Energy Use Efficiency on Mid-Rise Hotel Building to Reduce Carbon Emissions Using Sefaira

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| Submitted: July 02, 2023 | Revised: July 04, 2023 | Accepted: January 10, 2024 |

| Published: January 12, 2024 |

ABSTRACT

A lot of energy consumed by large hotel buildings can affect environmental degradation in a long period. Every building plan, including hotels, must consider an integrated balance in utilizing existing and limited resources based on low CO_2 emissions. Excessive use of energy has a negative impact which increases the amount of CO_2 emissions. This research aims to determine the effect of energy efficiency to provide recommendations, which require significant reduction of energy and environmental degradation by minimizing energy use and CO_2 emission. The methods used in this research are modeling, and simulating the energy use intensity and carbon emission using Sefaira as a Sketchup Software plug-in by simulating the existing design and providing a recommendation. The object that is being used in this research is a hotel building that has 11 floors and 1 basement in Yogyakarta, Indonesia. The result shows EUI of the existing hotel building is 977 kWh/m^2/year and carbon emission is 1.872.042 kgCO_2e/year. Compared to the EUI standard which is at the limit of 290–400 kWh/m^2/yr. It is recommended to build additional windows at the dismantled room area on the north and south side of the hotel's corridor. The recommended design provides a reduction of EUI to 744,22 kWh/m^2/year (31,28%). Meanwhile, the carbon emission was reduced to 1.467.072 kgCO_2e/year (27,60%) from the existing design.

Keywords: energy efficiency; energy use intensity; sefaira; carbon emission; energy conservation.

INTRODUCTION

The hotel industry is an industry that consumes quite a lot of energy (Kelly et al, 2007). Unlike other types of commercial buildings, hotels have many various functional spaces, such as guest rooms, business centers, meeting rooms, restaurants, etc. Exploring the energy usage characteristics of hotels aids in understanding the degree of building energy consumption and determining alternatives to improve hotel building energy efficiency.

One of the ways to decrease energy expense, that efforts to save energy are urgently needed (Dalem, 2010). Increasing energy efficiency is a major way to save energy and thus reduce energy expenses from the existing building. Every building plan, including hotels, must consider an integrated balance in utilizing existing and limited resources and based on low CO_2 emissions. Excessive use of energy has a negative impact, which increases the amount of CO_2 emissions. According to experts, excessive CO_2 emissions can cause environmental damage, global warming, and shifting of seasonal cycles.

Currently, the energy crisis is receiving special attention from countries in the world, because energy needs continue to increase along with the increasing population. Currently, many energy sources have been used to meet energy needs, but the energy crisis remains a threat due to limited availability in nature. One of the efforts made by countries in the world as a form of concern for the energy crisis that is currently hitting is by carrying out an energy-saving Earth Hour action involving 132 countries in the world (Australia, Asia, Europe, Africa, the Pacific, and America) within a day a year, this action aims to provide understanding and awareness of loving the environment and saving energy. To limit excessive energy consumption, the construction of hotels is expected to apply the green building method (GBCI, 2011).

Volume 13, Issue 1, February 2024, pp.212-224
DOI: http://dx.doi.org/10.32832/astonjadro.v13i1 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

The Green Building concept is one of the efforts to reduce the impact of energy consumption and global warming through development, by saving energy starting from the planning, construction, and operational stages of the building. The concept of 'green' can also be applied by reducing energy use (e.g. electricity), low-energy houses, and zero-energy buildings by maximizing building cover (renewable energy such as solar energy, water, biomass, and waste treatment), thus saving on building operating costs and has excellent energy performance at reducing energy consumption in Indonesia. The Green Building method itself has an assessment criterion called Greenship. Greenship has determined that there are six aspects of assessment including Land Appropriateness, Energy Efficiency and Conservation, Water Conservation, Material Sources and Cycles, Health and Comfort in Space, and Building Environment Management, which of these criteria have a certain value content in the Green Building assessment. Based on the description above, one aspect that has a very large impact on nature is Energy Efficiency and Conservation (GBCI, 2011). Energy Energy Efficiency and Conservation on infrastructure can be an option in efforts to reduce world energy consumption. In this research, the energy audit uses the Sefaira software to analyze daylight, energy consumption, and carbon emissions from the building.

