Energy Efficiency Consumption of Building Planning Based on Indonesia Green Building Rules: A Case Study

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***Abstract*—This study evaluates the energy performance of the Tower B building in Riau Province, Indonesia, based on green building assessment criteria, with a focus on energy use efficiency. The initial design showed a total energy consumption of 2,255,923 kWh/year, corresponding to an Energy Use Intensity (EUI) of 95.46 kWh/m²/year, and earned a moderate energy score of 30 out of 46. Two operational strategies were proposed to address inefficiencies: (1) reducing the number of elevator units from six to four, and (2) implementing separate grouping of luminaires based on daylight exposure. Simulation results indicated that these strategies could reduce energy consumption in the elevator system by 33% and in the lighting system by 13%, without compromising user service standards. The combined application of both measures reduced total building energy use to 1,949,861 kWh/year (EUI 82.51 kWh/m²/year), yielding a 29% overall reduction and increasing the energy efficiency score to 38. While the results are promising, further research is needed to validate implementation through sensitivity analysis, behavioral modeling, and integration into regulatory frameworks. This study highlights the potential of adaptive operational strategies in optimizing building energy performance in tropical urban contexts.**

***Keywords*—Green Building, Energy Efficiency, Daylighting, Elevator Efficiency, Energy Use Intensity (EUI)**

I. Introduction

Indonesia ranks as the third-largest energy consumer in the building and construction sector, with projections indicating a continued increase in demand by 2030 if energy use is not properly managed [1]. Buildings currently account for approximately 50% of the nation's total energy consumption and more than 70% of electricity use, predominantly sourced from fossil fuels [2]. The surge in national energy consumption from 850 million to 1.1 billion barrels in 2022 underscores the urgent need for transformative energy strategies, particularly within high-demand sectors such as buildings [3].

In response, the green building movement has gained increasing attention both globally and nationally as a strategic approach to enhance energy efficiency and minimize environmental impacts. Green buildings integrate sustainable principles into the design, construction, and operation of buildings, aiming to reduce their environmental footprint while promoting occupant comfort and operational cost efficiency [4]. In Indonesia, this commitment is formalized through Ministerial Regulation of the Minister of Public Works and Housing of the Republic of Indonesia No. 21 of 2021, which provides a comprehensive assessment framework for green buildings, encompassing energy and water efficiency, materials use, waste management, and indoor environmental quality.

The development of Indonesia's green building standards has been informed by international rating tools, such as BREEAM (UK), LEED (USA), NABERS and Green Star (Australia), and Green Mark (Singapore) [5]. At the national level, two main frameworks are widely adopted: the Greenship rating system by the Green Building Council Indonesia (GBCI), and the government's own regulation, namely Ministerial Regulation of the Minister of Public Works and Housing of the Republic of Indonesia No. 21 of 2021 [6]. Despite these institutional mechanisms, the application of green building principles remains predominantly concentrated in Java and is mostly limited to projects developed by private and state-owned enterprises [6]–[9]. Meanwhile, there are still no buildings outside Java Island that have received green building certification, especially in government buildings.

This is proven by the G building of the Ministry of PUPR which is one of two green building certified government buildings among private buildings. The Ministry of PUPR building received the ASEAN Energy Awards 2023 green building awards sub-category Large Building. Building G of the Ministry of PUPR was built with the concept of green building with an estimated electricity savings of around 59% against the average Energy Use Intensity (EUI) of office buildings and 29% against the design IKE and 71.7% savings in water consumption against the Indonesian national standard EUI [10].

One of the aspects regulated in the Minister of Public Works and Public Housing Regulation No. 21 of 2021 related to green buildings is the aspect of energy use efficiency [11]. This aspect has the highest score with a score of 46 out of a total score of 165 or 28% of the maximum score. Green buildings have an important role in rationalizing energy consumption, this is in accordance with the purpose of designing green building, which is to reduce negative impacts on the environment, focus on sustainability, and energy efficiency. Prior research has demonstrated the significant potential of energy-saving measures in certified green buildings. These include architectural interventions (e.g., orientation, daylighting, passive design), technological upgrades (e.g., low-E glazing, efficient HVAC), and operational strategies (e.g., lighting schedules, smart controls) [12]–[18]. However, these studies typically assess

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outcomes after construction or certification, and primarily in urban or Java-based contexts, leaving a critical gap in understanding how green building regulations are interpreted and applied in decentralized provinces especially in government-led developments.

Moreover, the planning phase of public projects remains underexplored, despite its critical importance in determining long-term building performance. Few studies have evaluated whether public-sector building designs in non-Java regions are aligned with national energy efficiency benchmarks before construction begins. Additionally, there is limited understanding of the practical feasibility, institutional readiness, and scoring potential of such projects when evaluated against the stringent criteria of Ministerial Regulation of the Minister of Public Works and Housing of the Republic of Indonesia No. 21 of 2021. To address these gaps, this study poses the following research question: *To what extent do publicly funded building projects in decentralized provinces like Riau align with national green building energy efficiency criteria during the planning phase?*

This study makes two key contributions. First, to the best of our knowledge, it presents the first empirical assessment of a government-owned project outside Java that applies the national green building framework during the design and planning phase. Second, it introduces a forward-looking evaluative model by analyzing energy use projections based on architectural and engineering design documents, before construction begins. This approach enables critical insights into regulatory feasibility, scoring outcomes, and implementation readiness in decentralized regions offering evidence-based recommendations to enhance the effectiveness of national policies at the subnational level.

Therefore, this study aims to evaluate the planned energy performance of a government building project in Riau Province, using the criteria set out in Ministerial Regulation of the Minister of Public Works and Housing of the Republic of Indonesia No. 21 of 2021, with a specific focus on energy use efficiency the most heavily weighted aspect in the regulatory framework. By doing so, the study contributes to a more context-sensitive understanding of green building policy implementation in Indonesia.

II. Material and Methods

The approach used in this research is a quantitative approach, which aims to analyze the achievement value of the green building concept in the aspect of energy use efficiency. The assessment is carried out based on the calculation of energy use efficiency criteria. The results of the temporary assessment will be validated by experts, and this research will provide recommendations related to indicators that do not comply with green building requirements.

A. Location

The research site is located in Pekanbaru City, Riau Province, Indonesia. Riau Province is located on the island of Sumatra. Fig. 1 shows the location on an Indonesian map of the Province of Riau and the city of Pekanbaru.

