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Green Building Management Strategy Based on SWOT and Cost–Benefit Analysis: A Case Study of the Chairul Saleh Building

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Abstract: Urban growth has increased demand for office buildings, affecting energy consumption, water use, and carbon emissions. This study analyzed energy and water management strategies for the Chairul Saleh Building, Ministry of Energy and Mineral Resources, by integrating preliminary Cost-Benefit Analysis (CBA), SWOT analysis, and advanced economic feasibility evaluation. The analysis used a previously published Greenship Existing Building assessment as the contextual baseline and focused on the economic feasibility of actual and optimization strategies for energy and water management. SWOT analysis placed the building in Quadrant I, or the growth position, with internal and external factor differences of 1.44 and 0.63, indicating that improvement strategies should build on existing management capacity while addressing technical and financial constraints. Recommended strategies included MVAC/chiller retro-commissioning, site performance testing, MVAC evaluation, fluorescent-to-LED lamp replacement, AHU ducting repair, solar PV capacity improvement, rainwater and AC condensate optimization, and greywater treatment. The CBA showed that energy management was economically feasible, with NPV increasing from IDR 2,535,923,971 in the Actual Scenario to IDR 3,440,911,684 in the Optimization Scenario, with a Net B/C of 2.2 and DPP of 13.3 years. Water conservation became feasible in the Optimization Scenario, with NPV of IDR 5,564,844, Net B/C of 1.0, and DPP of 19.1 years.

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1. Introduction

Rapid urban development has driven economic growth, particularly in the industrial and office sectors. Office buildings, both public and private, are among the major contributors to energy consumption, resource utilization, and carbon dioxide emissions in urban areas [1]. Without proper management, office operations may generate negative environmental impacts, including increased energy consumption, higher carbon emissions, and deterioration of urban environmental quality [2].

As one of Indonesia's metropolitan cities, Jakarta has experienced rapid population growth and physical development alongside economic expansion.

The growing number of buildings, particularly office buildings, has significantly increased energy consumption and carbon emissions in urban areas.

Globally, the building sector accounts for approximately 30–40% of total energy consumption and greenhouse gas (GHG) emissions, making it a key sector in climate change mitigation efforts [2].Efforts to reduce GHG emissions in the building subsector can be achieved through the implementation of Green Buildings (GB). The application of green building principles in both new and existing buildings has the potential to yield average energy savings of 31% to 54%, with the highest potential in government buildings [3].

The implementation of green building practices in existing buildings in Indonesia has expanded considerably in recent years. As of September 2025, under the government's Green Building (BGH) certification scheme, 28 government buildings had obtained BGH certification [3]. Furthermore, according to the Certified Building list published by the Green Building Council Indonesia (GBCI), dozens of projects have received Greenship Existing Building certification, the majority of which are existing office and commercial buildings [4]. Previous studies also indicate that stakeholder awareness and institutional support influence the application and acceptance of green building rating systems [5,6].

In Indonesia, Greenship Existing Building has also been applied to evaluate existing government office buildings and formulate improvement recommendations [7]. One government building that has adopted green building principles is the Chairul Saleh Building of the Secretariat General of the Ministry of Energy and Mineral Resources (MEMR). A previous study on the Chairul Saleh Building, entitled *Analysis of Four Categories of Environmentally Friendly Building Assessment: Case Study of the Ministry of Energy and Mineral Resources, Jakarta*, evaluated the building using the Greenship Existing Building version 1.1 rating tool and reported that the building achieved a GOLD rating with 72 out of 117 points. The study showed that the building performed relatively well in Energy Efficiency and Conservation and Building Environmental Management, while Water Conservation remained one of the categories requiring further improvement [8].

Following the previous assessment [8], several management practices and supporting documents were updated, including energy and water monitoring, indoor environmental quality documentation, water conservation data, and operational evidence related to green building implementation. An updated internal review, using more recent operational data, indicated an increase in the Greenship score from 72 to 77 out of 117 points. This improvement suggests that the building has made progress in maintaining and enhancing green building performance. However, several technical and financial challenges remain, particularly in optimizing the MVAC/chiller system, increasing the use of renewable energy, improving the use of rainwater and AC condensate, and evaluating the economic feasibility of additional energy and water conservation strategies.

Therefore, the present study does not repeat the Greenship assessment as a primary research output. Instead, this manuscript shifts the focus from rating evaluation to strategic and economic decision-making. The updated building condition is used to identify remaining gaps and improvement priorities, while the feasibility of the proposed strategies is evaluated through actual and optimization scenarios using NPV, Net B/C, and DPP indicators.

