technology in Building Maintenance**Dimas Wahyu Kurniawan<sup>1</sup>, Silvia Yulita Ratih<sup>2</sup>, Fahmi F. Dalimarta<sup>3</sup>, Adhi Susilo<sup>4</sup><sup>1,2,3,4</sup> Civil Engineering, Surakarta University, Indonesia**Article History**

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**Corresponding author\*:**[vierahyu1125@gmail.com](mailto:vierahyu1125@gmail.com)**Cite This Article:**

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**Abstract:** Hospitals are resource-intensive facilities with continuous operations that result in high energy and water consumption, making the implementation of green building technology essential to improve environmental performance during the operational phase. **Objective:** This study aims to identify the energy, water, and material efficiency measures implemented at RSUD dr. Soeratno Gemolong, Sragen, and to evaluate the level of efficiency achieved based on EDGE (Excellence in Design for Greater Efficiencies) standards. **Methods:** The research employed an applied evaluative approach by collecting primary and secondary data through direct observation, interviews, documentation review (as-built drawings and material data), and literature review. The collected data were analyzed using the EDGE application and compared with EDGE benchmarks and relevant Indonesian regulations. **Findings:** The results indicate that baseline energy efficiency was 19.85%, slightly below the EDGE minimum requirement of 20%, but increased to 24.09% after targeted improvements such as reducing building envelope air infiltration and improving cooling system efficiency. Water efficiency reached 25.75%, and material efficiency achieved 34%, both exceeding the EDGE minimum standard. **Implications:** These findings demonstrate that EDGE-based evaluation can support maintenance-driven optimization strategies in hospital buildings and provide practical guidance for facility managers and policymakers in prioritizing high-impact efficiency interventions. **Originality/Value:** This study provides an integrated empirical assessment of energy, water, and material efficiency (EEM, WEM, MEM) in an operational public hospital, showing how targeted improvements can shift energy performance from near-compliance to compliant status within the EDGE framework.

**Keywords:** Green Building; EDGE; Hospital Building Maintenance.

**INTRODUCTION**

Growing awareness of environmental sustainability has encouraged various sectors, including healthcare, to adopt environmentally responsible practices. Hospitals are among the most resource-intensive building types due to their continuous operational activities, high energy consumption, substantial water use, and complex waste management systems. As a result, healthcare facilities contribute significantly to greenhouse gas emissions and environmental degradation if sustainability measures are not implemented. Globally, the healthcare sector is estimated to account for a considerable share of carbon emissions, highlighting the urgent need for sustainable building operation and maintenance strategies

([Eckelman & Sherman, 2016](#)). Consequently, integrating green building principles into hospital maintenance has become increasingly important as part of broader sustainable development initiatives ([World Green Building, 2011](#)).

The concept of green building emphasizes efficient resource utilization, reduced environmental impacts, and improved indoor environmental quality throughout the building life cycle, including design, construction, operation, and maintenance. Green building practices aim to minimize energy and water consumption, optimize material efficiency, and reduce ecological footprints while maintaining functionality and occupant comfort ([Darko & Chan, 2016](#)). In the context of building maintenance, the application of green technologies plays a strategic role in sustaining building performance over time and ensuring that environmental objectives continue to be achieved beyond the construction phase. Effective maintenance strategies are essential because operational stages typically account for the largest proportion of a building's environmental impact.

In Indonesia, the implementation of green building practices is supported by regulatory frameworks that promote sustainable construction and building operation. The Ministry of Public Works and Public Housing Regulation No. 02/PRT/M/2015 on Green Buildings provides technical guidelines for energy efficiency, water conservation, indoor environmental quality, and sustainable site development. These policies aim to ensure that green building principles are not only applied during design and construction but are also maintained during building operation. Regional policies, such as the Jakarta Governor Regulation No. 38 of 2012, further reinforce the importance of sustainable building management at the local level, demonstrating Indonesia's commitment to environmental performance in the built environment.

Beyond national regulations, international certification systems serve as important benchmarks for assessing building sustainability performance. One widely recognized framework is EDGE (Excellence in Design for Greater Efficiencies), developed by the International Finance Corporation (IFC) ([International Finance, 2016](#)). Performance-based certification systems such as EDGE provide measurable indicators of resource efficiency and enable benchmarking against conventional buildings. Studies have shown that green certification frameworks can significantly improve building energy performance and operational efficiency when properly implemented ([Azhar et al., 2011](#)). The EDGE standard requires at least 20% savings in energy, water, and embodied energy in materials, offering a practical pathway toward sustainability, particularly in developing countries.