This research was conducted at the Riau Province Office Tower Construction Project, Indonesia based on the Minister of Public Works and Public Housing Regulation No. 21 of 2021, especially in Tower B. This project is still in the planning stage. The project occupies an area of 38,007 m^2, with 5 building periods in it, namely 2 towers, each tower consists of 12 floors and 3 buildings including the conference building, archive building, and mosque. This integrated office is a place where several government activities take place which are united into one area so as to create cooperation between one activity and another. The development aims to achieve good governance through the development of office infrastructure. However, in this study the building under study is specifically the Tower B building which occupies an area of 10,616 m^2, consisting of 12 floors shown in Fig. 2.



Fig 1. Pekanbaru City.



Fig 2. Tower B site plan project.

B. Data Analysis

The research employed a quantitative analysis approach to evaluate project planning data based on energy use efficiency criteria stipulated in the Regulation of the Minister of Public Works and Public Housing No. 21 of 2021 on Green Building Performance Assessment. The parameters assessed include six key indicators: building envelope, ventilation system, air conditioning system, transportation system within the building, energy efficiency calculation, and electrical system. Data were obtained from the technical planning documents of the Riau Province Office Tower Project. The analysis was conducted by comparing each component of the planning documents with the regulatory parameters, using a scoring rubric aligned with the official evaluation guidelines. Each criterion was scored according to the corresponding weight outlined in the regulation, and the total energy efficiency score was calculated by summing all component scores.

The primary data sources consisted of official technical planning documents for the Riau Province Office Tower Project, including the Detail Engineering Design (DED), Terms of Reference (TOR), and Specifications and Planning Requirements. These documents provided architectural, mechanical, electrical, and environmental design data essential for energy performance assessment. To perform the analysis, this study used Autodesk Revit, a Building

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Information Modeling (BIM) software, specifically its built-in Energy Analysis Tool. The 3D digital model of the building, constructed based on the collected documents, was simulated using Revit to generate quantitative data such as Energy Use Intensity (EUI), HVAC loads, lighting efficiency, and building envelope thermal performance. The simulation outputs were then matched with the assessment criteria from the Regulation of the Minister of Public Works and Public Housing No. 21 of 2021. A comparative scoring analysis was applied to quantify the degree of compliance across six sub-criteria of energy efficiency. The analysis was conducted by comparing each component of the planning documents with regulatory parameters, using a scoring rubric aligned with the official evaluation guidelines. Each criterion was scored according to the corresponding weight outlined in the regulation, and the total energy efficiency score was calculated by summing all component scores.

To ensure methodological rigor, an expert validation process was conducted involving two professionals certified as key experts in green building assessment by the Ministry of Public Works and Housing. These experts are green building consultants with experience in energy audits of government buildings. The validation was conducted in two stages: (i) content validation, where the experts assess the relevance and accuracy of the simulation parameters and assessment criteria; and (ii) outcome validation, where the experts review the assessment results and provide feedback to refine the compliance rating and guide the final recommendations. To improve clarity and replicability, Fig 3 has been added to illustrate the data analysis workflow, from data collection and modeling to assessment and validation by experts.

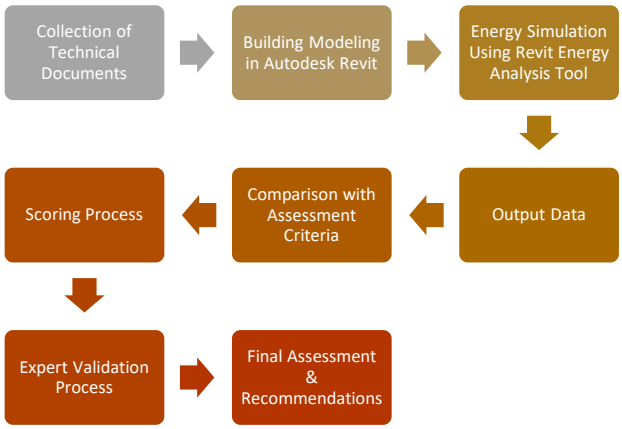

Fig 3. Flowchart analysis.

The findings of this study provide important insights that extend beyond the specific case of the Riau Province Office Tower and can serve as a valuable input for shaping national energy efficiency policies in Indonesia. By demonstrating a structured methodology for evaluating energy performance during the *planning stage* using official design documents, BIM-based simulations, and expert validation this study highlights the potential for early-stage interventions that can significantly improve the energy profile of public buildings. Integrating such an approach into national procurement guidelines or green public infrastructure standards could promote cost-effective and performance-oriented planning in future government projects.

Furthermore, the methodology developed in this study is replicable and adaptable, particularly for projects that adhere to formal technical documentation and standardized design workflows. It can be generalized and applied to other public and private building projects across Indonesia especially in urban development initiatives where compliance with Ministerial Regulation of the Minister of Public Works and Housing of the Republic of Indonesia No. 21 of 2021 or similar sustainability frameworks is required. The combined use of Revit-based energy modeling, regulatory mapping, and expert review offers a robust framework for energy evaluation that supports both design validation and policy compliance.

However, this study also has some limitations. First, the analysis is limited by the availability and accuracy of planning documents; inconsistencies between design and actual construction may lead to deviations in actual energy performance. Second, the use of simulation software assumes a standard occupancy schedule and environmental baseline, which may not fully reflect dynamic user behavior or local climate variations. Third, the number of experts involved in the validation process was limited to certified professional consultants, which, while adequate, could benefit from broader stakeholder input in future studies. These limitations point to the need for future studies that integrate post-occupancy performance data and expand stakeholder engagement to further validate and refine the methodology.

III. Results

A. *Building Envelope*

The building envelope is the outermost element of the building that directly faces the external environment, serving as a barrier between the external environment and the interior of the building [19]. The purpose of calculating the building envelope is to assess the thermal performance of the building envelope wall and determine whether the building is energy efficient by choosing the right building envelope. Fig 4 shows the building that will be studied in this research, the building uses a curtain wall facade. The curtain wall facade is a non-structural wall system consisting of glass panels combined with a frame made of aluminum or steel. Curtain walls have several advantages, one of which is related to energy efficiency. By using glass, the building can receive daylighting, which can reduce the need for artificial lighting. Thus, this system is one of the efforts in saving energy consumption by maximizing daylighting and by using materials that have good insulation properties.



Fig 4. Tower B building drawing plan.