However, in practice, implementing Green Buildings (GB) often faces complex technical, financial, and coordination challenges. Several studies have identified high initial investment costs, limited technical knowledge, and insufficient stakeholder engagement as major barriers to the optimal realization of green buildings. This is supported by Leontev's findings, who identified initial costs and information limitations as the two most significant obstacles [9]. On the other hand, a study by Cagan and Unel demonstrated that although green buildings may require an additional 7–9% of construction costs during the initial development stage, annual energy savings of 30–40% can shorten the payback period to less than 15 years [10]. Studies on green office buildings in Indonesia also show that green building implementation may require additional

initial investment, but can provide long-term benefits through energy and water savings, lower operational costs, and improved building value [11].

To address these complexities, this study adopts a SWOT (Strengths, Weaknesses, Opportunities, and Threats) approach as a strategic analytical tool [8]. A SWOT analysis was selected for its ability to comprehensively identify existing conditions, including the building's internal strengths and weaknesses, as well as external opportunities and threats associated with green building management. This approach involves key stakeholders with direct authority or knowledge of building operations, including facility managers, energy and water system technicians, and green building consultants. The selection of respondents followed a purposive approach, which is commonly used when participants are chosen based on their relevance and knowledge of the research topic [12,13]. In addition, this study employs Cost–Benefit Analysis (CBA) to evaluate the long-term costs and benefits of green building implementation [14,15].

The findings of this study are expected to provide recommendations for building managers in developing strategies to enhance sustainable energy and water management practices.

2. Methods

2.1. Study Area and Research Period

This study was conducted at the Chairul Saleh Building, Secretariat General of the Ministry of Energy and Mineral Resources (MEMR), Central Jakarta, from September 2024 to August 2025. A case study approach was employed, using both quantitative and qualitative descriptive analyses to evaluate green building implementation, assess the economic feasibility of energy and water management programs, and formulate strategies to improve green building performance in existing office buildings.

2.2. Data Collection

The study utilized both primary and secondary data. Primary data were collected through field observations, questionnaires, and in-depth interviews with stakeholders involved in the management of the Chairul Saleh Building. Respondents were selected using purposive sampling based on their knowledge, experience, and involvement in building management activities. Seven respondents participated in the SWOT analysis, consisting of building managers and individuals who had previously been involved in green building assessments. In-depth interviews were conducted with three key informants: the Head of the Maintenance Subdivision, the Building Manager of the Secretariat General of MEMR, and the Health, Safety, and Environment (HSE) Coordinator.

Secondary data included electricity and water consumption records, investment costs, operation and maintenance costs, electricity and water tariffs, carbon emission factors, building floor area, number of occupants, technical building documents, Energy Management System documents, and relevant regulations and standards.

The secondary data were interpreted with reference to relevant Indonesian regulations and standards, including energy management and energy conservation regulations [15,16], green building performance assessment regulation [18], drinking water quality requirements [19], and the carbon pricing framework used to estimate carbon emission reduction benefits [20].

2.3 Data Analysis

The analysis was conducted in three sequential stages: a preliminary Cost-Benefit Analysis (CBA), a SWOT analysis, and an advanced Cost-Benefit Analysis. The published Greenship Existing Building assessment was used solely as secondary background information and as contextual input to identify improvement priorities; this study did not recalculate Greenship category scores or treat the assessment as a separate methodological stage.

2.4 Preliminary Cost–Benefit Analysis

The first stage involved conducting a Cost–Benefit Analysis (CBA) of the energy efficiency and water conservation programs already implemented in the Chairul Saleh Building. This analysis served as a benchmark for evaluating the current condition of building management practices. The cost components included investment costs and operation and maintenance (O&M) costs. The benefit components consisted of electricity cost savings, water cost savings, benefits from photovoltaic (PV) system electricity generation, and carbon emission reduction benefits. All costs and benefits were converted into present values using a predetermined discount rate [14]. This approach is consistent with previous green building economic studies that evaluate feasibility by comparing investment costs, operational costs, and long-term life-cycle benefits [10,14,15]. A sustainable office building renovation framework has also shown that green building rating systems can be integrated with CBA to support early-stage decision-making for renovation [21].

Economic feasibility was evaluated using three indicators: Net Present Value (NPV), Net Benefit–Cost Ratio (Net B/C), and Discounted Payback Period (DPP). A program was considered economically feasible if it generated a positive NPV, a Net B/C ratio of 1 or greater, and an investment payback period within the analysis period [14].

The energy-related cost and benefit components were evaluated in relation to national energy management and energy conservation frameworks [16,17]. In addition, the benefits of carbon emission reductions were monetized using the carbon pricing reference established under Law No. 7 of 2021 [20].

2.5 SWOT Analysis

The second stage involved a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis to identify the internal and external factors affecting green building management. Internal factors consisted of strengths and weaknesses, while external factors included opportunities and threats. The assessment was conducted using the Internal Factors Analysis Summary (IFAS) and External Factors Analysis Summary (EFAS) matrices based on the published green building assessment findings, preliminary CBA results, field observations, questionnaire responses, and in-depth interviews.

