THE IMPACT OF SECONDARY SKIN ON NATURAL LIGHTING IN THE OFFICE OF BPS SALATIGA: A SIMULATION STUDY USING DIALUX EVO 13.0 AND GREEN ARCHITECTURE PRINCIPLES

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ABSTRACT

The development of technology and the demand for sustainability encourage the importance of applying green architecture principles in office buildings. The implementation of green architecture principles in government office buildings often encounters challenges such as limited stakeholder awareness, budget constraints, and the absence of passive design strategies that optimize natural resources. These conditions highlight the urgency of exploring design interventions that balance energy efficiency, user comfort, and sustainability. This study aims to evaluate the effectiveness of using secondary skin in improving daylighting in the Central Statistics Agency (BPS) of Salatiga City. The approach used is a green architecture approach with a focus on energy efficiency and the visual comfort of space users. The research method includes analyzing the existing conditions and redesigning the facade using secondary skin elements based on daylighting simulation through DIALux Evo, Revit, and EDGE App software. Simulations were conducted on several main workspaces to compare the value of light intensity between the existing conditions and the redesign results. A comparative simulation between DIALux Evo 13.0 and Autodesk Revit revealed consistent daylight distribution patterns, confirming the effectiveness of a 90° vertical secondary skin configuration. The EDGE Application 2.1.5 analysis indicated potential energy savings of 55.32% in redesigned conditions, highlighting the secondary skin's role in reducing artificial lighting dependency and contributing to the overall building's energy efficiency. The results show that the application of secondary skin can improve the even distribution of natural light and reduce dependence on artificial lighting. In addition, the proposed redesign contributes to achieving energy efficiency principles and improving workspace quality. This research is expected to serve as a reference for the application of sustainable passive design in government agency buildings in tropical areas.

Keywords: *Daylighting, DIALux Evo, Energy Efficiency, Green Building, Secondary Skin*

INTRODUCTION

The increasing need for energy efficiency and sustainable buildings is driving the transformation of architectural design towards a green architectural concept. One of the strategies used to achieve this goal is the use of secondary skin, which is an additional layer on the facade of buildings that functions to control natural lighting and improve the visual comfort of residents. With this role, the secondary skin becomes an important element in optimizing the intensity of natural light without causing excessive heat conditions (Irfan, Winandari and Tundono, 2023)

The Office of the Central Statistics Agency (BPS) of Salatiga City as a government institution, requires a work environment that supports productivity, including in terms of natural lighting and energy use efficiency. However, existing buildings still have limitations in optimal natural lighting management, which has an impact on visual comfort and energy consumption.

Previous research has also shown that the use of secondary skin can increase the effectiveness of natural light distribution into buildings by up to 30% compared to conventional facades (Alkan and Yazıcıoğlu, 2016). Research conducted by Lohwanitchai and Jareemit (2021) declares that the use of secondary skin in the building lighting system can reduce energy consumption by up to 20%. DIALux Evo 13.0 was chosen for its precision in daylighting simulation and its ability to evaluate illumination levels in accordance with GBCI daylighting criteria. Autodesk Revit complements the analysis by providing BIM-based daylight visualization and spatial distribution patterns, allowing qualitative assessment of visual comfort. The EDGE Application 2.1.5 was employed to quantify energy performance improvements resulting from passive design interventions, ensuring alignment with green architecture principles. In the context of natural lighting performance evaluation, simulation software such as the DIALux Evo 13.0 has proven to be effective in accurately analyzing light intensity and distribution.

This study offers a novel contribution by evaluating the effectiveness of the use of secondary skin on natural lighting in office buildings through a simulation approach based on DIALux Evo 13.0. The evaluation is carried out within the scope of green architecture as a reference for sustainable and energy-efficient building design. The main objective of this study is to examine the effectiveness of the use of secondary skin on natural lighting at the BPS Office of Salatiga City using the DIALux Evo 13.0 simulation. The results of the research are expected to be a reference for designing an office building that is energy efficient and environmentally friendly.

THEORY / RESEARCH METHODS

Green Building Architecture

Green buildings are sustainable buildings designed with the principle of environmentally friendly energy efficiency from the stage of site selection, design, construction, use, maintenance, renovation, and demolition (Laksmi Widyawati, 2020). The emergence of the concept of green building architecture is a response to the disadvantages of conventional construction, such as energy consumption and high carbon emissions. Green building is a solution to these problems, by emphasizing the principles of sustainability, energy efficiency, and the comfort and health of residents (Vasudha and Dutta, 2024). These principles aim to maintain a balance between human needs and nature conservation (Fikri Mauludi and Fitri Satwikasari, 2020). Application of green built environment design plays a crucial role in realizing a sustainable built environment by prioritizing the use of eco-friendly materials, ensuring a balanced design between buildings and green spaces, and incorporating integrated energy-efficient systems (Jordan *et al.*, 2024).

The application of green building principles in Indonesia refers to the GREENSHIP assessment system by Green Building Council Indonesia (Widyakusuma, 2023), which consists of six categories: Appropriate Site Development (ASD), Energy Efficiency and Conservation (EEC), Water Conservation (WAC), Material Resources and Cycle (MRC), Indoor Health and Comfort (IHC), and Building and Environment Management (BEM). Each category includes aspects such as strategic location selection, efficient use of energy, and building operational management. The dependence on artificial resources keeps buildings away from the concept of sustainability, so the use of renewable natural resources such as sunlight and rainwater is key to creating environmentally friendly buildings that are low emissions and comfortable for their occupants (Zuliana and Fitriani, 2024).

Green building architecture encompasses the entire building life cycle from planning to demolition with a focus on energy efficiency and sustainability. According to (Budiman *et al.*, 2024), the green building approach includes active and passive strategies. Active strategy includes the use of Building Management System (BMS), renewable energy such as solar panels, and eco-friendly materials to reduce emissions and energy consumption. Meanwhile, a passive strategy is applied from the initial design stage by utilizing natural light, cross ventilation, proper building orientation, and low-heat-absorbing sheathing materials such as green roof and green wall, to create natural thermal comfort without reliance on mechanical systems.

Secondary Skin as a Passive Strategy

Efforts to realize green buildings are carried out through passive strategies that maximize the natural potential of the environment to support energy efficiency and space comfort. One of the important elements is natural lighting, which can reduce dependence on artificial lighting while creating visual comfort (Fleta, 2021a). However, excessive sunlight without regulation can cause the effect of glare and heat, so it requires an element of secondary skin as a solution to control the intensity and distribution of incoming light (Saifulhaq, Hendrawati and Ananda, 2023). Building design, opening size, depth of space, orientation, and environmental conditions greatly affect the quality of natural lighting received and distributed within the space (Fleta, 2021b). Therefore, proper planning at an early stage greatly determines the success of passive strategies in green building.

