Energy Optimization on Campus Building Using Sefaira

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Abstract. Energy efficiency in buildings is an important target to be met to reduce the greenhouse effect's impact. Simulation methods and techniques are essential for conducting energy analysis and producing targets more accurately and quickly. This research calculates and simulates the Energi Use Intensity (EUI) and Spatial Daylight Autonomy (sDA) in Semarang's campus building. Simulations are carried out using Sefaira software as a plug-in to the Sketchup software. The first energy use simulation (EUI) analysis as a baseline was carried out using the ASHRAE 90.1-2019 material standard resulting in a 144 kWh/m²/year. The second simulation on the facade's conditions and existing materials becomes my baseline result increasing to EUI 157 kWh/m²/year. The first engineering improvement was to replace the existing TL/PL lighting with an LPD value of 15.0 watts/m² and replaced it with LED with an efficiency of 5.0 watts/m², which can reduce energy use 131 kWh/m²/year. Furthermore, the 2nd scenario reduced window openings on the west and east sides, which had an immense contribution to heat intake, resulting in an additional efficiency of 118 kWh/m²/year. In the third scenario, replacing all glass types with several alternatives results in a reduced value EUI 99-109 kWh/m²/year. Still, all changes to this type of glass resulted in a decrease in natural lighting quality so that the sDA value fell below 50%, with the status changing from my baseline "well lit" to "under lit." 4th scenario, the analysis was carried out by replacing glass without reducing the wall openings (WWR reduction). The results show that all changes to glass types/colors resulted in a decrease in natural lighting quality, except for replacing the Panasap Euro Gray glass types that still provide 61% sDA and 11% ASE values, thus providing a "well lit" quality. Of the four scenarios, only scenarios 1 to 3 provide a value of natural lighting quality that remains "well lit." Scenario 4 causes the rate to drop to "under-lit." Furthermore, from scenarios 1, 2, and 3, the lowest EUI value is in scenario 2 with a value of 118 kWh/m²/year, so the 2nd scenario is the best in this optimization process. The first section in your paper

1. Introduction
Indonesia has high intensity of building growth, has a target of reducing energy use by 26% from business as usual (BAU), and reducing it up to 41% if it has adequate support from the international community [1]. This energy use sector is the third-largest, which comes from the use of energy in buildings after the industrial and transportation sectors. This condition is estimated to increase to 39% in 2030. A significant effort is needed to achieve higher energy efficiency in buildings; with this approach, reducing the greenhouse effect can be optimized. From the various efforts to reduce emissions, one of the most effective ways to increase energy efficiency in the building sector is through green building codes [2]. This green building offers the most outstanding global opportunity to reduce carbon emissions by up to 35% and save 30-50% energy use [1].
The city of Semarang is the third city in Indonesia that has imposed regulations on Green Building after the cities of Jakarta and Bandung. This city is contained in the city regulation of Semarang No. 24 of 2019 concerning Green Buildings. In this regulation, various codes are regulated to be able to make savings on small (300-2,500 m²), medium (2,500-5,000 m²), and large (> 5,000 m²) buildings for all buildings, especially in public buildings [3]. From applying this rule, it is hoped that the City of Semarang can make real efforts to save energy and reduce greenhouse gas emissions.

UPGRIS, as one of the educational campuses in the city of Semarang, also strives to implement these green building provisions, both for existing and existing buildings. One of the large buildings owned is the Gedung Pusat (GP) as the operational center building for rectos and student lectures [4]. With an area of 8,894 m², according to the city regulation No. 24 of 2019 concerning Green Buildings, this building is a large building with an area of more than 5,000 m². Requirements for large buildings should include energy efficiency, water efficiency, and management of indoor air quality. Energy efficiency will include building envelopes, air conditioning systems, artificial lighting systems, indoor transportation systems, and electrical systems [3].

How can architects find a building design with good natural lighting, low energy use, and low operating costs? How are these factors measured? This study will simulate using two main parameters, namely Energy Use Intensity (EUI) and Spatial Daylight Autonomy (sDA), using Sefaira Plugin for Sketchup [5]. This simulation can be obtained as the main building factors and elements determining the most optimal building energy value with the building's exclusive conditions.