The results of the SWOT analysis were used to determine the building's strategic position and to formulate alternative strategies to improve energy and water management.

2.6 Advanced Cost–Benefit Analysis

The third stage involved evaluating the economic feasibility of the proposed strategies through an advanced Cost–Benefit Analysis. The analysis was conducted under two scenarios, namely the Actual Scenario and the Optimization Scenario, over a 20-year analysis period. The Actual Scenario represented the continuation of existing programs without additional interventions. In contrast, the Optimization Scenario incorporated additional green building measures to improve energy efficiency and water conservation, based on the strategies identified through the SWOT analysis. The analysis results were used to determine the most economically feasible and environmentally beneficial energy and water management strategy for the Chairul Saleh Building.

3. Result and Discussion

3.1. Preliminary Cost–Benefit Analysis

A preliminary economic feasibility analysis was conducted to evaluate the extent to which the existing energy and water management programs have generated economic and environmental benefits during the actual implementation period. This analysis served as a benchmark prior to the formulation of green building improvement strategies. The cost components included investment and operation and maintenance (O&M) costs, while the benefit components consisted of electricity cost savings, photovoltaic (PV) system generation benefits, carbon emission reduction benefits, and water cost savings.

For the energy aspect, the actual analysis period covered 2016–2024, corresponding to the implementation of energy efficiency measures following the installation of the PV system and the initial energy audit. For the water aspect, the analysis period covered 2020–2022, based on the availability of water consumption data and the implementation period of water conservation measures. The calculated costs and benefits are presented in **Table 1**.

Table 1. Actual Costs and Benefits of Existing Programs at the Chairul Saleh Building

Aspect	Period	Program Cost (IDR)	Benefits	Total Program Benefits (IDR)
Energy	2016–2024	6,102,978,500	Electricity cost savings, PV electricity generation, and carbon emission reduction	3,838,174,733
Water	2020–2022	359,400,000	Water bill savings resulting from reduced water consumption	54,213,600

Based on **Table 1**, the energy program generated substantially higher costs and benefits than the water conservation program. This indicates that energy-related interventions have been implemented over a longer period, involved greater technical investments, and produced more diverse benefits, including electricity cost savings, PV electricity generation, and carbon emission reductions. In contrast, the water conservation program remains at an early stage, with measurable benefits limited to reductions in water utility expenses.

Regarding energy, electricity consumption decreased from 1,505,670 kWh in 2016 to 1,059,239 kWh in 2024. This reduction resulted in energy savings of 446,431 kWh in 2024 compared with the 2016 baseline year. In addition to reducing electricity costs, energy savings also generate environmental benefits by reducing carbon emissions. Building-related electricity emissions declined from 1,320.47 tCO_2 in 2016 to 928.95 tCO_2 in 2024, resulting in an emission reduction of 391.52 tCO_2 in 2024. The total nominal benefits of the energy program during 2017–2024 amounted to IDR 3,838,174,733, consisting of electricity cost savings of IDR 3,395,473,073, PV generation benefits of IDR 367,117,417, and carbon emission reduction benefits of IDR 75,584,243.

Regarding water conservation, water consumption decreased from 15,744 m^3 in 2020 to 12,207 m^3 in 2022, resulting in savings of 3,537 m^3. This reduction indicates that water consumption monitoring, leakage inspections, plumbing system maintenance, and the installation of water-saving devices, such as dual-flush toilets and faucet aerators, have contributed to improved water-use efficiency. Previous studies on certified green buildings indicate that water-efficiency assessment should be supported by quantitative estimation and validation of actual water-saving performance [22]. However, the economic benefits of water conservation remained substantially lower than those generated by the energy program. This difference is not solely attributable to utility tariffs but also to differences in the units and volumes of savings achieved. Energy benefits were calculated based on electricity savings measured in kilowatt-hours (kWh), which involved larger volumes and a longer implementation period. In contrast, water benefits were calculated based on water savings measured in cubic meters (m^3), which were relatively smaller in volume and covered a shorter period. Furthermore, the energy program generated additional benefits from PV electricity production and carbon emission reductions, whereas the water conservation program, under current conditions, generated benefits only from reduced water bills. With a water tariff of IDR 9,800/m^3, total water savings of 5,532 m^3 generated economic benefits of only IDR 54,213,600 during 2021–2022.

After calculating all costs and benefits within the initial analysis period, an economic feasibility assessment was conducted. The analysis was based on the present value (PV) of costs and benefits using a discount rate of 4.79% [9]. The results are presented in **Table 2**.