Sefaira software is a web-based performance analysis platform from Sketchup explicitly used for conceptual design. Energy analysis in this software includes annual energy performance, annual production of CO_2 emissions, and heating and cooling loads using the ASHRAE 90.1-2019 standard. This software has also been used by previous researchers, including Paramita (2019), at The Botani Museum, Pangarsa (2021) at the Lecture Building, Sidik (2021) at the Residential House Building, Wibawa (2021) on the Campus Building, Lisa (2022) on Resort Dome Building, and Priyanka (2022) on Office Building. In previous research using the Sefaira software, especially in hotel-type buildings, the researchers only did simulations and explored the direction of the building's orientation to solar radiation.

Several studies of energy-efficient analysis on hotel buildings have been conducted in various parts of the world. (P. Bohdanowicz, 2009), studied the energy energy consumption data from 73 Hilton hotels and 111 Scandinavian hotels in Europe, with 364 kWh/m^2 and 285 kWh/m^2 values, respectively. In China, annual average EUIs differed, e.g. Hong Kong (S. Deng, 2000) Shenzhen (Y.L. Bin, 2009), and Hainan (P. Chen, 2001) were 564 kWh/m^2, 229 kWh/m^2, and 150 kWh/m^2. Then, in Indonesia, (Khadafi, 2022) with 464.45 kWh/m^2/year and (Triyono B, 2016) with 450.756 kWh/m^2/year, respectively. Despite of many studies on the energy performance of hotel buildings, previous research only evaluates energy efficiency by calculating the energy use, but do not consider the other aspects such as the CO_2 emissions effect for the environment.

To complete the research gap between previous Sefaira research and hotel energy analysis research, this study identified the indicators that can be used to measure the energy efficiency of all areas in a hotel building, for analyzing energy use intensity (EUI) of the hotel's existing and emission (CO_2), and giving the recommendation alternative design for achieving EUI and CO_2 reduction.

RESEARCH METHODS

Modeling Existing Design

The first stage of the process in this study was to conduct a 3D hotel building using the SketchUp software, and the existing design itself based on shop drawings from the building owner. After conducting the 3D hotel design, the next step is inputting the existing design to Sefaira software to analyze energy and emission consumption.

Sefaira Analysis Simulation

The Sefaira software development process began with the modeling of the Hotel in Yogyakarta, Indonesia, using the Sketchup Studio application. After modeling the 3D design, before simulating the existing design, each building material is input, and its function is determined from the 3D model. The purpose of each input, such as a wall, window, or roof, must be adapted to the existing conditions.

Then, the result of existing hotel building simulation will show the part of dark and glare sides of the natural light. This condition refers to the lux indicator bar color and then classifies which room is glare and dark, to determine what alternative recommendations can be made. The following in Figure 1. shows the lighting assessment indicator.

Figure 1. Percentage of Daylight Illuminance Indicator in Sefaira

After conducting a simulation using the Sefaira software, proceed to the calculation of Energy Usage Intensity (EUI) on the existing design of the Next Hotel Yogyakarta building. EUI electricity is a term commonly used to express the amount of energy used in buildings and is expressed in units of kWh/m² per year. EUI (Energy Usage Intensity) is needed in calculations to determine the level of energy efficiency of a building. The results of the EUI value must be the same or lower than the standard value and efforts are always made to keep it lower. To determine the level of energy efficiency can be done by comparing the EUI (Energy Usage Intensity) of a building with the EUI standard (Energy Consumption Intensity) that has been set in Indonesia. Based on SNI 03-6196-2011 concerning energy audit procedures for buildings, the intensity of energy consumption in each room can be calculated using the following equation:

$$EUI = Pk/A$$

Explanation :
EUI = Energy Usage Intensity (kWh/m^2/yr)
Pk = Total Usage Total (kWh)
A = Area (m^2)