This research to find the essential elements to increase efficiency in this building, this research was conducted. This study seeks to perform energy simulations on various building elements to determine the most significant efforts to increase energy efficiency in this existing building. It is hoped that this study's results can become a reference for managers to make improvements to the building to reduce building operating costs and a form of campus contribution to efforts to reduce the greenhouse effect.

2. Literature Review

From the survey, most of the energy use of buildings in Indonesia is for the HVAC system in all building functions. HVAC requires about 47%-65% of all energy use in buildings. Combined artificial lighting systems and sockets for appliances contribute 15% - 25% of all energy consumption [6]. Considering these conditions, efforts to reduce HVAC and artificial lighting through passive and active designs will significantly reduce energy in Figure 1.

![Figure 1. Details of Energy Consumption for Different Types of Buildings.](image)

Reference: Pemerintah Provinsi DKI Jakarta, 2012 [6]

The energy load for cooling air in the building consists of external loads due to the gain from outside the building (through walls, windows, etc.) and internal loads (lighting, equipment, people, etc.). For buildings with a large glass surface area, glass walls and windows' heat impact will be the primary cooling load. The impact of external heat from the walls and windows of office buildings in Jakarta is around 63%, while the internal heat from lighting, equipment, and occupancy is about 37% [6]. This
condition can indicate a massive opportunity for energy savings through a properly designed building envelope to reduce the air-cooling load (Figure 2).

As mentioned above, the building envelope can profoundly affect energy consumption, mainly due to heat radiation gain through windows and lighting by optimizing natural lighting. Through an integrated strategy of passive and active approaches, the design can generate energy savings of around 31% in office buildings. This condition can be achieved by designing the building envelope through the shade, the ratio of window to wall area (WWR), the selection of glass with a low SC coefficient, and natural light for indoor lighting [7].

Reference: Pemerintah Provinsi DKI Jakarta, 2012 [6].

**Figure 2.** Details of Cooling Load for a Typical Jakarta Office Building.

How can architects find a building design with good natural lighting, low energy use, and low operating costs? How are these factors measured? The following are two of the six performance measurement tools used through the Sefaira for Sketchup application (Figure 3).

**Figure 3.** UEI and sDA tools measurement on Sefaira.

**Energy Use Intensity** (EUI) is the annual energy use of a building per unit area in kWh/m²/yr units. The EUI can measure the energy consumed or energy use at the source used in generating electricity. We can compare the performance of buildings based on their size, type, and location. This way can help architects design buildings that use less energy to lower the operating costs. EU values are used as the building benchmark for public reporting in many cities. I can be used to set your design targets. This value can measure whether the building design already has a good or bad performance (its value is relative to the target or other similar buildings as the baseline). To reduce EUI is necessary to dig deeper into energy use data to determine what drives the most appropriate energy use [8].
Spatial daylight autonomy (sDA) Can describe how much the area can receive sunlight with satisfactory conditions. SDA is a standard that requires 50% of peak hours of the year to have adequate lighting in buildings. This sufficient level of illumination during the day is between 300 and 3,000 Lux. It is a climate-based natural lighting gauge, simulated using a location-specific weather file (similar to an energy model). The ASE (Annual Sunlight Exposure) present in this measurement is an indicator of possible glare or thermal comfort issues. However, this doesn't directly measure glare or thermal comfort, but rather direct sunlight. ASE is used with sDA in LEED v4. Simulated SDA can help you design a building with good natural lighting, as it is a good predictor of actual daylight performance when built.

Several building elements have a significant influence on building performance, so it is necessary to implement strategies to reduce energy consumption levels. Draw below the main building elements and outline the strategies you can implement to improve building performance.

3. Method
This type of simulation research aims to find a picture through a system with a small or straightforward scale in which manipulation or control will be applied to get its effect. This research is almost the same compared to experimental research. The difference is that simulation research requires an environment that is very similar to the original state.