The application of green building technologies in healthcare facilities is particularly relevant due to hospitals' high operational intensity. Continuous operation of medical equipment, HVAC systems, lighting, and water-intensive services presents both environmental challenges and opportunities for efficiency improvement. Empirical studies indicate that green hospital initiatives can reduce operational costs, lower energy use, improve indoor environmental quality, and positively influence patient recovery and staff productivity (MacNaughton et al., 2017). These findings highlight the dual environmental and social benefits of sustainable healthcare facilities.

Despite these advantages, the implementation of green building technologies in maintenance practices faces several challenges, including high initial investment costs, limited technical expertise, and organizational resistance to change. Financial constraints and lack of awareness are frequently cited as key barriers to adopting sustainable technologies in developing countries (Darko & Chan, 2016). Nevertheless, long-term benefits such as reduced operational expenditure, improved environmental performance, and regulatory compliance provide strong justification for integrating sustainability principles into routine maintenance practices.

Therefore, analyzing the implementation of green building technology in building maintenance is crucial to understanding how sustainability objectives can be effectively operationalized in existing buildings, particularly healthcare facilities. Such analysis provides empirical insights into environmental and operational impacts while supporting evidence-based decision-making for policymakers, facility managers, and stakeholders in promoting sustainable building management practices in Indonesia and other developing country contexts.

## RESEARCH METHOD

This study employed a quantitative approach, integrating literature review, case study, data collection, and data analysis techniques in accordance with green building regulations and standards in Indonesia as well as the EDGE certification framework developed by the International Finance Corporation (IFC). The research site was RSUD dr. Soeratno Gemolong, Sragen Regency.

The research variables analyzed in relation to the implementation of green building technology at RSUD dr. Soeratno Gemolong were aligned with EDGE standards and Indonesian green building regulations to ensure accurate and reliable results. The

independent variables were derived from the green building categories embedded in the EDGE 3.0 software system, namely energy efficiency, water efficiency, and material efficiency.

Several relevant variables were considered in this study:

1. Energy Efficiency

This variable includes the application of energy-efficient technologies such as efficient lighting systems (e.g., LED lamps), high-efficiency HVAC systems, and the utilization of renewable energy sources (e.g., solar panels or geothermal systems).

2. Water Management

This variable considers the efficient use of water through technologies such as rainwater harvesting and reuse systems, water-saving fixtures, and wastewater treatment systems.

3. Materials and Resources

This variable includes the selection of environmentally friendly building materials, such as recycled or recyclable materials, as well as strategies to reduce construction waste.

4. Indoor Air Quality

This variable encompasses improvements in indoor air quality through proper ventilation systems, air filtration, and control of indoor pollutants.

5. Waste Management

This variable covers strategies for the safe and efficient management of medical and non-medical waste in accordance with applicable regulations.

6. Site Management

This variable includes environmental aspects of site management such as landscaping, stormwater management, and the application of sustainable site development concepts.

7. Innovation

This factor includes the assessment of innovation and the adoption of best practices in green building technologies within the hospital context, such as smart building technologies and the use of information technology for energy management.

Primary data included the physical condition of the building, material usage, and the application of green technologies, as well as the efficiency of material use and green building technologies. The data collected comprised:

1. Existing Building Data

Data on the existing building conditions related to EDGE categories and criteria.

2. Energy and Water Consumption Data

Data on hospital energy and water consumption were obtained from monthly or annual records maintained by the technical department or facility management. These data include electricity, gas, and water usage for daily operations, as well as energy consumption records for cooling (MacNaughton et al.) and heating systems.

3. Policy and Procedure Documents

Documents related to environmental management and green building practices, including medical waste management guidelines, procedures for handling hazardous chemicals, and policies on energy conservation and water management in compliance with prevailing regulations.

To ensure a systematic and structured research process, this study was conducted through several sequential stages, starting from preparation to the determination of research variables. Each stage was designed to ensure that the data obtained were relevant, valid, and aligned with the objectives of evaluating green building technology implementation in building maintenance. The research stages include preparation, literature review, data collection, and determination of research variables. The overall framework of the research methodology is illustrated in Figure 1.