Secondary skin is the outer layer of the building that is separated from the inner layer by air cavities, serves as a heat and light controller, and contributes to the aesthetics of the façade (Figure 1 & Figure 2) (Kustiawan, Felly and Syafrina, 2023; Darmawan and Hendri, 2024). Secondary skin material is essential to improve thermal and visual comfort, as well as support energy efficiency. Eco-friendly materials such as wood and bamboo are considered ideal because they have renewable, reusable, and recyclable properties, and provide aesthetic and functional value (Figure 4) (Fathia, Oka Sindhu Pribadi and Utami, 2020). Wood, for example, in addition to being a good thermal insulator, also has a natural appearance that enriches the visual character of the building (Figure 3) (Wiriantari, 2023). The selection of materials in this context has a great influence on the sustainability of buildings and the achievement of green architectural principles.

Figure 1. Example of Secondary Skin
Source: (Sá, 2021)

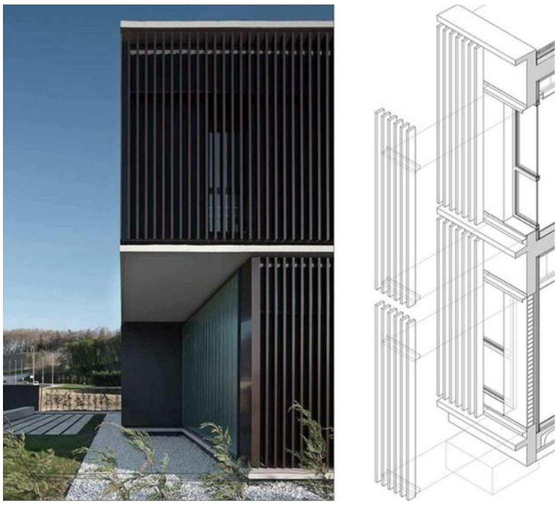


Figure 2. Secondary Skin Illustration
Source: (Normadin, 2025)

Figure 3. Secondary Skin Wood
Source: (Pinterest.id, 2025)

Figure 4. Secondary Skin Bamboo
Source: (Yang, 2011)

Kartika Pratiwi, Kridarso and Iskandar (2021) discussed the concept of natural lighting in the design of the gallery space using DIALux Evo 9.0 at the Center for Arts and Culture Performance Building at TMII, East Jakarta. The goal is to find out whether the lighting intensity meets the SNI 03-6575-2001 standard and the GREENSHIP Rating Tools GBCI through the DIALux Evo 9.2 simulation. The methods used include natural lighting simulations based on data on coordinates, shapes, and dimensions of space, as well as openings, carried out at 08.00, 12.00, 14.00, and 16.00 WIB, with analysis of light intensity, range, and distribution. The results showed the 500 lux standard was achieved at all simulation times, with the percentage of bright areas being 42%, 76%, 68%, and 54%. The use of low-E glass affects the distribution of light, and it is necessary to adjust the layout and artificial lighting in areas where natural light is less accessible.

Fahrezi and Widiastuti (2023) researched the optimization of secondary skin for natural lighting quality in the UNESA Faculty of Art and Design Building through DIALux Evo simulation under existing conditions and redesign. The purpose is to evaluate the facade of the building in distributing natural light in accordance with SNI 6197-2011 for thermal comfort. The simulation was carried out in classrooms, libraries, offices, and lecturers' rooms at 10.00 and 14.00 WIB. Results show existing conditions exceed 2000 lux causing glare; vertical secondary skin lowers the intensity to 279–112 lux (morning) and 256–879 lux (noon), more optimal than horizontal skins which tend to make rooms dark.

Various facade strategies within green architecture, including green facades and secondary skin systems, have been shown to improve building energy performance by reducing solar heat gains and enhancing thermal comfort. According to Raji (2015), integrating an additional facade layer can act as an effective passive design solution, decreasing cooling loads while maintaining adequate daylight levels. This supports the present study's evaluation of vertical secondary skin geometry as part of green architecture implementation.

The deductive-qualitative method was used in the study. The principle brings the theory to see how the process of behavior settings is formed, especially how the elderly in BPSTW Pakembinangun, Sleman, DIY, as the object of research, behave on existing settings related to the condition of the potential disaster situation Mt. Merapi. This study uses a rationalistic paradigm that researchers see the truth not only from empirical terms (experience in the field), but also from perceptual arguments that are part of the construction of thinking (Muhadjir, 1996). The qualitative analysis process researchers feel appropriate in discussing this study. Data collection methods include observation, behavioral mapping, time budgeting, and interviews.

Research Methods

This research method uses a simulation based on the DIALux Evo 13.0 software to determine the effectiveness of secondary skin in measuring the intensity and distribution of natural lighting. DIALux Evo was chosen because of its high level of precision and ability to visualize simulation results well (Ariestadi *et al.*, 2023). In addition, Autodesk Revit is used because it supports natural lighting simulation and end-to-end continuous design (Perdana, 2024). Despite its advantages, DIALux Evo is limited in the form of windows, while Revit cannot simulate time after 2010. Therefore, the two are used in a complementary manner. The DIALux Evo simulation was performed with a variation of the tilt angle secondary skin (30°, 45°, 60°, 90°), then the design results were re-simulated using Revit. In addition, EDGE Application 2.1.5 is used to evaluate the energy efficiency of existing buildings and redesign (Salsabila and Prianto, 2020).

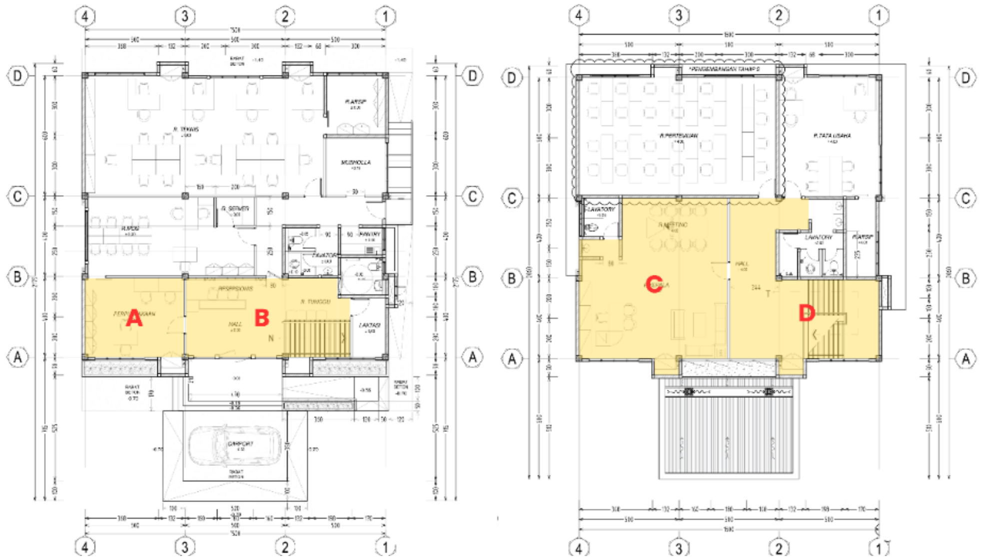


Figure 5. Plans for Research Objects

The object of the research is the Central Statistics Agency of Salatiga City Office, which is located on Jl. Hasanudin Number 01, Salatiga (Figure 5). The study focused only on four main areas with high openness and activity: A) libraries; B) receptions and waiting rooms; C) workspaces and meetings; and D) halls. The simulation time was selected at 08.00, 12.00, and 14.00 WIB to represent the natural lighting of the morning, afternoon, and evening (Kartika Pratiwi, Kridarso and Iskandar, 2021).