Table 2. Economic Feasibility of Existing Programs at the Chairul Saleh Building

Aspect	PV Benefit (IDR)	PV Cost (IDR)	NPV (IDR)	Net B/C	DPP	Status
Energy	3,007,694,777	5,309,868,773	-2,302,173,996	0.60	Not achieved	Not feasible
Water	50,223,453	342,589,870	-292,366,417	0.15	Not achieved	Not feasible

Based on **Table 2**, the preliminary CBA results indicate that neither the energy program nor the water conservation program achieved investment payback during the actual implementation period. For the energy program, the NPV value of −IDR 2,302,173,996 and Net B/C ratio of 0.60 indicate that the accumulated benefits were insufficient to offset investment and O&M costs during 2016–2024. This outcome was primarily influenced by substantial initial investments, including the installation of PV systems, Energy Management Systems (EMS), Building Automation Systems (BAS), modular chillers, Air Handling Units (AHU), and improvements to the energy management system.

Similarly, the water conservation program generated an NPV of −IDR 292,366,417 and a Net B/C ratio of 0.15, indicating that the economic benefits from water savings remained considerably lower than the associated investment and O&M costs. This result was mainly due to the shorter analysis period, relatively low water savings, and limited storage capacity for harvested rainwater and air-conditioning condensate water under existing conditions.

The preliminary CBA results demonstrate that the ongoing green building programs have achieved positive outcomes in energy efficiency, water conservation, and carbon emission reductions. However, these benefits have not yet been sufficient to recover the program costs within the actual implementation period. Therefore, a SWOT analysis was conducted to identify internal and external factors influencing building management and to formulate improvement strategies better aligned with the characteristics and operational conditions of the Chairul Saleh Building, an existing building.

3.2 SWOT Analysis

SWOT analysis was conducted to identify the internal and external factors influencing green building management at the Chairul Saleh Building. Internal factors consisted of strengths and weaknesses related to technical conditions, institutional arrangements, human resources, operational systems, and achievements in energy and water management. External factors included opportunities and threats associated with regulations, technological developments, policy support, investment costs, incentives, and challenges related to green building implementation in existing buildings.

The SWOT factors were identified based on the previously published green building assessment findings, the preliminary Cost–Benefit Analysis (CBA), field observations, questionnaires, and interviews with building management personnel. Each factor was assigned a weight reflecting its importance to green building management success, on a scale from 0 to 1, with a total weight of 1.00. Ratings were assigned using a scale of 1 to 5 to reflect the current building condition or the building's response to each factor. The weighted score was calculated by multiplying each rating by its weight and summing the results to obtain the subtotal for each factor. The results of the internal factor assessment are presented in **Table 3**.

The results of the internal factor analysis indicate that the Chairul Saleh Building possesses substantial strengths in its well-established energy management system. The highest weighted score was achieved by routine monitoring and evaluation of the Energy Management System (0.38), followed by the availability of qualified technical personnel, the Energy and Water Conservation Team, top management support, and the achievement of ISO 50001 certification and energy-related awards, each with a weighted score of 0.36. Interview results revealed that electricity and water consumption data have been routinely recorded through daily checklists, internal reporting systems, and periodic evaluations whenever consumption increases. However, vampire energy control measures and the utilization of rainwater and recycled water received relatively low weighted scores (0.22), indicating that some electrical load controls remain manual and the use of alternative water sources has not yet been fully optimized.

Table 3. Internal Factor Evaluation (IFE) Matrix

No.	Internal Factors	Weight	Rating	Weighted Score
Strengths				
S1	Availability of technical personnel with knowledge and experience in green building management	0.08	4.57	0.36
S2	Routine monitoring and evaluation of the Energy Management System to ensure efficiency targets are achieved	0.08	4.71	0.38
S3	Active Energy and Water Conservation Team responsible for monitoring energy and water consumption	0.08	4.57	0.36
S4	Strong support from top management through policies, budget allocation, and official directives supporting green building implementation	0.08	4.57	0.36
S5	Training programs to improve employee awareness of green building concepts	0.08	4.43	0.33
S6	Achievement of ISO 50001 certification, ASEAN Energy Awards, and related recognitions	0.08	4.57	0.36
S7	Installation of load-control systems to reduce vampire energy consumption in utility systems	0.06	3.57	0.22
S8	Availability of infiltration wells, rainwater filtration systems, and partial utilization of recycled water (air-conditioning condensate)	0.06	3.57	0.22
	Subtotal Strengths	**0.60**	**4.32**	**2.62**
Weaknesses				
W1	Significant investment costs required for implementing environmentally friendly technologies	0.05	3.00	0.15
W2	Limited and unstable budget allocation for green building development and maintenance	0.05	2.86	0.14
W3	Limited understanding of the Energy Management System among employees within the Secretariat General of MEMR	0.04	2.14	0.08
W4	Insufficient coordination among stakeholders involved in building management	0.05	2.86	0.14
W5	Aging building infrastructure and equipment (more than 10 years old)	0.06	3.43	0.20
W6	Limited availability of environmentally friendly products in the surrounding area	0.05	2.71	0.13
W7	Limited land availability, constraining compliance with the minimum 30% green open space requirement	0.05	3.14	0.17
W8	Uncertainty regarding measurable benefits obtained from green building implementation	0.05	3.00	0.15
	Subtotal Weaknesses	**0.40**	**2.89**	**1.18**
	Internal Factor Difference (Strengths − Weaknesses)	**1.00**		**1.44**