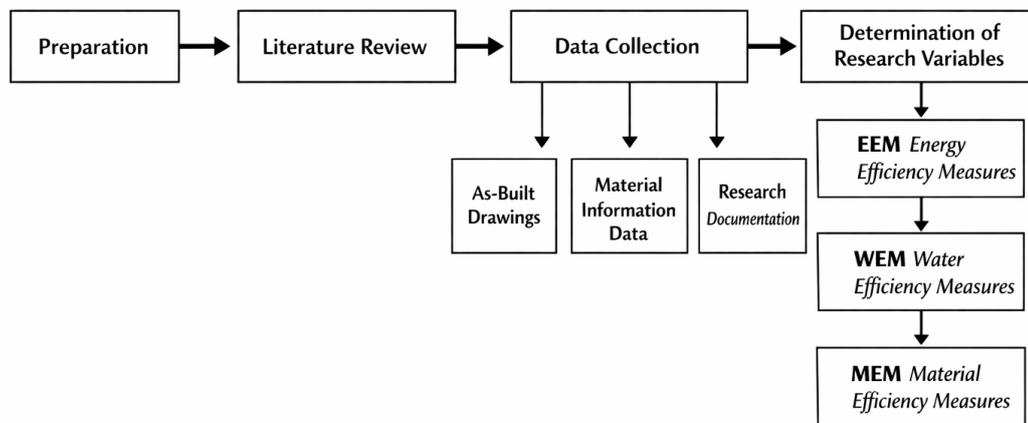


Figure 1. Research Methodology Framework

As shown in Figure 1, the research began with the preparation stage, which involved defining the research scope, identifying the case study, and preparing research instruments. The second stage was a literature review to establish the theoretical foundation related to green building concepts, sustainability assessment, and efficiency measures. The third stage involved data collection, including as-built drawings, material information data, and supporting research documentation. Finally, the determination of research variables was carried out, consisting of Energy Efficiency Measures (EEM), Water Efficiency Measures (WEM), and Material Efficiency Measures (MEM), which served as the main parameters for evaluating building sustainability performance.

Data analysis in this study was carried out in three main steps. First, the collected secondary data were processed, verified, and then input into the EDGE system using the official EDGE software to generate performance outputs based on the parameters entered. Second, the outputs were used to measure the level of conservation and efficiency in energy, water, and material use by comparing the existing building performance against the baseline standards provided in the EDGE framework. Third, an optimization analysis was conducted to identify feasible improvement options for the existing building, focusing on strategies that could increase efficiency and conservation levels while remaining compatible with the building's operational conditions and maintenance practices.

## RESULT

Prior to the implementation of green building technology, the hospital building was designed to meet comprehensive medical service requirements and to provide optimal healthcare services. The EDGE (Excellence in Design for Greater Efficiencies) application requires baseline data as initial input. Before proceeding to the calculation of energy, water, and material efficiency levels, design data were entered into the system, including building type, location data, detailed area and load specifications, building dimensions, HVAC system configuration, and climate data. Based on this information, the EDGE application performs analysis and calculates efficiency levels according to the input building design parameters.

The hospital building structure utilizes conventional construction materials, such as reinforced concrete for the structural frame and brick masonry walls with plaster finishing, in compliance with Indonesian building regulations. The hospital's facilities and spatial layout were designed to maximize operational efficiency and comfort for patients and

medical staff. The lighting system uses conventional fluorescent lamps installed throughout the hospital areas, while the ventilation system relies on split-type air conditioning units in each room to maintain indoor temperature and air quality. Water and waste management are carried out in accordance with healthcare standards; however, no effective recycling programs have yet been implemented. The building design indicates that although it already complies with Indonesian regulatory standards, there remain many aspects that can be improved, particularly in terms of energy efficiency, water management, indoor air quality, and waste management. The location map displayed in the EDGE system is presented in Figure 1.



**Figure 1.** Building Location Data

The EDGE Building system requires building data inputs to monitor and control various building aspects such as safety, energy efficiency, water, materials, and connectivity. The building data are entered based on the actual conditions of the building, as presented in Table 1.