This indicator has several calculations such as Overall Thermal Transfer Value (OTTV), Roof Thermal Transfer Value (RTTV), and Window to Wall Ratio (WWR). OTTV is

the overall heat transfer value of the building's outer envelope, RTTV is the overall heat transfer value for the roof, while WWR is the ratio of window area to external wall area. Facade area is the building area seen from each view (m^2), α is the value of solar radiation absorption based on the building materials and paint colors used, in this building the α value is 0.76. U light brick is (U_w) is the value of the thermal transmittance of opaque walls obtained based on the conductivity value and the thickness of the wall material used (W/ m^2K), U light brick value of 1.74 W/ m^2K. While U glass is (U_w) is the value of the thermal transmittance of translucent or translucent walls (W/ m^2K) the value taken is 4.40 W/ m^2K, shading coefficient (SC) is the shading coefficient of the penetrating system, SC value taken 0.21. SF is the solar radiation factor (W/m^2). In the OTTV calculation, each building orientation has a different SF value. T_{dek} is the equivalent temperature difference (K) in this building according to the calculation results obtained T_{dek} value of 12 K, and ΔT is the planning temperature difference between the outside and the inside which has been set at 5K.

TABLE I. OVERALL THERMAL TRANSFER VALUE (OTTV) CALCULATION

Building Orientation	Phase Area (m^2)	WWR	SF (W/m^2)	OTTV (W/m^2)	OTTV Total (W/m^2)
North	3,887.73	48%	125	31.20	32.68
South	3,887.73	48%	129	31.60	
East	2,269.08	50%	152	34.54	
West	2,846.25	40%	200	34.68	

RTTV calculation is the same as OTTV calculation. The α value on the roof is taken as 0.54 according to the material and paint used, the SC value is taken as 0.22, and the SF value is the same as the SF value in OTTV. Roof area (Ar) is the area of the roof that is not transparent (m^2), As is the area of the light hole or the roof area that is transparent (m^2), T_{dek} is the equivalent temperature difference (K) in this building according to the calculation results obtained T_{dek} roof value of 16 K, and ΔT is the planning temperature difference between the outside and the inside which has been set at 5K.

TABLE II. ROOF THERMAL TRANSFER VALUE (RTTV) CALCULATION

Total Roof Area (m^2)	Roof Area (Ar) (m^2)	Light Hole Area (As) (m^2)	U Roof (W/ m^2K)	U Glass (W/ m^2K)	RTTV (W/m^2)
1,969.33	1,679	290.79	2,040	4.40	32.08

Based on the calculations in this project shown in Table I and 2, the OTTV result is 32.68 W/ m^2 < 35 W/ m^2, RTTV is 32.08 W/ m^2 < 35 W/m^2, and WWR is 47%. The indicators of the building envelope require that the OTTV and RTTV values should not exceed 35 W/ m^2. Therefore, this project received 4 points in the OTTV and RTTV indicators, and 3 points in the WWR indicator.

B. Ventilation System

The tower B building uses an air conditioning system, but the building is planned not to condition some or all passive spaces such as (corridors, lobby lifts, and toilets) and equip with mechanical ventilation such as exhaust fans, smoke extract fans, and pressurized fans. Therefore, the tower B building gets 3 points on this indicator.

C. Air Conditioning System

In the tower B building, it is planned to use Air Conditioning (AC) with a room temperature of 25 °C and a relative humidity of 60%, and the building uses a Variable Refrigerant Volume (VRV) refrigeration system with a minimum Coefficient of Performance (COP) value of 3.81 and a maximum power consumption (kW / TR) of 0.92 in accordance with SNI 6390:2020. VRV is a system that circulates the cooling and heating system between indoor units and outdoor units. VRV have the ability to control humidity and provide specific set points for each indoor unit.

TABLE III. COEFFICIENT OF PERFORMANCE (COP) CALCULATION

AC Capacity (btu/h)	AC Capacity (kW)	COP According to SNI	COP	Description
38,200	11.20	3.81	**4.24**	OK
47,800	14.01		**5.31**	OK

TABLE IV. POWER CONSUMPTION (KW/TR) CALCULATION

AC Capacity (btu/h)	AC Capacity (TR)	kW/TR According to SNI	Power Consumption	Description
38,200	3.18	0.92	**0.83**	OK
47,800	3.98		**0.66**	OK

Based on Table III and Table IV, it is known that the air conditioner used in this building has a COP value of more than 3.81 and a small power consumption of 0.92, so it is in accordance with the requirements set out in SNI 6390:2020. Thus, the tower B building gets 4 points from these indicators.

D. Lighting System

Lighting systems are designed to maximize the comfort and productivity of building occupants while taking into account cost and environmentally friendly aspects. The lighting system consists of daylighting and artificial lighting. The lighting system criteria has 2 parameters that are assessed, namely artificial lighting and daylighting.

1) Artificial Lighting

Tower B already has a room artificial lighting system with maximum lamp power density (W/m^2) and minimum average lighting level (lux) for each room in accordance with SNI 6197:2020. Based on SNI 6197: 2020 the coefficient of utilization (CU) is 0.8 while the light loss factor (LLF) is 0.7 according to the lamp product used. In this case, to find out the maximum lamp power density and average lighting level, it is necessary to calculate the lighting intensity (E), the number of lamps (n), and the total luminous flux (F_{tot}) of all lamps illuminating the field. Each room has its own standard maximum lamp power density and minimum average lighting level as regulated in SNI 6197:2020. Based on these calculations, it is known that each room has met the requirements set out in SNI 6197: 2020. One example is in the room of the head of the inspectorate office, the SNI requires that the maximum lamp power density is 7.53 W/m^2 while the room has a lamp power density of 5.71 W/m^2 and the minimum average lighting level is 350 lux, but the room produces maximum lighting of 373.24 lux. Thus, the building gets 2 points on the indicator.

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2) Daylighting

This building does not have a separate grouping of lights with areas that do not get daylighting, so this building does not get points on this indicator.