The research utilized a three-stage simulation approach: 1) DIALux Evo 13.0 for quantitative daylighting analysis; 2) Autodesk Revit for BIM-based qualitative validation of daylight distribution; and 3) EDGE Application 2.1.5 to assess overall energy efficiency gains from the passive facade design. DIALux Evo provided numerical lux data for comparison against GBCI standards, while Revit offered visual mapping to confirm distribution uniformity. EDGE quantified the energy-saving potential of the proposed facade in the context of green architecture (Figure 6).

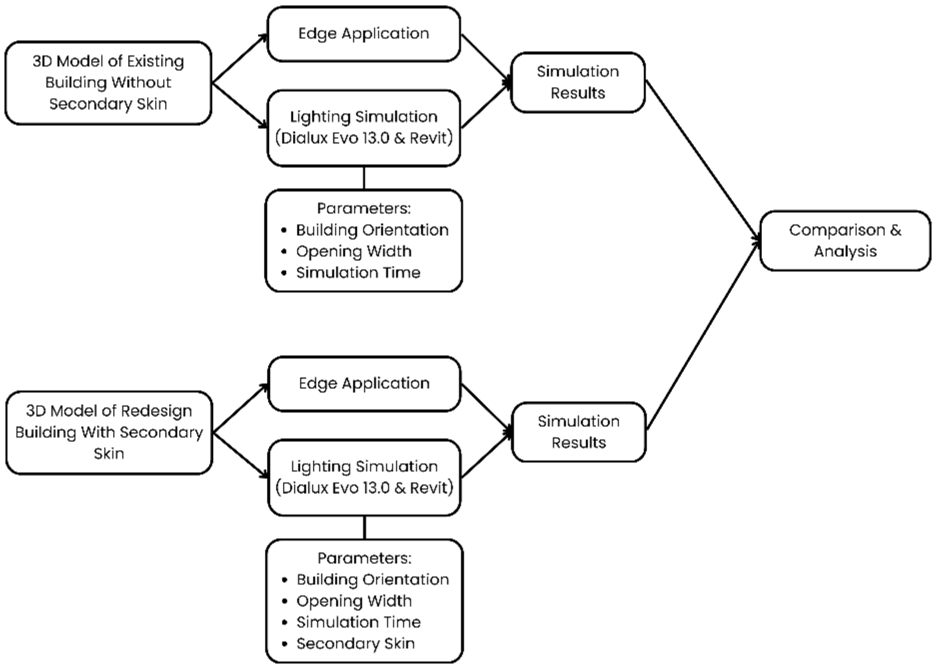


Figure 6. Research Method Flow Diagram

The data collection technique in this study uses a quantitative method with a simulative approach through DIALux Evo 13.0 and EDGE Application 2.1.5 software. Data were collected on existing conditions and redesigned in the form of light intensity (lux) in the area studied, as well as building data through working drawings to simulate energy efficiency based on a green architecture approach, and then the results were compared. The simulation was carried out under two conditions, namely existing without secondary skin and redesign with secondary skin, at 8.00, 12.00, and 14.00 WIB local time as a representation of the natural lighting of the morning, afternoon, and early afternoon—the active time of the workspace use, referring to (Kartika Pratiwi, Kridarso and Iskandar, 2021). 08.00 was chosen because the sun was starting to rise but not yet dazzling, 12.00 because of the position of the sun above the earth with maximum illumination, and 14.00 as the transition from noon to evening with the light starting to decrease but still dazzling from the west. These three times are relevant for analyzing the intensity of natural lighting thoroughly. Some of the data collection steps via DIALux Evo 13.0 are presented in Figure 7.

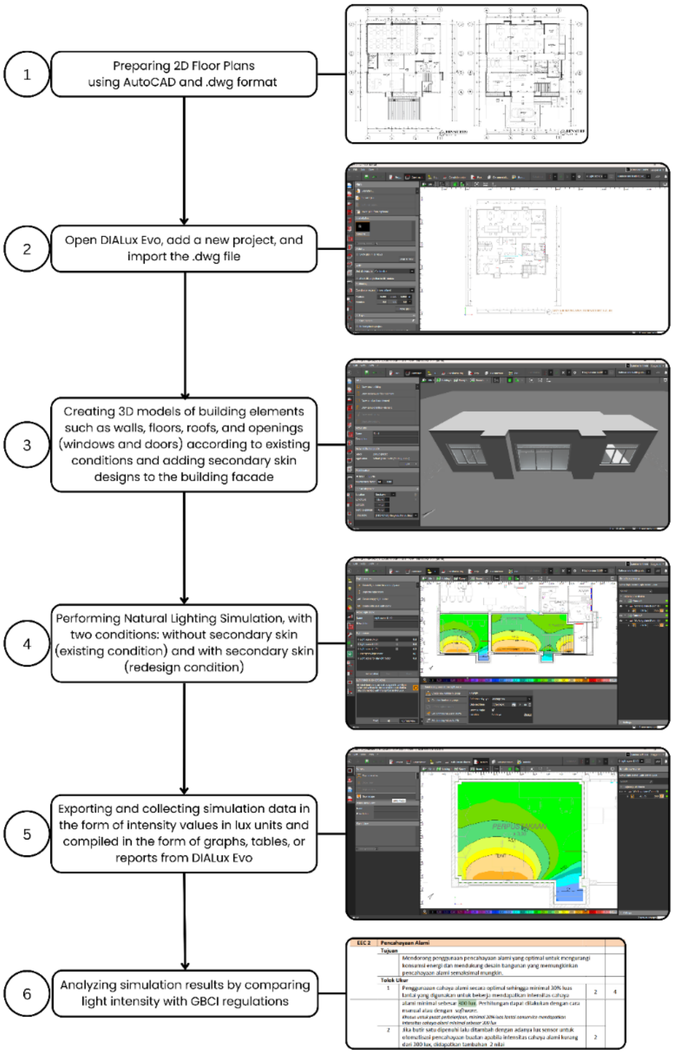


Figure 7. DIALux Evo 13.0 Data Collection Step Flow Diagram

RESULTS AND DISCUSSION

Redesign Plan

The secondary skin design in the BPS Office building in Salatiga City is a passive strategy that functions to optimize natural lighting and thermal control, referring to green architecture principles based on GBCI standards on energy efficiency (EEC) and indoor comfort (IHC) points. This element uses a low-carbon material, namely Wood Plastic Composite, and is designed in three main shapes based on its location and shape, which are categorized into types A, B, and C as shown in Figure 8.