**Table 1.** Building Input Data

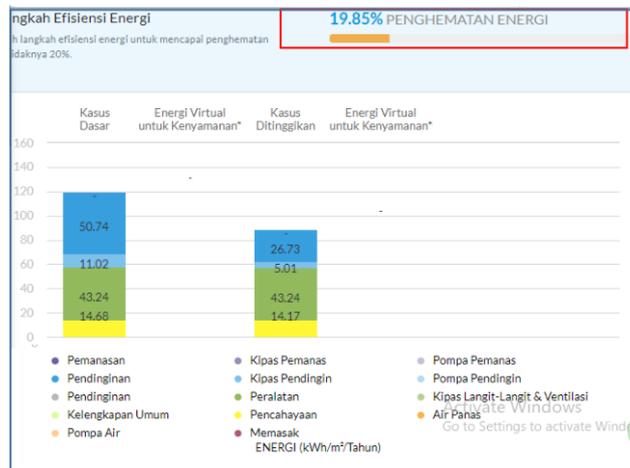
No.	Parameter	Description
1	Land Area	15,657.87 m <sup>2</sup>
2	Building Area	10,535.20 m <sup>2</sup>
3	Gross Internal Area	9,834.45 m <sup>2</sup>
4	Aggregate Roof Area	3,467.92 m <sup>2</sup>
5	North Building Dimension	55.87 m
6	East Building Dimension	64.25 m
7	South Building Dimension	52.14 m
8	West Building Dimension	67.37 m

The detailed input data on areas and loads are presented in Table 2.

**Table 2.** Area and Load Details

No.	Space/Function	Floor(s)	Area (m <sup>2</sup> )
1	General Patient Area	1, 2, and 3	1,023.45
2	Specialized Ward Patient Area	All floors	856.75
3	Intensive Care Unit (ICU)	1	450.3
4	Operating and Pre-Operating Rooms	1, 2, and 3	625.5
5	Operating Rooms	1, 2, and 3	754.65
6	Consultation Rooms	1, 2, and 3	395.25
7	Therapy Rooms	1 and 2	520.4
8	Offices	2	315.6
9	Corridors	1 and 2	1,120.70
10	Bathrooms/Storage Rooms	1, 2, and 3	325.45
11	Diagnostic Services	2	620.5
12	Central Sterile Supply Department (CSSD)	2	450.8
13	Mechanical & Electrical Room	1	240.9
14	Kitchen and Food Storage	1	285.6
15	Food Court and Snack Center	1	305.75
16	Indoor Car Parking Area	1	375.4
17	Data Center	2	210.35
18	Waiting Area	1, 2, and 3	825.5
<b>Total</b>			<b>10,535.20</b>

The energy savings results at RSUD dr. Soeratto Gemolong, Sragen can be seen in Figure 2.



**Figure 2.** Energy Efficiency Results

Based on Figure 2, the energy savings achieved at RSUD dr. Soeratto Gemolong, Sragen have not yet reached the required level of energy efficiency. The result obtained is

19.85%. This indicates that RSUD dr. Soeratno Gemolong, Sragen does not yet meet the minimum standard requirement for green building certification according to EDGE (20%) under the energy savings criteria.

The blue-colored segment represents the cooling category with a value of 26.73 kWh/m<sup>2</sup>/year. This value was obtained after inputting the existing building data into items EEM01 to EEM11. The light blue segment represents the cooling fan category with a value of 5.01 kWh/m<sup>2</sup>/year. The green segment represents the equipment category with a value of 43.24 kWh/m<sup>2</sup>/year. The yellow segment represents the lighting category with a value of 14.17 kWh/m<sup>2</sup>/year, which was obtained after entering the existing data for item EEM23. The results of the energy assessment for RSUD dr. Soeratno Gemolong, Sragen are presented in Table 3, which shows the percentage of energy savings, achievement status, and compliance with green building standard requirements.

**Table 3.** Energy Savings Results

Name	Achieved (Yes/No)	Energy Efficiency Level (%)	Compliance Status
RSUD Gemolong	No	19.85%	Not yet compliant

The energy efficiency results were obtained after inputting the building design data into the following EDGE items: EEM01 Window-to-Wall Area Ratio, EEM02 Reflective Roof: Solar Reflectance Index, EEM03 Reflective Exterior Walls: Solar Reflectance Index, EEM05 Roof Insulation, EEM08 Exterior Wall Insulation, EEM09 Glass Efficiency, EEM11 Natural Ventilation, EEM12 Ceiling Fans, and EEM23 Efficient Lighting for External Areas.