This energy use simulation is carried out using the Sefaira for Sketchup plug-in application. Sefaira is an application to build modeling with all its elements and parameters and simulation results related to energy size, natural light levels, operational costs, etc. The energy modeling process used here is real-time between the input inputs and the resulting performance feedback to inform design decisions.
during the design process. Sefaira was chosen for this study because it can provide immediate feedback on energy, daylight, and other metrics, with a preference for conditions in the original building environment. Sefaira is built with real-time analysis in a 3D modeling environment. The comparison of design options or alternatives quickly delivers the results of many different design strategies. Exploration is the key to answering questions oriented towards the best design options. Feedback is designed to be actionable to help designers understand how the building operates and what they can do to improve it. It allows the designer to shape designs based on results, rather than just analyzing the finished design [12].

**Figure 5.** Research step.

The energy simulation process carried out in this study begins with a simulation using the building element baseline from ASHRAE 90.1-2019 with a location according to the existing building. The simulation results show the EUI with the ASHRAE baseline parameter. Furthermore, adjustments to building elements in ASHRAE 90.1-2019 with the existing building conditions are carried out by modifying the wall, roof, floor, and window glass material parameters; this second analysis produces the existing building's EUI value. Several alternatives were carried out with modifications to LED lights for the third simulation stage, reducing WWR and replacing glass types with different SC and U-value variations.

A comparative analysis can be carried out between parameters and the baseline from the three stages' simulation results. In the last step, for the modification of the glass material, several glass types were provided so that the results that best suit your needs can be selected.

4. Findings and Discussion

4.1. Existing Data

The baseline data were determined based on the condition of the building location on Sidodadi Timur Street No. 24, Semarang, Central Java, Indonesia with building coordinates -6.98; 110.43 or 6°59'21.1"S; 110°26'07.7" E. This building has an orientation direction at an angle of 5.30 CW from the north (Figure 6). This location is included in ASHRAE Climate Zone 2 [13]. Weather data is taken from the Weather Station at Ahmad Yani Airport, Semarang, Indonesia.

The building is a campus for lectures with the most considerable function for classrooms and offices. The total floor area of the building is 8,894 m², with a total of 8 floors. The Central Building (GP) is one of several buildings located in the UPGRIS Campus 1 complex. The Central Building (GP) is a building for the Rectorate and lectures for the Faculty of Engineering and Informatics, the Faculty of Law, and the Faculty of Economics and Business. This building consists of 8 floors with various parking
facilities and a meeting building on the 7th floor. The ground floor is the car park floor, while the 1st floor with the split level floor is used for motorbike parking.

Figure 6. Buildings, locations, and sun path.

4.2. Calculations on the ASHRAE 90.1 – 2019 (Standard Baseline)
As an initial baseline calculation for comparison, energy calculations are carried out using standard assumptions based on ASHRAE 90.1-2019 [14], one of the options available at Sefaira. Changes are only made to the height of the work plane, which is changed from 85 cm to 80 cm. The HVAC system used is standard in the Sefaira VAV - Return Air Package (System 5/6) and climate set 2 for the region to Asia. The results of the analysis on this baseline can be seen in Figure 7.

Figure 7. Simulation results with the ASHRAE baseline 90.1-2019.

The result of the Energy Use Intensity (EUI) is 144 kWh/m²/yr; this value is, of course, very far if compared to the ASHRAE 90.1-2019, the target for 2030 at 69 kWh/m²/yr for school buildings, there is a deviation of 75 kWh/m²/yr. The two most immense energy consumption is for room cooling and lighting. The percentage of floor area exposed to annual sunlight shows the MOSTLY WELL LIT value, where the value is underlit as much as 28%, well lit is 58%, and overlit is 14%.

4.3. Energy Calculation in Existing Conditions (My Baseline)
The baseline calculation analysis above is carried out with several assumptions about using standard indicators that are not suitable for the field conditions. In this section, several building elements will be made to adjust to their existing conditions (Table 1) and set as My Baseline.