Figure 8. Secondary Skin Design

Based on the results of the analysis of the existing condition of the Salatiga City Central Statistics Agency (BPS) Office building, it is known that the facade of the Salatiga City Central Statistics Agency Office building has not been able to optimize natural lighting and energy efficiency. Although the simulation results show that the intensity of natural lighting entering some rooms has exceeded the minimum standard set by GBCI, which is 300 lux, the intensity of light entering the room tends to be uneven and creates potential glare, thus impacting the visual comfort of the user and increasing dependence on artificial lighting. In addition, existing facades have not taken advantage of passive design elements that help significantly reduce thermal load and energy consumption.

In response to this, the redesign of the facade of the Salatiga City Central Statistics Agency Office building was carried out with a green architecture approach through the application of secondary skin as a passive strategy. This effort is directed to control the distribution of natural light more effectively, improve the energy efficiency of buildings, and strengthen the visual aesthetics of the office as a public service institution that is adaptive to sustainable issues. One of the aspects that determines the effectiveness of secondary skin is the slope of the corners. This tilt angle affects how sunlight is transmitted or reflected before it reaches the interior surface, thus contributing directly to visual comfort and energy efficiency.

The angle of inclination in shading elements such as lattices has been shown to affect the quality of natural lighting in a space. Changes in angle cause variations in the direction and intensity of incoming light, thus impacting the distribution of light in the room. When the angle of inclination is precisely set, the shading element can reflect light in a certain direction before it enters space, resulting in more even and visually comfortable lighting. Conversely, inappropriate angles can cause light concentration at certain points and create an illumination imbalance. Therefore, the adjustment of the grate tilt angle is an effective design strategy to control natural lighting, both to reduce glare and to improve lighting efficiency in buildings (Sabtalistia, 2023). The redesign of this building was carried out in several stages as follows: 1) Use of secondary skin, 2) Change of the shape of the roof from a *limasan* to an inclined, 3) Solar panel usage.

DIALux Evo 13.0 Simulation Redesign Conditions

The redesign stage is carried out by applying vertical secondary skin elements as a passive strategy in improving the quality of natural lighting while reducing the potential for glare and energy load in the building. The lighting simulation was carried out using DIALux Evo 13.0 software by varying the angle of tilt of the grille, the secondary skin grille, namely 30º, 45º, 60º, and 90º. This angular variation aims to observe how the orientation and tilt angle of the lattice affect the intensity of natural light entering the space at different times.

The simulation was carried out in several rooms with different functions and at three main activities (morning, noon, and evening). Each angle variation was tested to see if the light intensity (lux) results obtained met the minimum natural lighting standards based on the criteria of the Green Building Council Indonesia (GBCI), which is 300 lux. The results of this simulation show a significant difference in the intensity of natural lighting.

Simulation of Secondary skin Grid Tilt Redesign Conditions 30º

The first simulation uses an alternative secondary skin design with a 30º angular grid tilt. This angle was chosen due to considerations of visual efficiency and natural lighting, where the 30º angle is still able to dispel the intensity of direct sunlight from the east without completely blocking the access of natural light into the room.

Simulation of Redesign Conditions of the Slope of the Secondary Skin Grid 45º

The second simulation uses an alternative secondary skin design with a 45º angular lattice tilt. This angle was chosen because the lattice is tilted to the east, effectively reducing morning sunlight.

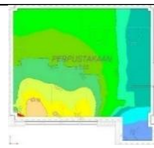
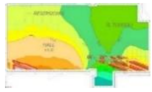
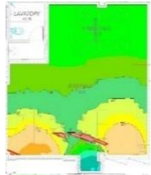
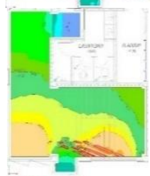
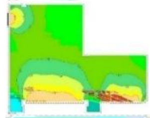
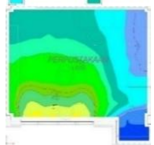
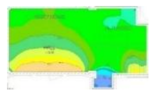
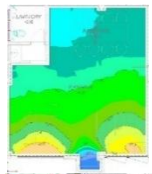
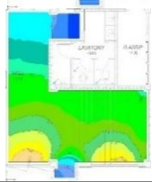
Simulation of Secondary skin Tilt Redesign Conditions 60º

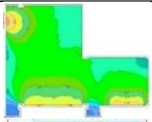
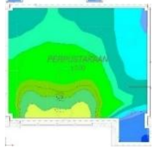
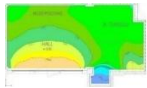
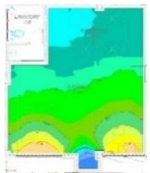
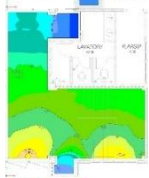
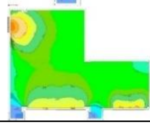
The third simulation used a variation in the tilt of the secondary skin grid with an angle of 60º. This angle provides stronger shading than the previous angle, still effective at blocking morning and part of the day. This simulation is carried out with the same parameters, but produces different light intensities in each predetermined area

Simulation of the Redesign Condition of the Slope of the Secondary Skin Grid 90º

The last simulation is to use a secondary skin design with a perpendicular grid or has a 90º angle. This angle balances the amount of natural light that enters without causing excessive glare, whether in the morning, afternoon, or evening. The vertical position makes the grid work neutral in blocking light from various directions (Table 1).