TABLE V. ELEVATOR PLANNING DATA

Description	Initial Planning
Function	Passenger elevator (PE)
Speed (s)	105mpm (1.75 m/s)
Capacity	1050 kg
Traction Machine	VVVF
Elevator opening system	Center Opening (CO)
Elevator opening size	900 mm x 2100 mm
Hoist-way size	2300 mm x 2100 mm
Pit elevator size	1500mm
Elevator motor power	15 kW
Number of elevator passengers (K)	15
Height between floors (h)	4
Number of floors (n)	11
Number of building occupants	687

TABLE VI. LIGHTING SYSTEM ENERGY CONSUMPTION CALCULATION

No	Description	Unit	Baseline	Design
1	*Lighting Power Density (LPD) during operational hours*	W/m²	7.53	4.385
2	Lighting Power Density (LPD) during operational non hours	W/m²	1	1
3	*Net Lettable Area* (NLA)	m²	17,055	17,055
4	% Number of light points in daylighting zone	%	30%	45%
5	% Of daylighting hours during operational hours	%	70%	0%
6	Total number of hours per year	Hours	8,760	
7	Total number of hours per day	Hours	8	8
8	Total number of hours per week	Hours	40	40
9	Operating hours per year	Hours	2,080	2,080
10	Non-operational hours per year	Hours	6,680	6,680
11	Number of hours of daylighting during operational hours	Hours	1,456	0
12	Number of hours of non-daylighting during operational hours	Hours	624	2,080
13	Floor area receiving daylighting	m²	5,116	7,675
14	Floor area that is not daylighted	m²	11,939	9,380
15	Lighting system energy consumption during operating hours (non-daylighting zone)	kWh/year	186,993	85,558
16	Lighting system energy consumption during operating hours (daylighting zone)	kWh/year	24,042	70,002
17	Lighting system energy consumption during non-operational hours	kWh/year	113,932	113,932
	Total lighting system energy consumption	**kWh/year**	**324,967**	**269,493**
	Reduction of lighting system energy consumption	**kWh/year**	**55,473**	
	Lighting system energy consumption savings	**%**	**17%**	

E. In-Building Transportation System

This building uses Variable Voltage Frequency (VVF) technology in vertical elevator (lift) transportation. Based on SNI 03-6573-2001, the calculation of traffic analysis lifts is seen from the Combined Transport Capacity (CCC), which is the number of passengers that can be transported by the elevator under peak traffic conditions, and the Average Waiting Time (AWT), which is the time required for elevator users to wait until the elevator can be used. Based on SNI 03-6573-2001, the average waiting time of an institution office building is 40 seconds. Table V shows the elevator planning data for the tower B building.

In the planning, the tower B building has 6 elevator units, this is because in the middle of the tower B building has a void and has 2 sides connected by a connecting bridge. Therefore, the number of elevators used in the tower B building is 6 elevators, each side has 3 elevator units. In this case, it is to make it easier for building occupants to use the elevator facility, so that building occupants do not need to move to one side of the building if they want to use the elevator facility. CCC is calculated by multiplying the number of elevators by the unit carrying capacity. In this calculation, what is assessed is the value of CCC > Circulation Flow Demand (CFD) and AWT < criteria set in SNI 03-6573-2001. Calculation of Combined Carrying Capacity (CCC) and Average Waiting Time (AWT) on 6 elevator units as follows:

$$CCC = N \times DAS \quad (1)$$

$$= 6 \times 35 = 210 \text{ people}$$

$$= \frac{210}{687} \times 100\%$$

$$= 30.57\% = 31\%$$

$$CCC = CFD \text{ or } CCC > CFD \quad (2)$$

$$= 31\% > 14\% \rightarrow \text{OK}$$

$$AWD = \frac{RT}{N} \quad (3)$$

$$= \frac{103}{6}$$

$$= 17.16 \text{ sec} = 17 \text{ sec}$$

$$\text{AWT} < \text{criteria}$$

$$17 < 40 \rightarrow \text{OK}$$

From the results of these calculations, the CCC and AWT results for 6 elevator units are obtained, namely the CCC of building occupants as many as 210 people. In addition, AWT building occupants use 6 AWT elevator units for 17 seconds. Thus, this building gets 0.5 points on this indicator. However, the use of elevators in this building can still be minimized, this is because the output of the energy use efficiency aspect is to analyze the results of energy consumption in this building. So, the more use of the elevator, the greater the use of energy consumption in the building.

F. Energy Efficiency Calculation

In this indicator, researchers analyze energy consumption savings by calculating electrical energy consumption comparing the baseline with the design. The regulations that are the reference for this indicator are SNI 6197: 2020, namely regarding energy conservation in lighting systems, SNI 6389: 2020 regarding energy conservation of building envelopes in buildings, and SNI 6390: 2020 regarding energy conservation of air conditioning systems in buildings. The analysis is carried out on the energy consumption of the lighting system, plug load energy consumption, elevator energy consumption, and energy consumption in the air conditioning system.

Table VI shows the consumption calculation for the lighting system. In the design, this building is known to have a percentage of the number of light points in the daylighting zone which is 45%, but the percentage of daylighting hours during operational hours is 0%. Based on the design, this building does not use daylighting optimally because it does not have a separate grouping of lights, namely lights that get sunlight and lights that do not get sunlight. The switch used between lights that get sunlight and lights that do not get sunlight only uses 1 switch. Thus, if the light switch is turned on, the lights that are close to the arrival of sunlight will remain on even though the lighting in the room can use the help of daylighting not only using artificial lighting.

TABLE VII. CALCULATION OF PERCENTAGE OF CONSUMPTION SAVINGS PER-SYSTEM

No	Description	Unit	Baseline	Design	% Savings
1	Lighting System	kWh/year	324,967	269,493	**17%**
2	Plug Load	kWh/year	468,691	355,168	**24%**
3	Elevator System	kWh/year	394,200	788,400	**-100%**
4	Air Conditioning System	kWh/year	1,222,058	842,861	**32%**

Based on the energy consumption calculations shown in Table VII, the elevator and lighting systems show the least contribution to the overall energy savings. In particular, the total energy consumption of the elevator system doubled from 394,200 kWh/year to 788,400 kWh/year due to the simultaneous operation of six elevators. The elevator system was found to be significantly over-designed with six elevator units operating continuously resulting in a 100% increase in energy use beyond the optimal demand. This increase reflects an over-design scenario, where the elevator configuration significantly exceeds the actual service demand of the building, resulting in inefficiencies.

In contrast, the lighting system showed a modest reduction of 269,493 kWh/year from 324,967 kWh/year-equivalent to 17% energy savings. However, this improvement is still not optimal due to the absence of zonal lighting control and daylight integration strategies, which are critical to maximizing lighting efficiency in large buildings.