The most significant difference in material elements is in the glass with additional energy of + 22 kWh/m²/yr. Simultaneously, the change in brick walls with plaster gives an energy reduction of −4 kWh/m²/yr, changes with ceramic tile roofs reduce -5 kWh/m²/yr, and floors changes with concrete has no impact (Table 1).
Table 1. Changes to building elements according to their existing

| No. | Building Element       | Units | ASHRAE 90.1-2019 | Building Existing        | Deviation of energy |
|-----|------------------------|-------|------------------|--------------------------|---------------------|
| 1   | Wall insulation        | W/m²-k| 2.09             | 0.81 Brick with plaster | - 4                 |
| 2   | Floor Insulation       | W/m²-k| 0.30             | 1.45 Concrete            | 0                   |
| 3   | Roof Insulation        | W/m²-k| 4.55             | 0.50 Ceramic Roof        | - 5                 |
| 4   | Glazing U-Factor       | W/m²-k| 3.44             | 5.80 Indoflot Clear 5 mm | + 1                 |
| 5   | Visible Light Transmittance | W/m²-k | 0.82 | 0.82 No change | 0                   |
| 6   | Solar Heat Gain Coefficient | SHGC | 0.23           | 0.84 No change | + 21                |
| 7   | Infiltration Rate      | m³/m²h| 7.43             | 7.43 No change           | 0                   |
| 8   | Ventilation Rate       | m³/person | 10 | 8 No change | 0                   |
| 9   | Equipment              | W/m²  | 10               | 10 No change             | 0                   |
| 10  | Lighting               | W/m²  | 15               | 15 No change             | 0                   |

Figure 8. Simulation results with the building's exclusive conditions.

The final results of the analysis of this existing building can be seen in Figure 8. The result of the Energy Use Intensity (EUI) is 157 kWh/m²/yr. This value is still very far from the ASHRAE target of 90.1-2019 in 2030 for school buildings of 67 kWh/m²/yr (Figure 9a).

The percentage of floor area exposed to annual sunlight is still the same as the baseline ASHRAE 90.1-2019 with the MOSTLY WELL LIT value (Figure 9c), where the underlit value is 28%, 58% well lit, and 14% overlit (Figure 9b).

Figure 9. Detailed simulation results with the existing building conditions.
The order of energy segmentation used in buildings from largest to largest is for HVAC, Lighting, Fans, and Equipment. For space heating (heating) is not necessary because the building is in the tropics.

The most significant energy load analysis, when calculated including dynamic load, then the most considerable load is from equipment and building users, then from lighting and continued with the building's physical components (Figure 10a). To calculate the load from the physical building alone, the component values that burden the most significant energy are from wall conduction, west, east, north, south facade conduction, glass conduction, roof conduction, and lastly, from floor conduction (Figure 10b).

4.4. Scenario 1: Changing the lamp to an LED
The lighting design's main objective is to provide a sufficient amount of light to work in the room. The minimum acceptable light level (illuminance) is determined by SNI 03-6197-2000 [15]. Lighting systems can be designed to meet these minimum requirements and do not overdo it as this may result in energy use.

Table 2. Impact of LPD (W / m2) on Total LPD Energy Saving.

| LPD (W/m2) | Office | Retail | Hotel | Hospital | Apartment | School |
|------------|--------|--------|-------|----------|-----------|--------|
| 20         | -      | -10,0% | -     | -        | -         | -      |
| 17         | -      | -      | 0,0%  | -        | -         | -      |
| 15         | 0,0%   | 0,0%   | -     | 0,0%     | -         | -5,0%  |
| 13         | -      | -      | -     | 4,6%     | -         | 0,0%   |
| 10,8       | 7,3%   | 8,3%   | 7,0%  | 9,5%     | 0,0%      | 5,3%   |
| 8          | 12,95  | -      | 10,0% | 15,9%    | 5,6%      | 12,2%  |
| 6          | -      | -      | -     | -        | 9,6%      | -      |

These lighting requirements can be achieved at different levels of efficiency. The desired lighting level can be achieved through good lighting design with relatively low lighting (Light Power Density - LPD) for operational energy without visual comfort [16].

The primary energy load on equipment and people is that there is no change in the optimization scenario. The second-largest energy load on lighting can be reduced by the use of energy-saving lamps. The existing calculations' baseline uses TL and PL lamps with an efficiency value of 15 watts / m2.
This scenario is planned to replace the lamps with LEDs with an efficiency value of 5 watts/m². The energy simulation results through changes in the type of lamp obtained decreased energy use from 157 to 131 kWh/m²/yr (Figure 11). These results indicate efficiency of 26 kWh/m²/yr.