The main weaknesses identified were the aging condition of building infrastructure and equipment (0.20), limited land availability (0.17), investment burden (0.15), and budget constraints (0.14). Overall, the subtotal strength score of 2.62 exceeded the subtotal weakness score of 1.18, resulting in an IFAS value of 1.44. This finding indicates that the internal condition of the Chairul Saleh Building is relatively strong. Nevertheless, green building improvements should be implemented selectively and gradually, while considering the existing building's characteristics and constraints.

Following the internal factor assessment using the Internal Factor Evaluation (IFE) Matrix, the next stage involved analyzing external factors through the External Factor Evaluation (EFE) Matrix. This analysis was conducted to assess the opportunities and threats influencing green building enhancement at the Chairul Saleh Building from regulatory, technological, financial, incentive-related, and existing-building implementation perspectives. Each factor was assigned a weight ranging from 0 to 1 and a rating on a scale of 1 to 5. The weighted score was obtained by multiplying the assigned weight by the rating, and the scores were subsequently summed to obtain the subtotal values for opportunities and threats. The results of the external factor assessment are presented in **Table 4**.

Table 4. External Factor Evaluation (EFE) Matrix of the Chairul Saleh Building

No.	External Factors	Weight	Rating	Weighted Score
Opportunities				
O1	Improving building energy performance through comprehensive recommissioning of major systems such as HVAC and chillers	0.07	4.57	0.33
O2	Potential for achieving a higher Greenship rating in the future	0.08	5.00	0.39
O3	Green Open Space (GOS) policies encouraging landscape optimization through green roofs and vertical gardens	0.07	4.29	0.29
O4	Improved stormwater management performance through quantitative monitoring of runoff volume	0.07	4.29	0.29
O5	Implementation of an integrated and documented environmentally friendly procurement system	0.07	4.43	0.31
O6	Regular monitoring of indoor temperature and relative humidity to meet thermal comfort standards	0.07	4.29	0.29
O7	Implementation of drinking water filtration systems to improve occupant health and water quality	0.06	3.71	0.22
O8	Water management innovations (AC condensate reuse, infiltration wells, and greywater utilization) to reduce dependence on municipal water supply	0.06	4.00	0.25
	Subtotal Opportunities	**0.55**	**4.32**	**2.36**
Threats				
T1	High levels of urban pollution potentially increasing building energy consumption	0.06	3.71	0.22
T2	Limited public awareness of green building concepts	0.06	4.14	0.27
T3	Insufficient government incentives to encourage green building investment	0.06	4.00	0.25
T4	Green building is not yet a primary development priority	0.06	3.86	0.23
T5	Perception that green building investment and maintenance costs are expensive	0.07	4.29	0.29
T6	Limited availability of certified green building professionals	0.04	2.29	0.08
T7	Relatively high costs of environmentally friendly technologies	0.06	3.57	0.20
T8	Weak regulatory enforcement may reduce stakeholder motivation to invest in sustainable initiatives	0.05	3.43	0.18
	Subtotal Threats	**0.45**	**3.66**	**1.72**
	External Factor Difference (Opportunities − Threats)	**1.0**		

The EFE matrix results indicate that the most significant opportunity for green building development at the Chairul Saleh Building is to achieve a higher Greenship rating, with a weighted score of 0.39. This is followed by the opportunity to improve energy performance through HVAC and chiller recommissioning (0.33) and water management innovations, including the utilization of air-conditioning condensate, infiltration wells, rainwater harvesting, and potential greywater reuse (0.25). These opportunities are highly relevant to the building's current condition, as the air-conditioning system is the largest energy-consuming component, while water management measures have already been initiated through a 1 m^3 rainwater storage tank, routine monitoring, and the installation of separate water meters for cafeteria tenants.

On the other hand, the major threats identified include the perception that green building investment and maintenance costs are expensive (0.29), limited government incentives to encourage green building investment (0.25), and the relatively low priority given to green building development within broader development agendas (0.23). The shortage of qualified green building professionals was considered a relatively minor threat, with a weighted score of 0.08, as the building already has an Energy and Water Conservation Team, internal auditors, and trained personnel with experience in energy management and green building implementation.

Overall, the subtotal opportunity score of 2.36 exceeded the subtotal threat score of 1.72, resulting in an EFAS value of 0.63. This finding indicates that the external environment remains favorable for further green building development and provides substantial opportunities to enhance the building's environmental performance.