**EEM01 Window-to-Wall Ratio**

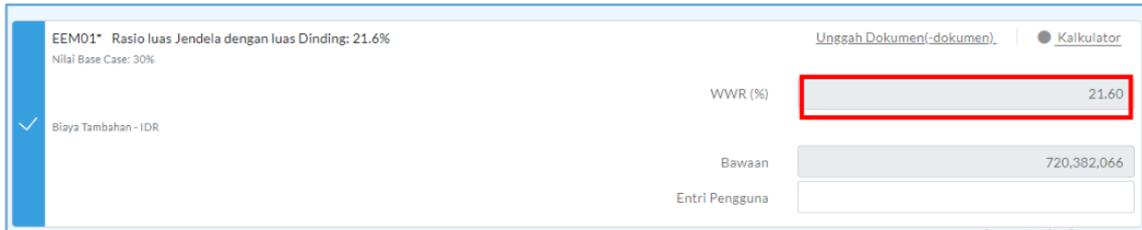
In calculating the ratio between window area and wall area in the EDGE system, a dedicated calculator known as the Window-to-Wall Ratio (WWR) calculator is used. The data entered into this calculator include the exposed façade area on each side of the building and the external glazing area. The detailed calculation of the window-to-wall ratio for RSUD dr. Soeratno Gemolong, Sragen is presented in Table 4.

**Table 4.** Window-to-Wall Ratio (WWR) Calculation for RSUD dr. Soeratno Gemolong

Window Orientation	Exposed Gross Façade Area (m <sup>2</sup> )	External Glazing Area (m <sup>2</sup> )
North	636.92	137.57
East	732.45	158.21
South	594.4	128.34

Window Orientation	Exposed Gross Façade Area (m <sup>2</sup> )	External Glazing Area (m <sup>2</sup> )
West	768.02	165.89
Aggregate (m <sup>2</sup> )	2,371.79	590.01
<b>Average WWR</b>		<b>21.60%</b>

After entering the façade area and glazing area data as shown in Table 4, the EDGE application calculates and displays the average WWR value. The WWR value obtained for RSUD dr. Soeratno Gemolong, Sragen, as shown in Figure 3, is 21.6%.



**Figure 3.** Data Input for EEM01

### EEM02 Reflective Roof: Solar Reflectance Index (SRI)

At RSUD dr. Soeratno Gemolong, Sragen, an Antique White colored paint is used for the roof. According to UVCOOL, this color has an SRI value of 85, as shown in Figure 5.



**Figure 4.** Data Input for EEM02

As shown in Figure 4, RSUD dr. Soeratno Gemolong, Sragen achieved an SRI value of 85.

### EEM03 Reflective Exterior Walls: Solar Reflectance Index (SRI)

Reflective exterior walls refer to the ability of wall surfaces to reflect a large portion of solar radiation. Walls coated with light-colored paint tend to have higher SRI values. At RSUD dr. Soeratno Gemolong, Sragen, the exterior walls are painted in a light color. The hospital uses Antique White wall paint, which, according to UVCOOL, has an SRI value of 85, as shown in Figure 5.

**Figure 5.** Data Input for EEM03

**EEM05 Roof Insulation**

The roof of RSUD dr. Soerarno Gemolong, Sragen does not have a dedicated insulation layer. The type of roofing material used is PVC (Polyvinyl Chloride) with a thickness of 30 mm. By inputting the roof construction material data and its thickness, the EDGE application calculates and displays the average U-value of the roof insulation. At RSUD dr. Soerarno Gemolong, Sragen, the average roof insulation U-value obtained is  $0.48 \text{ W/m}^2\cdot\text{K}$ .

**EEM08 Exterior Wall Insulation**

The U-value of the exterior wall insulation is obtained after inputting the percentage of wall area by orientation and the material data along with its thickness. The data input for exterior wall insulation is shown in Figure 6.

**Figure 6.** Data Input for EEM08

**EEM09 Glazing Efficiency**

The U-value for glazing efficiency is obtained by entering the percentage (%) of the total glazed area for each orientation, along with the SHGC (Solar Heat Gain Coefficient) and VT (Visible Transmittance) values in accordance with the default standards in the EDGE application. The data input process for glazing efficiency is shown in Figure 7.