With this scenario, there is a shift in the energy load, where the light load is no longer the second load but drops to the seventh load under the equipment/people and the conduction walls in all directions (Figure 12).

4.5. Scenario 2: Reduction of wall window ratio (WWR) on the West and East sides
The building envelope has a critical role to play in reducing energy consumption for cooling and lighting. In medium and high-rise buildings, the walls' area is much larger than the roof area. In these conditions, the design of vertical building envelopes, especially windows, must be carried out carefully, so that excess heat does not occur in the building. The proportion of window area has a considerable influence on the cooling load because it dramatically determines the total heat gain that enters the building. After all, glass windows can provide much higher heat to the building than massive walls. Therefore, a higher window to wall area ratio (WWR) usually results in a higher cooling load. Reducing the window area is one of the most effective solutions for reducing the cooling load and overall building energy consumption. Since window construction is usually more expensive than wall construction,
reducing WWR can also lower construction costs. The results of a simulation study on typical Jakarta buildings show that reducing the window area by half can reduce energy consumption by up to 10% [6].

On the west side, WWR reduced from 34% to 11%, and on the east side reduced from 37% to 17% (see Table 3).

**Table 3.** Reducing the value of WWR at each side of the building.

| Condition | West | East | North | South |
|-----------|------|------|-------|-------|
| Existing  | 34%  | 37%  | 13%   | 16%   |
| Reduced   | 11%  | 17%  | 13%   | 16%   |

In Figure 13, the energy load on the wall material's cooling is difficult to be repaired. Furthermore, the potential for improvement that can be done next is on the contribution of window openings, especially on the west and east sides. Both sides proposed optimization because, by reference to Figure 13, there is a lot of over lit. For the north and south walls, which are in fifth and sixth place with lower heat potential and existing conditions that are not over lit.

They reduce the wall window ratio (WWR) area, resulting in a decrease in energy consumption from scenario 1 of 131 kWh/m²/yr to 118 kWh/m²/yr. These results indicate a further efficiency of 13 kWh/m²/yr.

![Figure 13](image)

**Figure 13.** Baseline simulation results in scenario 2.

With this scenario 2, although it has contributed to energy efficiency, it does not shift the energy load distribution much except for the wall openings on the south side, which drops under lighting and infiltration (Figure 14).

In the second scenario, the window opening is reduced (WWR). The treatment is done on the sides of the walls that are overlit. The results still give a Mostly Well value on exposure to natural sunlight in buildings. When comparing the initial conditions (Figure 9b) and scenario 2 (Figure 14a), there is a change in underlit increasing from 28% to 40%, well-lit decreasing from 58% to 50%, and overlit, decreasing from 14% to 10%. Even though this scenario captures the amount of natural light entering the building, the total value still gives a WELL LIT value.
4.6. Scenario 3: Replacement of Glass Material

According to the sun's nature, the glass material has different properties according to the sun's transmittance, solar absorption, reflectance, and visible transmittance. The term thermal transmission of glass is measured from the U-Value, for conduction, and the Solar Heat Strengthening Coefficient (SHGC), while for radiation, it uses the Shading Coefficient (SC). In the calculation, the SHGC value is equal to 0.86 SC. Better performing glass materials with low SHGC values of up to 0.2 is available globally but still very high. As an alternative, we can use coated offline glass, which can be applied by the local industry at a lower price. This relatively inexpensive additional coating can reduce the SHGC value by up to 0.2 [6].

In Indonesian climatic conditions, which have a relatively small temperature difference between the outer and inner spaces, the selection of SHGC values will be more effective than increasing the U-Value. Thus, it is usually inefficient to use double glazing to reduce conduction heat gain through windows. For example, reducing SHGC from 0.67 to 0.38 would reduce total energy consumption by 8%. Meanwhile, adding clear glass to form double glass with the same SHGC and lowering the U-Value from 5.8 to 3.4 will only reduce the total energy consumption by about 1%. To show the SHGC drivers of total energy consumption for various types of buildings can be seen in Table 4. For all cases, the U-values and optical transmission were constant at 5.8 W/m² and 0.7%, and SHGC 0.6 as the baseline [6].