TABLE VIII. PERCENTAGE OF BUILDING ENERGY CONSUMPTION SAVINGS

No	Description	Unit	Baseline	Design
1	Lighting System	kWh/year	324,967	269,493
2	Plug Load	kWh/year	468,691	355,168
3	Elevator System	kWh/year	394,200	788,400
4	Air Conditioning System	kWh/year	1,222,058	842,861
Total building energy consumption		**kWh/year**	**2,409,917**	**2,255,923**
Building energy consumption reduction		**kWh/year**	**153,993**	
Building energy consumption savings		**%**	**6%**	

Based on Table VIII, presents the overall energy performance of Tower B. Under the baseline scenario, the building consumes 2,255,923 kWh/year, resulting in an Energy Use Intensity (EUI) of 95.46 kWh/m²/year. Although several energy efficiency measures were implemented, their impact was limited. The total reduction in energy consumption only reached 6%, allowing the building to earn only 3 of the 5 points available under the energy performance indicators of the national green building rating system.

G. *Electrical System*

The building is planned to install electrical energy sub-meters on electrical loads greater than 100 kVA. Tower B building also installs Building Management System (BMS) as a control and monitoring management system on all mechanical and electrical equipment, such as access control system, IP CCTV system, and sound system. The access control system is designed to enhance security by recording all access permissions by area and time for each user. Meanwhile, the IP CCTV system is integrated with the Smart Building Integration System so that it can be monitored via mobile devices. In addition, the sound system is also connected to the BMS, the sound system will use the central system to function as a paging, announcement system and emergency/ evacuation system. Therefore, the building received a total of 7 points on this indicator. Under this baseline scenario, the building scored 30 out of 46 possible points for energy efficiency based on the national green building assessment.

IV. DISCUSSION

Although some energy efficiency measures have been implemented, the impact is still limited. The total reduction in energy consumption based on the design drawings only reached 6%, allowing the building to earn only 3 out of 5 available points under the energy performance indicators of the national green building rating system. This analysis underlines that the limited energy savings in the elevator and lighting systems limit the improvement of the overall building performance. Therefore, future design revisions should prioritize properly sized mechanical systems and incorporate advanced control strategies to optimize operational energy efficiency.

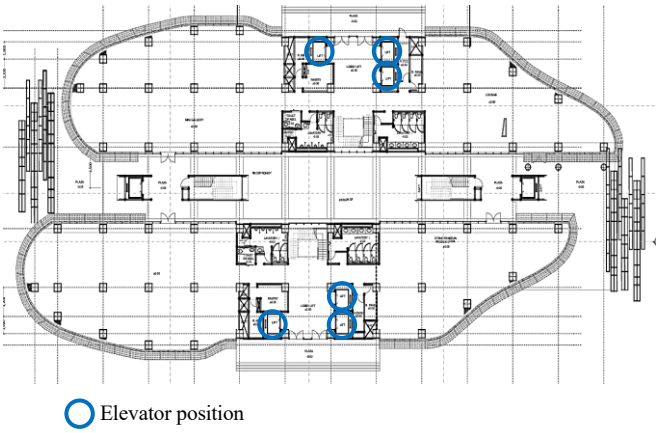

Fig 5. Elevator position plan.

A. *Reducing The Use Of Elevator Units*

The energy performance analysis of Tower B showed that the elevator and lighting systems were the main contributors to the inefficiencies in the original design. The original design of Tower B included six elevator units, which were evenly distributed on both sides of the tower, three units on each side due to the central void and connecting bridge between the two towers shown in Fig. 5. While this configuration facilitates

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ease of access for building occupants from both sides, it also introduces significant operational redundancy. This is reflected in the energy analysis, where the annual elevator energy consumption reaches 788,400 kWh/year as shown in Table IX, contributing disproportionately to the overall building energy intensity.

TABLE IX. ELEVATOR ENERGY CONSUMPTION

No	Description	Unit	Baseline	Design
1	Elevator during operating hours	kW	15	15
2	Number of elevator units	W/m²	3	6
4	Operating hours per year	Hours	2,080	2,080
5	Non-operational hours per year	Hours	6,680	6,680
6	Energy consumption of elevator during operational hours	kW	93,600	187,200
7	Energy consumption of elevator during non-operational hours	kW	300,600	601,200
Total energy consumption of elevator		**kWh/year**	**394,200**	**788,400**
Reduction in elevator energy consumption		**kWh/year**	**-394,200**	
Elevator energy consumption savings		**%**	**-100%**	

Circulation Flow Demands (CFD)

=14% × 687

= 96 people per 5 minutes

Up and Down Traffic Tempo (UDTT)

$$= \frac{(2h + 4s) \times (n-1) + s\,(3K + 4)}{s} \quad (4)$$

$$= \frac{(2 \times 4 + 4 \times 1.75) \times (11-1) + 1.75\,(3 \times 15 + 4)}{1.75} = 93.57 \text{ sec}$$

10% tolerance = 9.357 sec = 103 sec

Unit Carrying Capacity (CCC)

$$= \frac{300 \times 0.8\,K}{UDTT} \quad (5)$$

$$= \frac{300 \times 0.8 \times 15}{103}$$

Unit Carrying Capacity (UCC)

= 34.95 = 35 people per 5 minutes

Number of Elevators(N)

$$= \frac{CFD}{UCC} \quad (6)$$

$$= \frac{96}{35} = 2.7\ unit = 3\ elevator\ units$$

Combined Transport Capacity (CCC)

$$CCC = N \times UCC \quad (7)$$

= 3 ×35=105 people

$$= \frac{105}{687} \times 100\%$$

= 15.28% = 15%

CCC = UCC or CCC > UCC

15 % > 14% →OK (acceptable)

Average Waiting Time (AWT)

$$\text{AWT} = \frac{RT}{N} \quad (8)$$

$$= \frac{103}{3}$$

AWT = 34.33 sec = 34 sec

AWT < criteria

34 < 40 →OK (acceptable)

Therefore, this research recommends that the building uses 4 elevator units, where each side of the building has 2 elevator units.