The SWOT analysis further revealed that the subtotal strength score (2.62) was higher than the subtotal weakness score (1.18), while the subtotal opportunity score (2.36) exceeded the subtotal threat score (1.72). Consequently, the internal factor difference was calculated at 1.44, whereas the external factor difference was 0.63. These values position the Chairul Saleh Building in Quadrant I (Growth Position) of the SWOT matrix. The IFAS and EFAS values were subsequently used to determine the building's strategic position in the SWOT diagram. The results of this mapping process are presented in Figure 1.

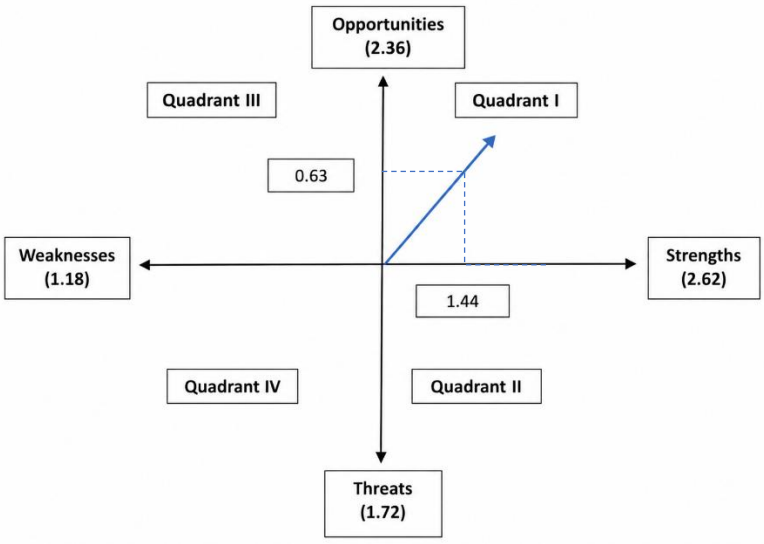


Figure 1. SWOT Diagram of the Chairul Saleh Building

The SWOT diagram confirms that the Chairul Saleh Building is positioned in Quadrant I, or the Growth Position. This position indicates that the building has relatively strong internal capacity and favorable external opportunities to support further green building development. The strengths identified in the analysis, such as qualified technical personnel, routine monitoring systems, strong management commitment, and previous

experience in energy management, provide an important foundation for improving building performance. At the same time, opportunities for energy performance improvement, greater potential for a higher Greenship rating, and water management innovation indicate that further enhancement strategies can still be developed.

Therefore, the SWOT results were not only used to describe the building's strategic position but also served as the basis for formulating energy and water management strategies. The recommended strategies were developed by considering the relationship between internal strengths and weaknesses, external opportunities and threats, and the practical constraints of managing an existing government office building. Based on this interpretation, the analysis was continued by grouping the recommended strategies into Actual and Optimization Scenarios, which were subsequently evaluated through economic feasibility analysis.

3.3 Recommended Management Strategies and Advanced Cost–Benefit Analysis

The building's primary strengths lie in the competence of its management personnel, well-established energy and water monitoring systems, strong management commitment, the active Energy and Water Conservation Team, and extensive experience in implementing ISO 50001 and green building practices. Based on the SWOT analysis results, green building management strategies were formulated using an adaptive approach that considers the strengths, weaknesses, opportunities, and threats affecting the management of the existing building. The recommended management strategies are presented in **Table 5**.

Table 5. Recommended Energy and Water Management Strategies for the Chairul Saleh Building

No.	Recommendation Focus	Key SWOT Evidence	Strategic Actions	Scenario
1	Strengthening energy audits, monitoring, and the Energy Management System	Supported by experienced technical personnel (S1), routine monitoring (S2), the Energy and Water Conservation Team (S3), and ISO 50001 certification (S6); however, the measurable benefits remain uncertain (W8)	(1) Continue periodic energy audits and evaluations; (2) Monitor electricity and water consumption; (3) Report monitoring and evaluation results.	Actual
2	Strengthening human resource capacity and promoting an energy- and water-saving culture	Supported by the active role of the Energy and Water Conservation Team (S3), top management commitment (S4), and training programs (S5), this strategy aims to improve employees' understanding of the Energy Management System (W3)	(1) Continue awareness-training programs; (2) Organize energy and water conservation seminars involving employees from different bureaus/divisions and building management staff; (3) Establish annual energy-saving awards among bureaus.	Actual
3	Optimization of EMS, BAS, and electrical load control systems	Supported by EMS monitoring (S2), the Energy and Water Conservation Team (S3), ISO 50001 certification and energy-related awards (S6), as well as vampire energy control (S7), this strategy needs to consider the high investment and maintenance costs of environmentally friendly technologies (T5, T7)	Optimization of EMS, BAS, load-shedding "vampire energy" control, and equipment operating schedules to maximize the efficiency of existing systems before considering investment in more expensive new technologies.	Actual