| SHGC | Office | Retail | Hotel | Hospital | Apartment | School |
|------|--------|--------|-------|----------|------------|--------|
| 0.6  | 0.0%   | 0.0%   | 0.0%  | 0.0%     | 0.0%       | 0.0%   |
| 0.5  | 5.7%   | 2.4%   | 5.1%  | 5.7%     | 3.7%       | 3.2%   |
| 0.4  | 8.4%   | 3.7%   | 8.5%  | 8.2%     | 6.1%       | 5.1%   |
| 0.3  | 11.0%  | 5.1%   | 11.9% | 10.8%    | 8.4%       | 6.7%   |
| 0.2  | 14.4%  | 6.6%   | 15.4% | 13.3%    | 10.6%      | 7.5%   |

In this building, according to Figure 10a, the infiltration element is an element that is difficult to do in this building, so that the next potential that can still be optimized is from replacing the use of glass material. The suggestion to change the type of glass from its exclusive condition in the form of Indoflot Clear 5 mm glass into several alternatives, several types of glass specifications that are carried out can be seen in Table 4.
Table 5. Changes by using some of the glass specifications.

| No | Type of Glass          | Unit | Indoflot Clear[17] | Panasap Euro Grey[18] | Panasap Dark Grey[18] | Stopsol Dark Blue[19] | T-Sunlux CS-108#2[19] | Stopray Smart 32T 6mm[19] |
|----|------------------------|------|---------------------|-----------------------|-----------------------|------------------------|----------------------|---------------------------|
|    |                        |      | (baseline)          |                       |                       |                        |                      |                           |
| 1  | Visible Light Transmittance | %   | 89                  | 21                    | 21                    | 28                     | 8                    | 20                        |
| 2  | U-Value                | W/m² | 5,8                 | 5,8                   | 5,8                   | 5,8                    | 4,4                  | 1,8                       |
| 3  | Shading Coefficient (SC) | -   | 0,97                | 0,59                  | 0,59                  | 0,46                   | 0,22                 | 0,31                      |
| 4  | Solar Heat Gain Coefficient (SHGC) | - | 0,84                | 0,51                  | 0,51                  | 0,4                    | 0,19                 | 0,27                      |
|    | EUI kWh/m²/yr          |      | 157                 | 113                   | 109                   | 106                    | 99                   | 100                       |
|    | sDA %                  |      | 72                  | 45                    | 26                    | 29                     | 18                   | 25                        |
|    | Daylighting            |      | Well Lit            | Under Lit             | Under Lit             | Under Lit              | Under Lit           | Under Lit                 |
|    | ASE %                  |      | 14                  | 9                     | 7                     | 7                     | 5                    | 7                         |

Table 5 shows that of the five alternative replacements for various types/colors of glass, T-Sunlux CS-108 # 2 glass provides the highest reduction value so that the building consumption becomes 99 kWh/m²/yr. However, when viewed from the quality of natural lighting (sDA), all the glass used causes natural light quality to decrease from "Well Lit" to "Under Lit" (sDA under 50%).

Furthermore, the results of energy simulations using several alternative glass types can be seen from Figure 15 until Figure 19.

Figure 15. Simulation results with the Panasap Euro Gray glass.
Figure 16. Simulation results with the Panasap Dark Gray glass.

Figure 17. Simulation results with the Stopsol Classic Dark Blue glass.

Figure 18. Simulation results with T-Sunlux CS-108#2 glass.
4.7. Scenario 4: Replacement of Glass Material without Reduce WWR

According to the results of scenario 3, the replacement of all types of glass will result in the quality of natural lighting being "under-lit." In scenario 4, a glass replacement is the same as proposed in scenario 3, but without using WWR reduction on the west and east walls. The results of the analysis in scenario four can be seen in Table 6.