Combined Transport Capacity (CCC)

CCC = 4×35=140 people

$$= \frac{140}{687} \times 100\%$$

= 20.38%=20%

CCC = UCC or CCC > UCC

20 % > 14% →OK (acceptable)

Average Waiting Time (AWT)

$$\text{AWT} = \frac{103}{4}$$

AWT = 25.75 sec =26 sec

AWT < criteria

26 < 40 →OK (acceptable)

TABLE X. ENERGY CONSUMPTION USAGE OF 4 ELEVATORS

No	Description	Unit	Design	Recommendation
1	Elevator during operating hours	kW	15	15
2	Number of elevator units	W/m²	6	4
4	Operating hours per year	Hours	2,080	2,080
5	Non-operational hours per year	Hours	6,680	6,680
6	Energy consumption of elevator during operational hours	kW	187,200	124,800
7	Energy consumption of elevator during non-operational hours	kW	601,200	400,800
Total energy consumption of elevator		**kWh/ year**	**788,400**	**525,600**
Reduction in elevator energy consumption		**kWh/ year**	**262,800**	
Elevator energy consumption savings		**%**	**33%**	

A critical evaluation of vertical transportation requirements using SNI 03-6573-2001 as the reference standard revealed that a reduction of the elevator to 4 elevator units would still meet performance standards, with a Combined Transport Capacity (CTC) of 140 people/hour and an Average Waiting Time (AWT) of 26 seconds-both within acceptable service thresholds. This configuration resulted in a 33% reduction in elevator energy usage, bringing it to 525,600 kWh/year shown in Table X, without compromising accessibility. Although the simulation also explored a three-elevator configuration (AWT: 34 seconds, CTC: 105 persons/hour), the asymmetrical distribution of elevators in the

current architectural layout would likely result in user flow inefficiencies, especially given the connectivity of the twin towers. Therefore, a 4 elevators configuration was determined to be the most balanced trade-off between energy performance and functional integrity.

These findings align with related research [20], which suggested elevator energy reduction through partial deactivation during off-peak hours. However, unlike time-based shutdown strategies, our approach emphasizes spatial-functional rationalization during the design phase, offering broader relevance for buildings with symmetrical cores or dual-access plans. The ability to maintain vertical transport service while lowering energy demands has implications not only for design optimization but also for policy development, particularly in countries where elevator capacity is overprescribed as a matter of convenience rather than necessity.

B. Separate Grouping of Lights

Offices as workplaces require adequate levels of daylighting so that occupants can carry out activities smoothly and productively [21]. his building does not get points for daylighting because it does not have a separate grouping of lights with areas that do not get natural light. In architecture, daylighting should always be considered because it impacts the building's energy use [22]. Therefore, the researcher recommends implementing a separate grouping of lights with areas that do not get natural light. Lamp grouping is a technique that organizes the placement of lamps in groups based on function, intensity or lighting area [23].

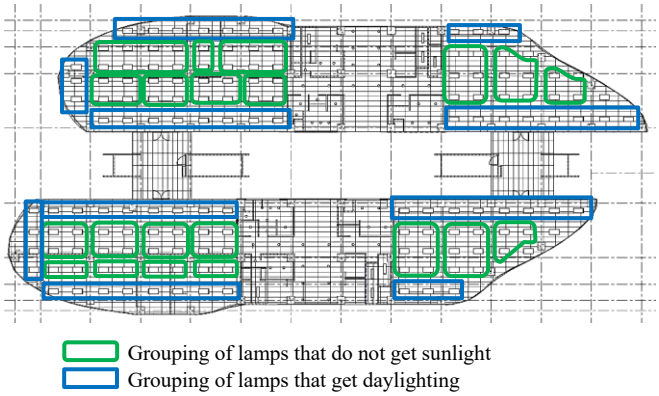


Fig 6. Separate grouping of lights.

In addition to vertical transportation, the lighting system in Tower B shows untapped potential for efficiency improvements. The building did not initially receive points for daylighting contribution in the green building assessment, mainly due to the absence of zone lighting controls. Fig. 5 illustrates how the fixtures were uniformly distributed without considering the availability of natural light.

Table XI shows a simulation of daylighting entering the room at certain hours. In this calculation analysis confirmed that 45% of the light points are located in zones with sufficient daylight during 50% of the operating hours, supporting the feasibility of this control strategy.

TABLE XI. DAYLIGHTING SIMULATION

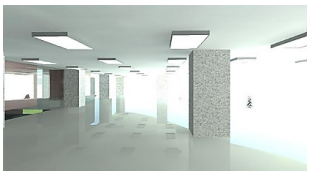
Image	Description
	Simulation of daylighting entering the room at 08.00 AM
	Simulation of daylighting entering the room at 10.00 AM
	Simulation of daylighting entering the room at 12.00 PM
	Simulation of daylighting entering the room at 04.00 PM

TABLE XII. ENERGY CONSUMPTION AFTER IMPLEMENTING SEPARATE LAMP GROUPING

No	Description	Unit	Design	Recommendation
1	Lighting Power Density (LPD) during operational hours	W/m²	4.39	4.39
2	Lighting Power Density (LPD) during non-operational hours	W/m²	1	1
3	Net Lettable Area (NLA)	m²	17,055	17,055
4	% number of light points in the daylighting zone	%	45%	45%
5	% hours of daylighting during operational hours	%	0%	50%
6	Total number of hours (/year)	Hours		8,760
7	Total number of hours (/day)	Hours	8	8
8	Total number of hours (/week)	Hours	40	40
9	Operating hours per year	Hours	2,080	2,080
10	Non-operational hours per year	Hours	6,680	6,680
11	Number of hours of daylighting during operational hours	Hours	0	1,040
12	Number of hours of non-daylighting during operational hours	Hours	2,080	1,040
13	Floor area receiving daylighting	m²	7,675	7,675
14	Floor area that is not daylighted	m²	9,380	9,380
15	Lighting system energy consumption during operating hours (non-daylighting zone)	kWh/year	85,558	85,558
16	Lighting system energy consumption during	kWh/year	70,002	35,001

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No	Description	Unit	Design	Recommendation
	operating hours (daylighting zone)			
17	Lighting system energy consumption during non-operational hours	kWh/year	113,932	113,932
Total lighting system energy consumption		**kWh/year**	**269,493**	**234,492**
Reduction of lighting system energy consumption		**kWh/year**	**35,001**	
Lighting system energy consumption savings		**%**	**13%**	

By implementing segregated luminaire grouping based on daylight exposure by turning off lights in zones with sufficient daylight during peak daylight hours, a 13% increase in energy savings on lighting can be achieved, reducing usage from 269,493 to 234,492 kWh/year as shown in Table XII. This comparison reflects two different scenarios: the "design" scenario as a standard baseline without zone clustering, and the "recommended" scenario that incorporates clustering and functional scheduling. These findings validate that energy efficiency can be significantly improved through relatively simple control strategies without requiring major infrastructure changes

TABLE XIII. TOTAL ENERGY CONSUMPTION

No	Description	Unit	Design	Recommendation
1	Lighting System	kWh/year	269,493	234,492
2	Plug Load	kWh/year	468,691	355,168
3	Elevator System	kWh/year	788,400	525,600
4	Air Conditioning System	kWh/year	1,222,058	834,601
Total building energy consumption		**kWh/year**	**2,748,643**	**1,949,861**
Building energy consumption reduction		**kWh/year**	**798,781**	
Building energy consumption savings		**%**	**29%**	

Cumulatively, the implementation of the elevator and lighting interventions resulted in a reduction of the building's total energy consumption from 2,748,643 kWh/year to 1,949,861 kWh/year, which translates into a lower EUI of 82.51 kWh/m²/year, yielding a 29% overall reduction from the design scenario shown in Table XIII. These measures increased the green building's energy efficiency score from 30 to 38 points (from 46 points maximum). Therefore, the reduction in energy consumption in this building assessed on each of its criteria can be seen in Fig 7.