No.	Recommendation Focus	Key SWOT Evidence	Strategic Actions	Scenario
4	Maintenance of PV systems, solar-powered street lighting, and existing energy infrastructure	Supported by energy monitoring (S2), top management commitment (S4), ISO 50001 certification (S6), and the opportunity to improve the Greenship rating (O2)	(1) Continue maintenance of PV systems and solar-powered street lighting; (2) Record PV electricity generation, evaluate output degradation, and inspect supporting components as the basis for future PV capacity improvement.	Actual
5	MVAC/chiller retro-commissioning and site performance testing	Supported by qualified human resources (S1), energy monitoring (S2), top management commitment (S4), and the opportunity to improve HVAC/chiller system efficiency (O1)	Conduct kW/TR evaluations, site performance tests, and retro-commissioning of MVAC/chiller systems to assess current performance and improve building energy efficiency.	Optimization
6	Improving lighting efficiency and chilled-air distribution systems	Supported by the Energy and Water Conservation Team (S2), energy monitoring (S3), management commitment (S4), and ISO 50001 certification (S6), this strategy is directed toward improving efficiency and the Greenship rating (O1, O2)	(1) Replace fluorescent lamps with LED lighting; (2) Improve AHU ducting systems to achieve more uniform air distribution and enhance HVAC efficiency.	Optimization
7	Strengthening existing water conservation practices	Infiltration wells, rainwater filtration systems, and AC condensate reuse are already available (S8). However, the measurable benefits still need to be strengthened (W8)	Continue leakage inspections and maintenance of plumbing systems, infiltration wells, and AC condensate collection systems.	Actual
8	Optimization of rainwater, AC condensate, and greywater utilization	Supported by infiltration wells and AC condensate reuse (S8), this strategy is directed toward managing stormwater runoff while reducing dependence on municipal water supply (O4, O8)	(1) Increase rainwater and condensate storage capacity; (2) Record harvested and utilized water volumes; (3) Implement a modular sewage treatment plant (STP) for greywater treatment and non-potable water reuse.	Optimization

Based on **Table 5**, the recommended energy and water management strategies for the Chairul Saleh Building were grouped into two scenarios: the Actual Scenario and the Optimization Scenario. The Actual Scenario consists of strategies to strengthen existing programs. Rather than introducing major new interventions, these strategies focus on maintaining the efficiency gains already achieved through routine operational activities, preventive maintenance, data recording, monitoring, and periodic evaluations. The objective is to ensure the long-term sustainability of current energy and water management practices while maximizing the effectiveness of existing resources and infrastructure.

In contrast, the Optimization Scenario includes strategies that require additional technical interventions and relatively substantial investments. These measures include MVAC/chiller retro-commissioning, site performance testing, replacement of fluorescent lamps with LED lighting, improvement of AHU ducting

systems, expansion of photovoltaic (PV) system capacity, increased rainwater and air-conditioning condensate storage capacity, and the implementation of a modular sewage treatment plant (STP) for greywater reuse in non-potable applications. These interventions are expected to generate greater economic and environmental benefits than those achieved under current conditions. The water-related measures are also consistent with studies showing that rainwater harvesting and greywater recycling can reduce freshwater consumption for non-potable uses and improve water efficiency in office buildings [23]. Previous studies on existing office buildings similarly show that HVAC optimization, lighting replacement, building control systems, and smart technologies can improve energy performance and reduce operational costs when supported by appropriate technical and economic evaluation [21,24,25].

To evaluate the feasibility of the proposed strategies, an advanced economic feasibility analysis was conducted using a scenario-based CBA approach. The analysis was developed from the recommended strategies presented in Table 5. For the energy aspect, the Actual Scenario represents the continuation of existing energy management practices, while the Optimization Scenario includes additional measures such as MVAC/chiller retro-commissioning, site performance testing, LED lighting replacement, AHU ducting improvement, and PV capacity expansion. For the water aspect, the Actual Scenario reflects existing water conservation practices, whereas the Optimization Scenario includes increased rainwater and AC condensate storage capacity and greywater reuse for non-potable purposes.

The cost components consisted of investment and O&M costs, while the benefit components included electricity cost savings, PV electricity generation benefits, carbon emission reduction benefits, and water bill savings. Annual costs and benefits were converted into present values and evaluated using Net Present Value (NPV), Net Benefit-Cost Ratio (Net B/C), and Discounted Payback Period (DPP) indicators. The results are presented in **Table 6**.