Table 6. Changes by using some of the glass specifications.

| No | Type of Glass       | Unit | Indoflot Clear [17] | Panasap Euro Grey [18] | Panasap Dark Grey [18] | Stopsol Classic Dark Blue [19] | T-Sunlux CS-108#2 [19] | Stopray Smart 32T 6mm [19] |
|----|---------------------|------|---------------------|------------------------|------------------------|------------------------------|------------------------|--------------------------|
| (1)| Visible Light Transmittance | %    | 89                  | 51                     | 21                     | 28                           | 8                      | 20                       |
| 2  | U-Value             | W/m² | 5,8                 | 5,8                    | 5,8                    | 5,8                          | 4,4                    | 1,8                      |
| 3  | Shading Coefficient (SC) | -    | 0,97                | 0,72                   | 0,59                   | 0,46                         | 0,22                   | 0,31                     |
| 4  | Solar Heat Gain Coefficient (SHGC) | -    | 0,84                | 0,62                   | 0,51                   | 0,4                          | 0,19                   | 0,27                     |

Table 6 shows that the replacement T-Sunlux glass still provides the highest energy reduction value (103 kWh/m²/yr). In this scenario, all changes to lamp types/colors resulted in a decrease in natural lighting quality, except for replacing the Panasap Euro Gray glass types that still provide 61% sDA and 11% ASE values, thus providing a "well lit" quality. Furthermore, the results of energy simulations using several alternative glass types can be seen from Figure 20 until Figure 24.

Figure 19. Simulation results with the Stopray Smart 32T 6mm glass.
Figure 20. Simulation results with the Panasap Euro Gray glass.

Figure 21. Simulation results with the Panasap Dark Gray glass.

Figure 22. Simulation results with the Stopsol Classic Dark Blue glass.
5. Discussion
The first energy use simulation (EUI) analysis by **baseline** uses the ASHRAE 90.1-2019 material standard resulting in **144 kWh/m²/yr**. This value still far above the ASHRAE target for 2030 at a value of **69 kWh/m²/yr** for school buildings; there is a deviation of **75 kWh/m²/yr**. The two most immense energy consumption is for room cooling and lighting. The percentage of floor area exposed to annual sunlight shows the **Mostly Well Lit** value, where the value is underlit as much as **28%**, well lit is **72%**, and overlit is **14%** (Figure 25).
Figure 25. Result summary of the research.

The second EUI calculation with material modification (wall, ceramic roof, clear glass, concrete floor, etc.) according to the existing conditions as my baseline gives 157 kWh/m²/yr. This value is 13 kWh/m²/yr higher than calculations using materials from the previous standard ASHRAE. The percentage of floor area exposed to annual sunlight is still the same as the baseline ASHRAE 90.1-2019 with the "Mostly Well Lit" value (without changing the lighting elements).

From the EUI calculations results, ASHRAE standard assumptions (baseline) compared to existing building elements (my baseline) results in a lower value. The difference in the EUI value of 13 kWh/m²/yr indicates that the use of the ASHRAE standard in this study must be adjusted to the conditions of material used as the basis and calculation assumptions. These adjustments should primarily be made to glass material (18 kWh/m²/yr), roof (5 kWh/m²/yr), and walls (3 kWh/m²/yr). Ignoring these three elements will result in considerable yield deviations. Adjustments to using materials like this must be adapted to the habits used at the local building location.

The difference between the baseline ASHRAE standard and the existing building conditions (my baseline) about 13 kWh/m²/yr can be understood because of differences in the use of building materials commonly used and local. The differences in the material of the walls, roof, floor, and glass are elements that must be adjusted in advance. The immediate adoption of the ASHRAE standard will result in a significant deviation of the EUI calculation results.

About the results of the distribution of energy consumption in the analysis on my baseline (Figure 10), then lighting consumption is the most extensive energy use after equipment and users. The first improvement effort can be prioritized on the lighting element by replacing the existing lamps using the TL and PL types (1st scenario). This change was made by modifying the LPD (Light Power Density) from 15 Watt/m² to 5 watts/m². This parameter modification reduced energy use from 157 kWh/m²/yr to 131 kWh/m²/yr. These results indicate efficiency of 26 kWh/m²/yr as the most excellent form of efficiency tracking done at this existing building.

Changing conventional lamps to LED lamps can significantly reduce energy use in terms of artificial lighting. The more diverse shapes and models of LEDs and the decreasing price of LED lamps are an
alternative to optimizing existing buildings by replacing lamps like this effectively. In practice, a replacement can be carried out in line with replacing the old lamp, which can be done gradually.