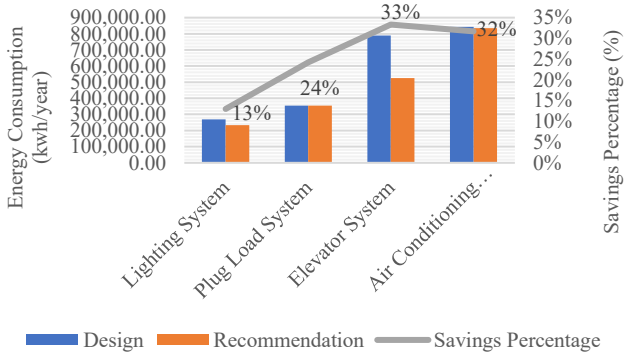

Fig 7. Energy consumption savings graph.

While these outcomes are promising, the analysis is not without limitations. The simulation assumes ideal implementation of lighting control systems and elevator scheduling without factoring in user behavior variability, control system responsiveness, or maintenance consistency. Additionally, the generalizability of these findings is currently limited to buildings with symmetrical cores and comparable operational profiles. Broader application would require further testing in diverse building typologies and climatic contexts.

We acknowledge that this 29% reduction projection is based on ideal implementation assumptions, however to support scalability and integration into policy, future research should include sensitivity analysis, cost-benefit evaluation, and pilot implementation, as variations in elevator usage patterns, lighting control effectiveness, and occupancy behavior can affect energy saving outcomes. This will provide a stronger understanding of the operational feasibility and robustness of the proposed strategy under real-world conditions. Moreover, urban development guidelines and green building certifications should evolve to encourage adaptive operational strategies, rather than focusing solely on envelope efficiency or prescriptive equipment standards. This paradigm shift could play a pivotal role in transitioning Southeast Asian commercial architecture toward resilient, context-sensitive energy performance models.

V. CONCLUSION

This study demonstrates that significant energy savings in high-rise buildings can be achieved through relatively simple but strategically planned interventions, such as reducing the number of elevator units and implementing zoned lighting control based on daylight availability. The simulation results show a potential 29% reduction in total energy consumption, with a decrease in the building's EUI from 95.46 to 82.51 kWh/m²/year and an improvement in the green building scoring from 30 to 38 points.

Beyond these quantitative outcomes, the findings hold important policy relevance, particularly for the formulation of energy efficiency guidelines in commercial and public buildings in tropical regions. Integrating such strategies into building codes or incentive frameworks (e.g., tax benefits or certification credits) could encourage broader adoption. From a cost-benefit perspective, the proposed interventions do not require major structural modifications, thus offering high impact with relatively low capital investment, especially for buildings in the design or early renovation stages.

However, potential barriers to implementation include limited awareness among stakeholders, the absence of enforceable energy performance standards, and resistance due to operational inertia or perceived disruption to user comfort. Therefore, successful implementation would require multi-stakeholder coordination, user education, and phased adaptation strategies supported by policy instruments. Future studies may focus on empirical validation through real-time monitoring, as well as sensitivity and financial feasibility analysis to refine the robustness and scalability of the proposed measures.

REFERENCES

[1] M. S. Hoesin, "Studi oleh IFC dan Green Building Council Indonesia menunjukkan sembilan Bangunan Gedung Hijau menghemat 30 - 80 persen biaya utilitas dibandingkan dengan bangunan pada umumnya," Internaltional Financ. Corp., pp. 28–30, 2019, [Online]. Available: https://pressroom.ifc.org/all/pages/PressDetail.aspx?ID=24900. [*Eng. Trans.: A study by IFC and the Green Building Council Indonesia shows that nine Green Buildings save 30–80 percent of utility costs compared to conventional buildings*]

[2] A. F. Tasya, P. Setijanti, and A. Dinapradipta, "Faktor Yang Mempengaruhi Implementasi Strategi Efisiensi Energi Pada Bangunan Spazio," Vitr. J. Arsit. Bangunan dan Lingkung., vol. 10, no. 1, p. 21, 2020, doi: 10.22441/vitruvian.2020.v10i1.003. [*Eng. Trans.: Factors affecting the implementation of energy efficiency strategies in Spazio Building*]

[3] G. Mahassin, "Model Konsumsi Energi Pada Bangunan Residensial Di Jakarta: Perbandingan Metode Rata-Rata Dan Median Serta Rekomendasi Efisiensi Energi," pp. 55–58, 2024. [*Eng. Trans.: Energy consumption model in residential buildings in Jakarta: Comparison of average and median methods and energy efficiency recommendations*]

[4] C. G. Buyang and F. Sangadji, "Penilaian Kriteria Green Building Pada Fakultas Teknik Universitas Pattimura," J. Simetrik, vol. 13, no. 1, pp. 677–682, 2023, doi: 10.31959/js.v13i1.1384. [*Eng. Trans.: Assessment of Green Building criteria at the Faculty of Engineering, Pattimura University*]

[5] F. Çiner and N. Doğan-Sağlamtimur, "Environmental and sustainable aspects of green building: A review," IOP Conf. Ser. Mater. Sci. Eng., vol. 706, no. 1, 2019, doi: 10.1088/1757-899X/706/1/012001.