EEM09\* Efisiensi Kaca Nilai-U 4.06 W/m<sup>2</sup>-K, SHGC 0.56 dan VT 0.45  
 Nilai Base Case: 5.8 W/m<sup>2</sup>-K & SHGC 0.8 & VT 0.7

Unseah Dokumen(-dokumen) | Kalkulator

Nilai-U (W/m <sup>2</sup> -K)	4.06
SHGC	0.56
VT (Faktor)	0.45
Bawaan	50,792,316
Entri Pengguna	

Blaya Tambahan - IDR

**Figure 7.** Data Input for EEM09

### EEM11 Natural Ventilation

The data to be input can be seen in Figure 8.

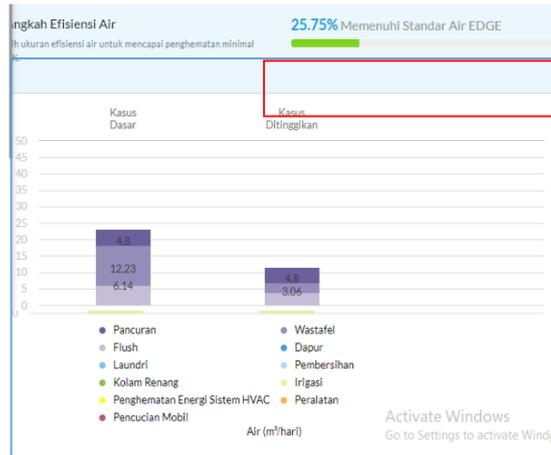
EEM11 - Kalkulator Ventilasi Alami

Area Fungsional	Apakah Area tersebut memiliki Ventilasi Alami?	% Pembukaan Fasad	Jenis Ventilasi
Area Pasien - Umum	Ya		Satu Sisi
Area Pasien - Bangsal Spesialisasi	Ya		Satu Sisi
Ruang Konsultasi	Ya		Satu Sisi
Kamar Terapi	Ya		Satu Sisi
Kantor	Ya		Satu Sisi
Koridor	Ya	15.60	Satu Sisi
Pusat Makan dan Jajan	Ya	20.30	Allran Silang

**Figure 8.** Data Input for EEM11

### Water Efficiency Measures (WEM)

After completing the data input process for the water efficiency criteria, a water savings result of 25.75% was obtained. The water usage at the research object, RSUD dr. Soerarno Gemolong, Sragen, has met the water efficiency standard set by the EDGE application system, which is 20%. The results can be seen in Figure 9.



**Figure 9. Water Efficiency Results**

The results of the evaluation of the water efficiency level at RSUD dr. Soeratno Gemolong, Sragen are presented in Table 5.

**Table 5. Water Savings Results**

Name	Achieved (Yes/No)	Water Efficiency Level (%)	Compliance Status
RSUD Gemolong	Yes	25.75%	Compliant

Source: EDGE Application

### Material Efficiency Measures (MEM)

The results of the evaluation of the material efficiency level at RSUD dr. Soeratno Gemolong, Sragen are presented in Table 6.

**Table 6. Material Savings Results**

Name	Achieved (Yes/No)	Material Efficiency Level (%)	Compliance Status
RSUD Gemolong	Yes	34%	Compliant

Source: EDGE Application

### Summary of EEM, WEM, and MEM

**Table 7. Assessment of the Implementation of Efficiency Measures for Energy, Water, and Materials**

Building Name	EEM Standard	EEM Result	WEM Standard	WEM Result	MEM Standard	MEM Result
RSUD	≥ 20	19.85	≥ 20	25.75	≥ 20	34

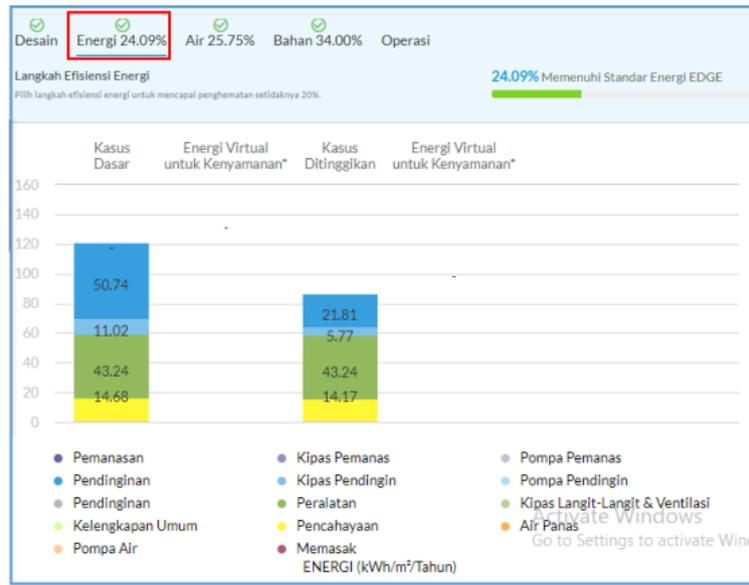
Remarks: Not Achieved (EEM); Achieved (WEM); Achieved (MEM)