The potential for improvement that can be done next is on window openings, especially on the west and east sides, which are in the third and fourth positions. These sides proposed optimization by reference to Figure 13, and there is a lot of over lit. For the north and south walls, which are in fifth and sixth place with lower heat potential and existing conditions that are not over lit. In the 2nd scenario, they reduce the wall window ratio (WWR) area, resulting in a decrease in energy consumption from scenario 1 of 131 kWh/m²/yr to 118 kWh/m²/yr. These results indicate a further efficiency of 13 kWh/m²/yr.

Reducing WWR can be an effective way to reduce energy consumption and reduce excess natural lighting on the west and east facades. This reduction can also reduce ASE by 14% to 10%, resulting in visual glare and discomfort. The reduction of WWR on the wrong sides will be detrimental to the quality of natural lighting that enters the building. The choice of WWR reduction on the building side must pay attention to the graph of the ASE analysis result, which is very overlit.

The next effort (3rd scenario) to improve energy consumption is replacing the glass used in all windows. The results are shown in Figure 15 until Figure 19 and Table 4 indicate that replacement using four glass types can reduce energy consumption. However, all of them result in the quality of natural lighting from well lit to under lit. The choice of Panasap Euro Grey dan Dark Gray glass, a type of tinted glass, provides an additional reduction in energy consumption of up to 123 and 109 kWh/m²/yr while replacing it with a more reflective Stopsol glass gives 106 kWh/m²/yr results. The use of T-Sunlux glass, which has the lowest transmittance level, provides a reduction of up to 99 kWh/m²/yr, then the use of Stopray glass can reduce up to 100 kWh/m²/yr. All changes to this type of glass resulted in a decrease in natural lighting quality so that the sDA value fell below 50%, with the status changing from my baseline Well Lit to Under Lit.

In the 4th scenario, the analysis was carried out by replacing the same glass type and color as the 3rd scenario without reducing the wall openings (WWR reduction) on the building's west and east sides. The results show that all changes to lamp types/colors resulted in a decrease in natural lighting quality except for replacing the Panasap Euro Gray glass types that still provide 61% sDA and 11% ASE values, thus providing a "well lit" quality. Of the four scenarios that have been carried out, only scenarios 1 to 3 provide a value of natural lighting quality that remains "well lit." Scenario 4 causes the quality to drop to "under-lit." Furthermore, from scenarios 1, 2, and 3, the lowest EUI value is in scenario 2 with a value of 118 kWh/m²/yr, so the 2nd scenario is the best in this optimization process.

6. Conclusion

EUI (Energy Use Intensity) calculations carried out on existing buildings in Semarang (Indonesia) using Sefaira on the ASHRAE 90.1-2019 standard (baseline) compared to adjustments to the material existing (my baseline) gave an increased value from 144 to 157 kWh/m²/yr.

There are four scenarios for optimization energy used in this building as follows:

- The first improvement effort (1st scenario) can be prioritized on the lighting element by replacing the existing lamps using the TL and PL types into LED lamps (change LPD from 15 Watt/m² to 5 watts/m²). This scenario resulted in a reduction of energy from 157 to 131 kWh/m²/yr.
- In the 2nd scenario, they reduce the wall window ratio (WWR) area, resulting in a decrease in energy consumption from scenario 1 of 131 kWh/m²/yr to 118 kWh/m²/yr.
- In 3rd scenario to improve energy consumption is by replacing the glass used in all windows. However, all of them result in the quality of natural lighting from well lit to under Lit.
- In the 4th scenario, the analysis was carried out by replacing the same glass type and color as the 3rd scenario without reducing the wall openings (WWR reduction) on the building's west and east sides. The results show that all changes to glass types/colors resulted in a decrease in
natural lighting quality, except for replacing the Panasap Euro Gray glass types that still provide 61% sDA and 11% ASE values, thus providing a "well lit" quality.

Of the four scenarios, only scenarios 1 to 3 provide a value of natural lighting quality that remains "well lit." Scenario 4 causes the quality to drop to "under-lit." Furthermore, from scenarios 1, 2, and 3, the lowest EUI value is in scenario 2 with a value of 118 kWh/m²/yr, so the 2nd scenario is the best in this optimization process.

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