Table 1. Simulation Results of 90º Angle Redesign Conditions

Time (WIB)	**Area**	**Location of the Area**	**Function**	**Corner**	**GBCI (lux)**	**Light Intensity (lux)**	**Information**	**Simulation Results**
08.00	A		Library	90º	300	281	Close to the standard	
08.00	B		Reception and waiting room	90º	300	1073	Exceed the standard	
08.00	C		Work space and meeting	90º	300	580	Exceed the standard	
08.00	D		Hall	90º	300	698	Exceed the standard	
08.00	E		Lounge	90º	300	518	Exceed the standard	
12.00	A		Library	90º	300	128	Not meeting	
12.00	B		Reception and waiting room	90º	300	331	Meet	
12.00	C		Work space and meeting	90º	300	214	Not meeting	
12.00	D		Hall	90º	300	256	Close to the standard	

Time (WIB)	Area	Location of the Area	Func-tion	Cor-ner	GBCI (lux)	Light Inten-sity (lux)	Infor-mation	Simulation Results
12.00	E		Lounge	90º	300	230	Not meeting	
14.00	A		Library	90º	300	138	Not meeting	
14.00	B		Recepti-on and waiting room	90º	300	365	Meet	
14.00	C		Work space and meeting	90º	300	221	Not meeting	
14.00	D		Hall	90º	300	277	Close to the standard	
14.00	E		Lounge	90º	300	308	Meet	

Comparison of Existing Conditions, Simulation Results, and Redesign

Natural lighting simulations using DIALux Evo 13.0 software have been carried out under two conditions, namely existing conditions and redesign. The purpose of this simulation was to evaluate the effectiveness of the design against the quality of natural lighting based on the GBCI (Green Building Council Indonesia) standard, which sets a minimum value of 300 lux for the visual comfort of the office space.

The orientation of a building is one of the important factors in controlling natural lighting because it determines the direction of sunlight coming into space. The Salatiga City Central Statistics Agency Office building has a main orientation facing southeast, which means that most of the main facade gets exposure to morning sunlight until late afternoon. The southeast direction allows direct sunlight to enter from 7.00 to around 11.00 WIB, depending on the season and geographical conditions. This causes the intensity of natural lighting in the morning to be very high, especially in the spaces that are on the side of the main facade, such as the Reception, Waiting Room, and Hall. Light intensity data under two existing and redesigned conditions are presented in Table 2.

Table 2. Comparison of Existing and Redesign Simulation Results

Time (WIB)	Area	Function of Space	Existing Simulation Results (lux)	Tilt Angle Grid Secondary skin			
				30°	45°	60°	90°
08.00	Area A	Library	1198	165	200	243	281
08.00	Area B	Reception and Waiting Room	2623	943	1017	1058	1073
08.00	Area C	Workspace and Meeting	1527	509	527	547	580
08.00	Area D	Hall	1609	538	556	586	698
08.00	Area E	Lounge	-	424	478	465	518
12.00	Area A	Library	421	83	99	114	128
12.00	Area B	Reception and Waiting Room	666	321	326	326	331
12.00	Area C	Workspace and Meeting	401	187	194	203	214
12.00	Area D	Hall	496	221	231	241	256
12.00	Area E	Lounge	-	218	224	224	230
14.00	Area A	Library	500	92	109	125	138
14.00	Area B	Reception and Waiting Room	754	350	361	361	365
14.00	Area C	Workspace and Meeting	445	189	199	210	221
14.00	Area D	Hall	571	241	251	262	277
14.00	Area E	Lounge	-	297	303	303	308

Information:

- Not meeting standards (< 250 lux)
- Close to standard (250 – 299 lux)
- Meet standards (300 – 500 lux)
- Exceeds standard (> 500 lux)

Natural lighting simulations under existing conditions show that most rooms are subjected to excessively high light intensity, especially in the morning, as seen in Area B (Reception and Waiting Room) and Area D (Hall) in Table 2, with a lux value exceeding 1500. This has the potential to cause glare and visual discomfort.

Based on the comparison, it can be concluded that the redesign has succeeded in significantly lowering the level of natural lighting, especially in Area A (Library), which was previously too bright and is now at the standard of visual comfort. This shows that lighting control efforts, both through opening orientation, modification of facade elements, and the potential use of secondary skin, have had a positive impact. However, some rooms still show high levels of light intensity, especially in areas B (Reception and Waiting Room) and D (Hall).

After redesigning using *a* secondary skin with various variations in tilt angles of 30°, 45°, 60°, and 90°, light intensity data (lux) were obtained in five main areas of the building and three observation times (morning, noon, and afternoon). The data is then compiled in Table 2 in the form of a recapitulative table with a coloring system to show the level of effectiveness of each corner in meeting the minimum natural lighting standard of 300 lux according to the criteria of the Green Building Council Indonesia (GBCI).

From the results of the analysis, the angle of inclination of the secondary skin of 90° in Table 2 proven to be the most effective in optimizing natural lighting passively. This angle shows relatively stable lighting performance in almost all observation areas and times. The Reception and Break Room consistently meet lighting standards, while the Work Room and Hall approach or achieve standard values in the morning and evening. In addition, the 90° angle can avoid over lighting conditions that have the potential to cause glare, as seen at angles of 30°, 45º, and 60°, which produce a lux value that exceeds the upper limit of visual comfort (>500 lux).

In general, the simulation results also show that the use of secondary skin is very effective in reducing excessive light intensity, especially in areas that receive direct exposure to sunlight in the morning and afternoon. With the ability to control the amount of light entering the room, secondary skins serve as a passive strategy that not only improves the quality of natural lighting but also supports visual comfort and overall energy efficiency. Therefore, the use of *a* secondary skin with a 90° inclination angle is recommended as the most optimal passive design solution in the redesign of the Salatiga City Central Statistics Agency Office building.

Simulation of Secondary Skin using Revit

Natural lighting simulation of the proposed design was carried out using DIALux Evo 13.0 software to evaluate the performance of secondary skin*s* with angle variations of 30°, 45°, 60°, and 90°. Based on the results of the simulation, *the* secondary skin with an angle of 90° showed the most optimal performance in distributing light evenly throughout the room, minimizing potential glare, and meeting the minimum natural lighting standard of 300 lux according to the guidelines of the Green Building Council Indonesia (GBCI).

As a complement to the analysis, additional simulations were carried out using Autodesk Revit software with a focus on the 90° angle that is most effective in the DIALux Evo simulation results. The purpose of this simulation is not to validate, but rather to compare the natural lighting distribution patterns of the two software programs using different technical approaches. Revit uses a Building Information Modeling (BIM)-based approach with an integrated lighting analysis system, while DIALux Evo uses more detailed timing and location settings.

DIALux Evo allows users to specify a specific time up to 2025, so in this simulation, the date is April 30, 2025. Meanwhile, Autodesk Revit only allows time-setting up to 2010, which causes differences in the position of the sun and the distribution of natural lighting produced.

For the simulation results to be directly compared, the building design, orientation, and secondary skin material parameters in Revit are matched with the parameters in the DIALux Evo simulation. The simulation was carried out at the same time, namely at 08.00, 12.00, and 14.00, as well as in five main rooms, namely Area A (Library), Area B (Reception and Waiting Room), Area C (Workspace and Meeting Room), Area D (Hall), and Area E (Break Room).