Source: EDGE Application

After conducting the assessment using the EDGE application, efficiency data were obtained for three main aspects: energy, water, and materials.

## Energy Efficiency Results After Improvements

Following improvement measures, including the implementation of a 50% reduction in building envelope air infiltration (EEM10) and enhancement of the cooling system efficiency by improving the COP (EEM13) at RSUD dr. Soeratno Gemolong, Sragen, a significant increase in energy efficiency was observed. As shown in Figure 10, the overall energy efficiency increased to 24.09%.



**Figure 10.** Energy Efficiency Results After Improvements

Initially, the energy efficiency level was 19.85%. With the addition of EEM10, which reduces building envelope air infiltration by up to 50%, and the implementation of a more efficient cooling system with a COP of 3.14 (EEM13), the overall energy efficiency improved significantly. Overall, the implementation of these two EEM measures has exceeded the EDGE standard, which requires a minimum energy efficiency improvement of 20%.

## DISCUSSION

The discussion of this study focuses on the evaluation of green building implementation at RSUD dr. Soeratno Gemolong, Sragen using the EDGE framework across three key indicators: energy efficiency (EEM), water efficiency (WEM), and material efficiency (MEM). The results indicate that the baseline energy performance reached 19.85%, slightly below the EDGE minimum threshold of 20%, whereas water efficiency achieved 25.75% and material efficiency reached 34%, both exceeding the

required standard. These findings suggest that, at the initial stage, the building was more prepared in terms of water management and material selection than in energy performance, which is typically the most challenging aspect for hospital buildings due to their continuous operations and high service demands (Eckelman & Sherman, 2016; González et al., 2018).

The variation in performance among the three indicators can be explained by the operational characteristics of healthcare facilities. The marginal gap in energy efficiency (only 0.15% below the standard) indicates that the building already incorporates certain efficiency-supporting features; however, the dominant loads, particularly cooling systems and medical equipment, continue to drive overall consumption. In hospital buildings in Indonesia, energy use is largely influenced by HVAC systems, temperature control requirements, and round-the-clock equipment operation, making improvements in cooling efficiency and building envelope performance critical for achieving higher energy savings (Balaras et al., 2007; González et al., 2018). In contrast, the higher water efficiency performance suggests that conservation measures such as efficient fixtures and usage management are easier to implement and produce measurable results, consistent with studies highlighting the effectiveness of water-saving technologies in green buildings (Khoshbakht et al., 2018; Zuo & Zhao, 2014). The material efficiency score of 34% also indicates that the building's material specifications are relatively efficient within the EDGE calculation framework, aligning with research showing that material selection strategies can significantly contribute to sustainability performance without disrupting daily operations (Khoshbakht et al., 2018; Zuo & Zhao, 2014).

When compared with previous studies on green building implementation in hospitals, the results of this research show a consistent pattern: energy efficiency is often the primary constraint, while water and material efficiency are more readily achieved when appropriate technologies and specifications are applied (Darko & Chan, 2016; Zuo & Zhao, 2014). The novelty of this study lies in demonstrating that a building with near-compliant energy performance can achieve full compliance through targeted optimization measures. Specifically, the introduction of envelope air infiltration reduction by 50% (EEM10) and improvements in cooling system efficiency through an increased COP (EEM13) raised the energy efficiency level to 24.09%. This finding highlights that focused upgrades to the building envelope and HVAC performance can shift an existing hospital from non-compliance to compliance without requiring major structural modifications. Such results reinforce the importance of maintenance-based optimization strategies as a practical

pathway for sustainability improvements in operational healthcare facilities ([Ascione et al., 2013](#)).