Table 6. Economic Feasibility Results of the Actual and Optimization Scenarios

Aspect	Scenario	NPV (IDR)	Net B/C	DPP	Status
Energy	Actual	2,535,923,971	1.9	13.2 years	Feasible
Energy	Optimization	3,440,911,684	2.2	13.3 years	Feasible
Water	Actual	-507,922,934	0.6	Payback Period Not Reached	Not Feasible
Water	Optimization	5,564,844	1.0	19.1 years	Feasible

Based on **Table 6**, the economic feasibility analysis indicates that energy efficiency and conservation measures are more economically viable than water conservation initiatives. Regarding energy, the Actual Scenario demonstrated economic feasibility, with an NPV of IDR 2,535,923,971, a Net B/C ratio of 1.9, and a DPP of 13.2 years. These results indicate that the existing energy management programs, including photovoltaic (PV) utilization, energy monitoring, electrical load control, implementation of the Energy Management System, and routine maintenance activities, have generated economic benefits that exceed their associated costs over the analysis period. Therefore, the Actual Scenario should serve as the foundation for energy management practices within the building.

However, compared with the Actual Scenario, the Optimization Scenario produced superior economic performance. The NPV increased to IDR 3,440,911,684, while the Net B/C ratio increased to 2.2. These improvements indicate that additional interventions, including MVAC/chiller retro-commissioning, site performance testing, replacement of fluorescent lamps with LED lighting, improvement of AHU ducting systems, and expansion of PV capacity, can significantly enhance both economic and environmental benefits. Although the DPP under the Optimization Scenario is slightly longer, at 13.3 years compared with 13.2 years under the Actual Scenario, the difference is negligible and remains well within the analysis period. Therefore, for the energy aspect, the Optimization Scenario is recommended because it generates higher net benefits and strengthens long-term energy efficiency performance.

For water conservation, the Actual Scenario was not economically feasible. The NPV of −IDR 507,922,934, Net B/C ratio of 0.6, and the absence of a payback period indicate that savings from reduced water consumption alone were insufficient to recover investment and operation and maintenance (O&M)

costs during the analysis period. This result is primarily attributable to the limited benefits generated under existing conditions, where the utilization of rainwater and air-conditioning condensate remains relatively low. Consequently, maintaining the current condition alone is insufficient to improve the economic feasibility of water conservation programs.

The Optimization Scenario for water conservation demonstrated improved performance, with a positive NPV of IDR 5,564,844, a Net B/C ratio of 1.0, and a DPP of 19.1 years. These results suggest that increasing rainwater and condensate storage capacity, combined with the utilization of greywater for non-potable purposes, can improve economic returns compared with the Actual Scenario. This is in line with previous studies showing that rainwater harvesting, greywater recycling, and quantitative water-saving assessment can strengthen water efficiency in green buildings [22,23]. Nevertheless, the relatively small NPV and the Net B/C ratio at the minimum feasibility threshold indicate that the economic viability of water conservation remains marginal. Therefore, optimization of water conservation measures can still be recommended; however, implementation should be carried out selectively and gradually, accompanied by strict control of investment and O&M expenditures.

Based on these findings, the recommended management strategy for the Chairul Saleh Building should focus on the Optimization Scenario, particularly in the energy sector, which demonstrated the greatest improvement in economic feasibility. For water conservation, the Optimization Scenario is also necessary because the Actual Scenario remains economically unfeasible. However, implementation should prioritize the most realistic and measurable interventions, including increased utilization of rainwater and air-conditioning condensate, systematic recording of alternative water volumes, and phased evaluation before the full implementation of greywater systems. Overall, the Actual Scenario serves as the baseline management approach that should be maintained, while the Optimization Scenario provides a strategic pathway to enhance long-term economic, environmental, and green building performance.

4. Conclusion

This study demonstrates that the management of the Chairul Saleh Building can be strengthened by combining economic feasibility analysis and SWOT-based strategy formulation. The preliminary Cost–Benefit Analysis showed that existing energy and water management programs have generated measurable benefits through energy savings, water savings, photovoltaic electricity generation, and carbon emission reductions, although the benefits had not fully recovered investment and operational costs within the actual implementation period. The SWOT analysis positioned the building in Quadrant I (Growth Position), indicating favorable internal and external conditions for further green building development. Based on the advanced economic feasibility analysis, the Optimization Scenario provides greater economic and environmental benefits than the Actual Scenario, particularly in the energy sector through MVAC/chiller retro-commissioning, site performance testing, LED lighting replacement, AHU ducting improvement, and photovoltaic system expansion. Meanwhile, water conservation optimization through increased use of rainwater, air-conditioning condensate, and greywater can improve economic feasibility, though the resulting benefits remain relatively limited and should be implemented gradually with strict cost controls. Therefore, maintaining existing management practices while progressively implementing optimization measures is recommended to enhance long-term economic performance, environmental sustainability, resource efficiency, and green building performance at the Chairul Saleh Building.

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