Another difference lies in the format of the output of the simulation results. DIALux Evo presents results in the form of quantitative numbers of units of lux at each simulation point, allowing for more detailed numerical analysis. Meanwhile, Revit displays results in the form of color gradation visualizations that represent the luminance range and include data on the percentage of area that is within the ideal range of natural lighting, which is 300–2000 lux. Figure 9 shows the color scale used in the Autodesk Revit simulation as a representation of the natural lighting intensity of each area of space.

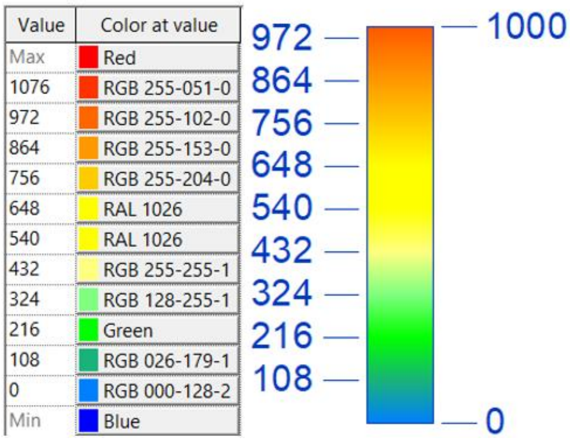


Figure 9. Revit Lighting Simulation Color Indicator

The image above shows the color gradation scale used in the lighting simulation to visually show the level of illumination in lux. This color indicator can make it easier to understand the spatial and fast distribution of natural light in a room without the need to look at the lux numbers in detail at each point. The scale in Revit used ranges from 0 to 2000 lux.

Based on the color mapping on the simulation indicators in Figure 9, the distribution of natural lighting in the building showed significant variations in illumination levels between rooms. The next analysis was carried out in each of the same rooms to determine the level of lux and compare the simulations that have been carried out on the DIALux Evo 13.0. The explanation for each space will be provided in the following time-based points:

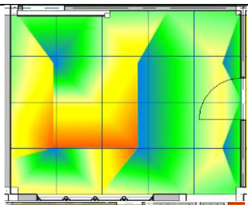
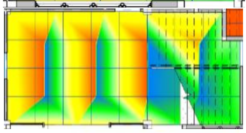
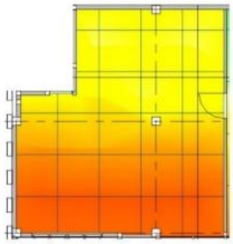
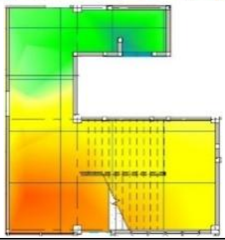
Simulation of 90° Tilt at 08.00 WIB

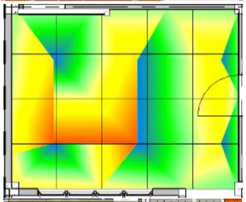
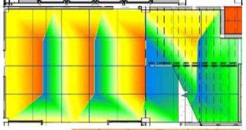
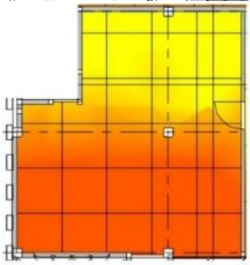
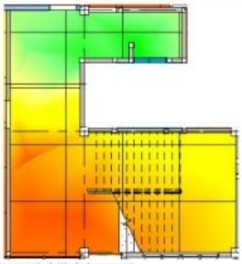
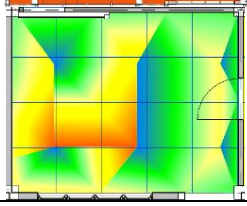
The natural lighting simulation carried out in Revit displays the results in visual form in the form of color gradations from red to blue. To obtain the lux value in the form of numbers, the average calculation of the color in the analyzed area is calculated by multiplying the estimated lux of each color by the percentage of the area of color. The estimated lux value is obtained from the average between the minimum and maximum lux values of each color and multiplied by the percentage of area. The first simulation was carried out at 08.00 WIB, for the calculation for each room is shown in the form of the Table 3.

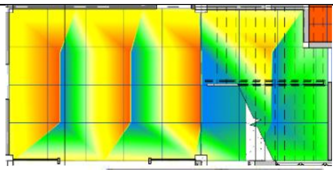
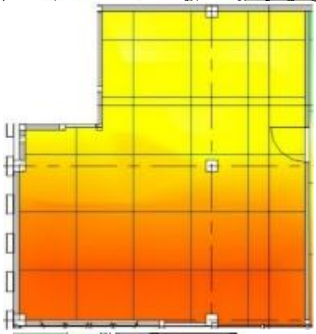
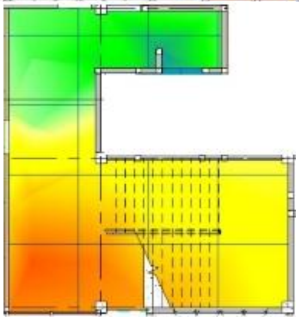
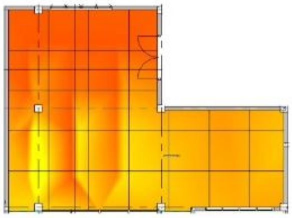
Simulation of 90° Tilt at 12.00
The second lighting simulation was carried out at 12.00 WIB in the afternoon with the same method and treatment as the previous simulation. The estimated lux value is obtained from the average between the minimum and maximum lux values of each color and multiplied by the percentage of area.

Simulation of 90° Tilt at 14.00
The last simulation was carried out at 14.00 WIB with the same method and treatment, as well as the same way to obtain the same lux value as the simulation carried out at 08.00 WIB and 12.00 WIB. The natural lighting simulation carried out in the Revit software was carried out 3 times, namely at 08.00 WIB, at 12.00 WIB, and at 14.00 WIB with the same method and treatment as the simulation carried out on the DIALux Evo. Then to make the analysis easier, the final lux results of 5 rooms at each time will be displayed in the form of a table below which contains information about the simulation time, area and location in the building, room functions, estimated lux weight, and information on the simulation results from Revit (Table 3).