Beyond technical implications, these findings emphasize that sustainability performance in healthcare buildings is shaped not only by design but also by operational management and maintenance practices. The fact that water and material indicators already meet the standard suggests that institutions can begin sustainability transitions through measures that are relatively low disruption, while energy improvements require more strategic, performance-oriented interventions. This perspective contributes to the broader understanding that green certification should not be viewed as a one-time design achievement but rather as an ongoing performance management process supported by continuous evaluation and capacity building ([Darko & Chan, 2016](#); [Zuo & Zhao, 2014](#)). The results also hold policy relevance by illustrating the need to align regulatory standards with operational practices so that sustainability targets are effectively realized in real-world building performance.

From a reflective standpoint, the implementation of green building strategies in the hospital demonstrates several functional benefits, including potential reductions in resource consumption, improved operational efficiency, and strengthened compliance with sustainable development objectives. However, the findings also reveal potential challenges, particularly the need for technical expertise, monitoring systems, and institutional commitment to sustain performance improvements over time. Without continuous maintenance and evaluation, efficiency gains may diminish, limiting long-term sustainability outcomes. Additionally, initial investment costs and the need for staff training may pose barriers to broader adoption, as noted in studies on environmentally friendly technologies in buildings ([Khoshbakht et al., 2018](#)). Therefore, successful implementation depends not only on technological solutions but also on organizational readiness and management capacity.

Based on these findings, several action-oriented implications can be proposed. First, hospital facility managers should prioritize energy-focused retrofit strategies, particularly those targeting HVAC performance and building envelope airtightness, as these interventions have proven to produce the greatest impact on overall efficiency. Second, integrating routine performance monitoring, such as periodic energy audits and system performance evaluations, is essential to sustain efficiency gains over time ([Ascione et al., 2013](#); [González et al., 2018](#)). Third, policymakers should strengthen the adoption of green

building frameworks in healthcare facilities by providing technical guidance, incentives, and capacity-building programs to ensure that sustainability initiatives extend beyond compliance into long-term operational performance. Finally, since water and material efficiency have already met the required standards, hospitals should maintain these practices while expanding efforts toward integrated waste management and recycling programs that were not yet fully implemented, thereby achieving a more comprehensive sustainability strategy (Khoshbakht et al., 2018; Zuo & Zhao, 2014)

## CONCLUSION

The main lesson from this study is that implementing green building technology in an operational hospital assessed using the EDGE framework and aligned with Indonesian regulatory requirements can produce measurable efficiency gains, but energy performance remains the most critical limiting factor for full compliance. The EDGE-based assessment shows that the case building achieved energy savings of 19.85%, which is slightly below the 20% minimum threshold, indicating that the building is very close to meeting the required performance level and that further targeted optimization has a strong likelihood of achieving compliance. In contrast, water efficiency reached 25.75%, exceeding the EDGE minimum standard, demonstrating that water conservation measures such as low-flow fixtures can be effectively implemented in hospital operations and yield substantial reductions in water use. Material efficiency also performed strongly, reaching 34%, which confirms that the building's material selection strategy has been aligned with sustainability principles and contributes to lowering the environmental impact associated with construction and maintenance activities.

This study contributes scientifically by providing an applied, performance-based evaluation of green building implementation in a real hospital setting using the three EDGE efficiency domains EEM, WEM, and MEM as an integrated measurement approach. The results offer empirical evidence that, within the Indonesian healthcare context, water and material efficiency measures can surpass certification benchmarks under existing operational conditions, while energy efficiency requires more focused interventions to address dominant loads. By quantifying baseline performance and identifying the proximity of energy outcomes to the EDGE threshold, the study strengthens the understanding of how certification-oriented tools can be used not only for assessment but also for guiding maintenance-driven improvement priorities in existing buildings.

Despite these contributions, this research has several limitations. First, the analysis relied primarily on secondary data inputs (e.g., as-built drawings, material documentation, and project records) and EDGE simulation outputs, which may not fully capture operational variability such as changes in occupancy patterns, equipment usage intensity, or seasonal performance differences in HVAC systems. Second, the scope of optimization discussion remains limited to efficiency measures identified within the EDGE framework, without conducting a detailed cost–benefit or lifecycle assessment of alternative retrofit packages. Future studies should incorporate longer-term operational monitoring (e.g., energy and water metering data), include financial feasibility analysis (CAPEX/OPEX and payback periods), and evaluate additional sustainability dimensions such as waste management and indoor environmental quality to provide a more comprehensive assessment of green hospital performance.

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