[6] GBCI, "Perangkat Penilaian GREENSHIP (GREENSHIP Rating Tools)," Greensh. New Build. Versi 1.2, no. April, pp. 1–15, 2013, [Online]. Available: http://elib.artefakarkindo.co.id/dok/Tek_Ringkasan%20GREENSHIP%20NB%20V1.2%20-%20id.pdf. [*Eng. Trans.: GREENSHIP assessment tools (GREENSHIP Rating Tools)*]

[7] D. M. Fatmayati, A. Trisiana, and L. A. Wicaksono, "Analisis Tingkat Capaian Green Building Berdasarkan Greenship untuk Bangunan Baru Versi 1.2 (Studi Kasus: Hotel Kokoon Banyuwangi)," J. Appl. Civ. Eng. Infrastruct. Technol., vol. 2, no. 1, pp. 27–34, 2021, doi: 10.52158/jaceit.v2i1.150. [*Eng. Trans.: Analysis of Green Building achievement level based on Greenship for new buildings version 1.2 (Case study: Kokoon Hotel Banyuwangi)*]

[8] A. Ratnaningsih, A. Hasanuddin, and R. Hermansa, "Penilaian Kriteria Green Building Pada Pembangunan Gedung IsDB Project Berdasarkan Skala Indeks Menggunakan Greenship Versi 1.2 (Studi Kasus: Gedung Engineering Biotechnology Universitas Jember)," Berk. Sainstek, vol. 7, no. 2, p. 59, 2019, doi: 10.19184/bst.v7i2.12153. [*Eng. Trans.: Assessment of Green Building criteria in the construction of IsDB Project building based on index scale using Greenship version 1.2 (Case study: Engineering Biotechnology Building, University of Jember)*]

[9] S. M. Rosalia, A. Annisa, and S. Zuraida, "Evaluasi Sertifikasi Green Building pada Gedung Institut Teknologi & Sains Bandung," J. Appl. Sci., vol. 2, no. 2, pp. 043–050, 2020, doi: 10.36870/japps.v2i2.183. [*Eng. Trans.: Evaluation of Green Building certification in the Institut Teknologi & Sains Bandung building*]

[10] D. Saputra, "Kantor Kementerian PUPR Masuk Jajaran Gedung Paling Hijau Se-ASEAN," detik.com, 2023. [Online]. Available: https://www.detik.com/properti/berita/d-6898034/kantor-kementerian-pupr-masuk-jajaran-gedung-paling-hijau-se-asean. [*Eng. Trans.: Ministry of PUPR office among the greenest buildings in ASEAN*]

[11] Kementerian PUPR, "Peraturan Menteri Pekerjaan Umum Dan Perumahan Rakyat Republik Indonesia Nomor 21 Tahun 2021 Tentang Penilaian Kinerja Bangunan Gedung Hijau," pp. 1–297, 2021, [Online]. Available: https://peraturan.bpk.go.id/Home/Details/217002/permen-pupr-no-21-tahun-2021. [*Eng. Trans.: Regulation of the Minister of Public Works and Housing of the Republic of Indonesia Number 21 of 2021 on Green Building Performance Assessment*]

[12] A. Divyadarshi et al., "Energy Consumption and Efficiency in Green Buildings," IJSRD-International J. Sci. Res. Dev., vol. 5, no. September 2020, pp. 2321–0613, 2018, [Online]. Available: https://www.researchgate.net/publication/322273339.

[13] Y. Geng, W. Ji, Z. Wang, B. Lin, and Y. Zhu, "A review of operating performance in green buildings: Energy use, indoor environmental quality and occupant satisfaction," Energy Build., vol. 183, pp. 500–514, 2019, doi: 10.1016/j.enbuild.2018.11.017.

[14] A. K. Sharma, "Energy Efficiency and Thermal Comfort in Heritage Buildings," Encycl. Renew. Sustain. Mater. Vol. 1-5, vol. 1–5, pp. 58–62, 2020, doi: 10.1016/B978-0-12-803581-8.10720-9.

[15] J. P. Kalikeri and S. U. Vanakudari, "Comparative Study of a Conventional Building and Green Building," Int. Res. J. Mod. Eng. Technol. Sci., no. 09, 2023, doi: 10.56726/irjmets44828.

[16] Anisah, I. Inayati, F. X. N. Soelami, and R. Triyogo, "Identification of Existing Office Buildings Potential to Become Green Buildings in Energy Efficiency Aspect," Procedia Eng., vol. 170, pp. 320–324, 2017, doi: 10.1016/j.proeng.2017.03.040.

[17] D. Bogin, M. Dorman, M. Kissinger, and E. Erell, "Beyond efficiency: Evaluation of the electricity saving potential of green residential buildings," Energy Build., vol. 320, no. August, p. 114627, 2024, doi: 10.1016/j.enbuild.2024.114627.

[18] G. H. Oktavian, I. Wijatmiko, C. R. Nainggolan, Y. P. Devia, and M. R. Anwar, "Energy Efficient Design of Building Based on Building Information Modelling (BIM)," Int. J. Integr. Eng., vol. 16, no. 4, pp. 31–38, 2024, doi: 10.30880/ijie.2024.16.04.005.

[19] S. Karya et al., "Sustainability in Architecture EVALUASI PERFORMA DESAIN SELUBUNG BANGUNAN TERHADAP Arsitektur untuk Indonesia Timur," pp. 260–270, 2020. [*Eng. Trans.: Sustainability in architecture: Evaluation of building envelope design performance for Eastern Indonesia architecture*]

[20] T. Suheta and M. F. Huda, "Audit Penggunaan Energi Listrik Pada Apartment Metropolis Surabaya," Semin. Nas. Sains dan Teknol. Ter. V, vol. 10, pp. 91–98, 2017, [Online]. Available: https://core.ac.uk/reader/289705280. [*Eng. Trans.: Audit of electricity usage in Metropolis Apartment Surabaya*]

[21] A. Fleta, "Analisis Pencahayaan Alami Dan Buatan Pada Ruang Kantor Terhadap Kenyamanan Visual Pengguna," J. Patra, vol. 3, no. 1, pp. 1–10, 2021. [*Eng. Trans.: Analysis of natural and artificial lighting in office spaces on user visual comfort*]

[22] Atthaillah, A. Bakhtiar, and Badriana, "Optimalisasi Pencahayaan Alami dengan Useful Daylight Illuminance pada," J. Nat., vol. 6, no. 1, pp. 11–26, 2019. [*Eng. Trans.: Optimization of natural lighting with Useful Daylight Illuminance*]

[23] R. A. Mangkuto, A. W. Wiratama, K. Fadla, and F. X. N. Soelami, "Optimisasi Perletakan dan Penjadwalan Sistem Pencahayaan untuk Meningkatkan Eksitansi Rata-rata Permukaan dalam Ruang," J. Permukim., vol. 14, no. 1, p. 45, 2019, doi: 10.31815/jp.2019.14.45-54. [*Eng. Trans.: Optimization of lighting placement and scheduling to increase average surface illuminance in rooms*]