Table 3. Comparison of Lighting Simulation Results using Revit

Time (WIB)	Area	Function of Space	Value (lux)	Information	Simulation results
08.00	A	Library	434.4	Meet Standards	
08.00	B	Reception and Waiting Room	542.4	Exceeding Standards	
08.00	C	Workspace and Meeting	695.5	Exceeding Standards	
08.00	D	Hall	627.9	Exceeding Standards	

Time (WIB)	Area	Function of Space	Value (lux)	Information	Simulation results
08.00	E	Lounge	817.2	Exceeding Standards	
12.00	A	Library	456.9	Meet Standards	
12.00	B	Reception and Waiting Room	470.3	Meet Standards	
12.00	C	Workspace and Meeting	736.1	Exceeding Standards	
12.00	D	Hall	600.95	Exceeding Standards	
12.00	E	Lounge	844.2	Exceeding standards	
14.00	A	Library	499.5	Meet Standards	

Time (WIB)	Area	Function of Space	Value (lux)	Information	Simulation results
14.00	B	Reception and Waiting Room	598.7	Exceeding Standards	
14.00	C	Workspace and Meeting	391.5	Meet Standards	
14.00	D	Hall	306	Meet Standards	
14.00	E	Lounge	722.55	Exceeding Standards	

The simulation carried out on the Revit software was carried out to compare the simulation results on the DIALux Evo in the building of the Central Statistics Agency of Salatiga City in redesign conditions with a secondary skin slope of 90°. To find out the comparison between the simulation results using DIALux Evo 13.0 software and the simulation results using Revit software, the simulation results between the two are presented in the following comparison table.

Natural lighting simulation results using Revit consistently show higher lux values compared to using DIALux Evo in almost every room and time of observation performed. This difference in lux value is caused by several factors, one of which is the difference in approach in displaying the simulation results. DIALux Evo displays the simulation results in the form of light intensity values (lux) numerically and directly in the observation area, while Revit presents results in the form of indicator visualizations with color gradations, lower and upper limits of lux intensity values, and area percentages (Table 4).

Table 4. Comparison of DIALux Evo and Revit Simulation Results

Time (WIB)	Area	Function of Space	Redesign simulation results	
			DIALux Evo.13.0	Revit
08.00	A	Library	281	434,4
	B	Reception and Waiting Room	1073	542,4
	C	Workspace and Meeting	580	695,5
	D	Hall	698	627,9
	E	Lounge	518	817,2
12.00	A	Library	128	456,9
	B	Reception and Waiting Room	331	470,3
	C	Workspace and Meeting	214	736,1
	D	Hall	256	600,95
	E	Lounge	230	844,2
14.00	A	Library	138	499,5
	B	Reception and Waiting Room	365	598,7
	C	Workspace and Meeting	221	391,5
	D	Hall	277	306
	E	Lounge	308	722,55

The difference in results can also be attributed to the difference in the simulation time used on each software. Simulations using DIALux Evo were carried out with a time setting of April 30, 2025, while Revit only allowed simulations until 2010, so it was used on April 30, 2010. This year's difference has an impact on the position of the sun and weather conditions that affect the intensity of natural light entering the building.

Although there are variations in lux values, the natural lighting distribution patterns generated by both software are relatively consistent in identifying rooms with high and low lighting. All rooms simulated using Revit exhibit natural lighting that meets or even exceeds the minimum natural lighting standard of 300 lux as per GBCI regulations. This shows that the 90° angular tilt of the *applied* secondary skin is functionally effective in optimizing natural lighting.

Therefore, the results of the simulation using Revit not only strengthen the results of the DIALux Evo simulation but also support the use *of* secondary skin*s* as a passive design strategy to improve visual comfort and energy efficiency in the Salatiga City Central Statistics Agency Office building.

EDGE Application 2.1.5 Redesign Conditions

In the building of the Central Statistics Agency of Salatiga City, the condition of the redesign, several adjustments were made to the architectural and technical aspects to achieve improvements in energy and water efficiency. One of the significant changes of the Salatiga City Central Statistics Agency building is the addition of a single floor where most of the area is designed as open space, which is used as an open park as part of active green space. In addition, the open space area is used as an area to manage rainwater using a rainwater harvesting system, and also the installation of solar panels. The redesigned building also added vertical secondary skin elements to the front facade to reduce heat and improve visual comfort by controlling natural lighting as has been done in the design stage. In addition, the secondary skin element is also applied as an effort to achieve energy-saving efficiency contained in the external shading devices points.

The efforts applied to the building are then assessed through the EDGE assessment approach version 2.1.5 to measure the extent to which energy efficiency and water efficiency are achieved in the building under redesign conditions. The details of efficiency achievements as well as strategies applied to energy efficiency and water efficiency are described as follows.

Energy Analysis with EDGE App

Efforts are made to improve energy efficiency in the redesigned building of the Central Statistics Agency of Salatiga City by optimizing energy-efficient building systems as well as the use of supporting technology. One of the strategies implemented is the use of materials and facade design that supports natural lighting and cross-ventilation, including the application of external shading devices by adding *vertical* secondary skin elements that function to reduce the potential for excessive glare and direct exposure to solar radiation. External shading devices with an Annual Average Shading Factor (AASF) of 0.23 succeeded in reducing the percentage of direct sunlight entering the room. Then, the redesign of the WWR (Window to Wall Ratio) aspect became 19.44% due to the addition of the 3rd floor.

The energy efficiency strategy is also supported by replacing conventional lighting systems with energy-efficient LED lights. In addition, the redesigned building also utilizes renewable energy in the form of installing solar panels (solar photovoltaics) which can supply the building's electricity needs by 24%. With solar photovoltaics with a capacity of 23.9 kWp that is able to reduce up to 24% of the building's electricity needs, it is an important part of reducing dependence on fossil energy.

Based on the results of the simulation using EDGE Application with version 2.1.5 under redesign conditions, the Salatiga City Central Statistics Agency Building showed a significant increase in energy efficiency compared to existing buildings (Figure 10). In the redesign condition, it shows that energy savings reach 55.32% With several strategies applied to the building, the final energy consumption has been successfully reduced to 7,566.88 kWh/month, which is equivalent to 112.43 MWh per year and makes this redesigned building in accordance with EDGE efficiency standards and supports the achievement of sustainable development in the office building sector.

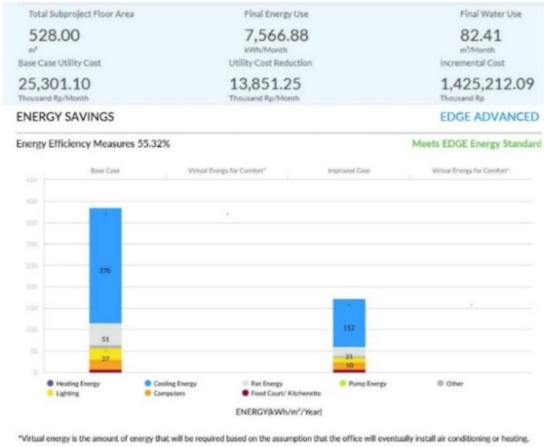


Figure 10. EDGE Application Simulation Results of Energy Aspects of Redesign Conditions
Source: (Edgebuildings, 2025)

The efficiency carried out also has a direct impact on reducing carbon emissions by 98.76 tons of CO_2 per year and saving monthly utility costs of Rp8,570,000. The main strategy that contributes to this achievement is the use of shading devices in the form of *vertical* secondary skin that has an Annual Average Shading Factor (AASF) value of 0.23, which effectively reduces the sun's heat on the facade. Then the Window to Wall Ratio aspect is 19.44%. In addition, the use of renewable energy through the installation of solar panels with a capacity of 23.9 kWp which is able to meet 24% of building energy needs, also strengthens overall energy efficiency.

Comparison of EDGE Simulation Results on Existing Conditions and Redesign
Simulation using EDGE Application version 2.1.5 was carried out to determine the efficiency of the building under two conditions, namely existing conditions and conditions after redesign. In addition, this simulation is also carried out as an effort to create sustainable and environmentally friendly buildings. Because in an effort towards sustainable and environmentally friendly buildings, the principle of green building is an important approach that not only considers the comfort of users, but also the impact caused by building operational activities.

The assessment in this simulation focuses on two aspects, namely energy efficiency aspects that include electricity consumption and CO_2 emissions, as well as water use efficiency related to clean water consumption and its management system. The simulations carried out showed a significant increase between the two conditions, be it technical efficiency or operational cost savings. Quantitative comparative data between existing and redesigned conditions is presented in Table 5.

The redesign of the building increases energy efficiency by 24.36% higher than the existing conditions. Final energy consumption has been significantly reduced through the implementation of several strategies, including the use of vertical secondary skin with AASF 0.23 and the use of solar panels that can cover 24% of the building's electricity needs.

The redesign not only reduces environmental burden through reducing carbon emissions but also shows a commitment to sustainable resource management in accordance with the concept of green building. Then an integrated strategy in the aspects of lighting, ventilation, and utilities makes the redesigned building of the Central Statistics Agency of Salatiga City an environmentally friendly office model.

Table 5. EDGE App Simulation Results Comparison Data

	Parameters	**Existing**	**Redesign**	**Efficiency Difference**
Energy Aspects	Energy Efficiency Percentage	30,96%	55,32%	24,36%
	Final Energy Consumption	8,865.09 kWh/month	7,566.88 kWh/month	1,298.21 kWh/month
	Annual Energy Savings	81.00 MWh/year	112.43 MWh/year	31.43 MWh/year
	Operational Carbon Emissions	93.50 tons CO_2/year	98.76 tons CO_2/year	5.26 CO_2/year
	Strategy	WWR 19.17%	WWR 19.44%, AASF shading 0.23, solar panel 30%	0,27%

The application of secondary skin is practical in regulating the intensity of natural light entering the workspace. With a design that considers the orientation of the sun, the secondary skin can reduce glare and increase the distribution of natural light evenly in the main work area. The redesign of the building with the addition of secondary skin elements shows a significant increase in the area of workspace that meets the natural illumination standard of 250–500 lux according to GBCI guidelines. This condition increases the chances of achieving EEC 6 points because the percentage of space that meets the daylighting criteria has increased significantly compared to existing conditions. With the improved quality of natural lighting, the reliance on artificial lighting during the day is reduced. This has the potential to reduce electrical energy consumption, support overall energy efficiency, and contribute to reducing the carbon footprint of buildings. The secondary skin design not only functions as an aesthetic element, but also supports green architectural principles, such as passive design strategies, energy efficiency, and improved visual and thermal comfort for building users.

Design recommendations are made based on the results of building condition analysis and natural lighting simulations that have been carried out previously. The main focus of this recommendation includes facade redesign, the addition of building floors, and more efficient use of energy. The three aspects are designed by considering the principles of green architecture, space efficiency, and the comfort of building users, so that the proposed design can be a solution to improve the quality of buildings functionally, visually, and environmentally. This design recommendation is also presented in the form of an illustration in Figure 11.

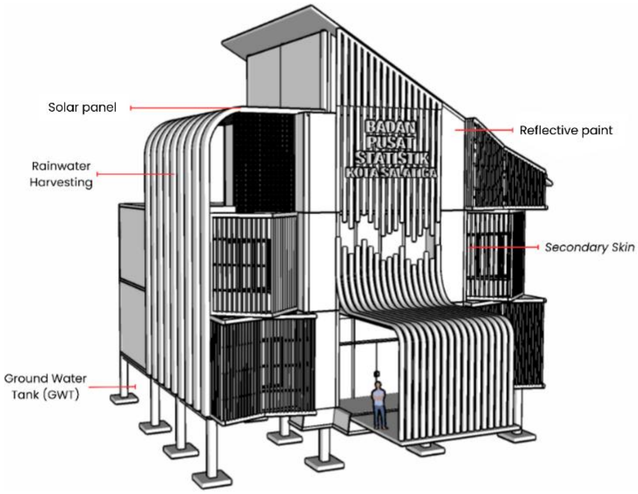


Figure 11. 3D Model Design Recommendations

The redesign of the facade of the building was carried out in response to the low thermal and visual comfort in the existing conditions. The redesign of the facade of this building is focused on the use of secondary skin as a passive strategy that can effectively control natural lighting. The secondary skin design used is in the form of grid panels with WPC (Wood Plastic Composite) material arranged vertically with three different types of shapes. The installation of secondary skin is given a space or cavity to create a gap between the main walls with an outer layer that functions to reduce heat directly into the building. The use of energy in building design leads to the efficiency and utilization of renewable energy sources as part of the principles of green architecture. Utilization of renewable energy, particularly the use of solar panels, is intended to meet some of the electrical energy needs so that energy efficiency can be implemented. The design recommendations described aim to improve building function, user comfort, and energy efficiency by prioritizing natural lighting and energy efficiency. With these recommendations, it is hoped that the building can function properly and support activities in the building optimally. This study is limited by the use of simulation tools that rely on idealized environmental inputs, without on-site validation under different seasonal conditions. The daylighting simulation in Revit is also constrained by its most recent available sun-path data (2010). Future research should incorporate field measurements to validate simulation results, investigate the impact of different material properties on shading efficiency, and expand the analysis to other building typologies in tropical climates.

CONCLUSIONS

This study evaluated the effect of secondary skin design on the quality of natural lighting in the Central Statistics Agency building of Salatiga City using DIALux Evo 13.0 simulations with a green architecture approach. The findings show that the application of secondary skin significantly improves daylight distribution and reduces glare, resulting in higher compliance with the Green Building Council Indonesia (GBCI) daylighting criteria (EEC 6). The secondary skin functions as an effective passive design strategy by optimizing natural illumination, reducing dependence on artificial lighting, and contributing to energy efficiency and carbon reduction. In addition to enhancing functional performance, the design supports the principles of green architecture through energy efficiency, sustainable design, and improved visual comfort for users. The results demonstrate that secondary skin is a feasible and low-cost solution for government buildings, providing both environmental and functional benefits. Future studies are encouraged to validate these simulation findings with on-site measurements and expand the analysis to other building types in tropical climates.

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