After determining which room is glaring and dark, proceed to the calculation of Energy Use Intensity (EUI) on the existing design. Energy Consumption Intensity (EUI) is a way to figure out how much energy a building needs by dividing the amount of electricity it used in the one last year by the size of the building in square meters (m^2). After knowing the lighting conditions and EUI value of the building, then it is determined whether the energy-wasteful or energy-efficient building. The next step is to compare EUI's existing condition to the EUI standard for hotel buildings which has a limit of 290–400 kWh/m^2/yr. If the simulation result of the existing design EUI does not fulfill the standard, the research building needs to giving recommendations for optimizing the energy and CO_2 emissions. The final step is to analyze the EUI and CO_2 emissions from the recommendation design and compare with the existing design.

Calculation of Energy and Emision Reduction

For analyze energy and emission reduction, the first step is to conduct the existing and alternative design energy usage, to find out the amount of energy usage (kWh) from the building. The next step is calculating energy and emission reduction from the alternative design, and providing handling recommendations based on energy efficiency and conservation.

Energy and Emission Reduction = Existing Design – Alternative Design

RESULT AND DISCUSSION

Existing Design Simulation

The stages of the Sefaira software process began with establishing the modeling of the Next Hotel Yogyakarta building using the Sketchup Studio software. After the 3D building is formed, the input of each building material is carried out, from the 3D model it is identified according to its function. The function of each input as a wall, glazing, or roof must be adjusted to the existing conditions, then after that a simulation of the previous existing design is carried out, after that a recommendation design simulation is carried out, after the existing design simulation and recommendations are completed, a comparison is made between the two designs to see a decrease in energy consumption used.

pISSN 2302-4240
eISSN 2655-2086

Volume 13, Issue 1, February 2024, pp.212-224
DOI: http://dx.doi.org/10.32832/astonjadro.v13i1 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

Figure 2. Existing 3D Model

Daylight analysis in Sefaira can be performed in various method. Annual daylight analysis was performed to shows daylight condition of all area in the building. Annual daylight analysis in Sefaira performed in two boundary, 150 lux daylight illumination to represent dark area and 1000 lux illumination to represent glare area. Sefaira daylight analysis results can be seen in the figure 3.

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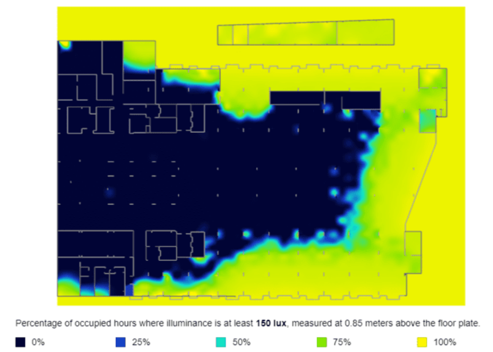
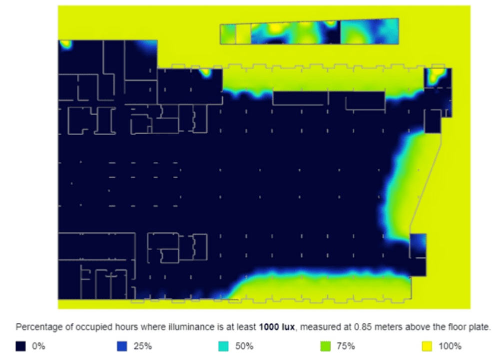
<tr><td>
</td><td>
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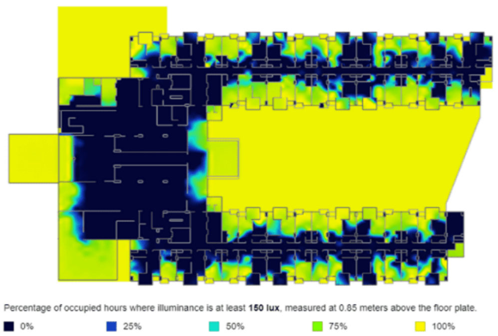
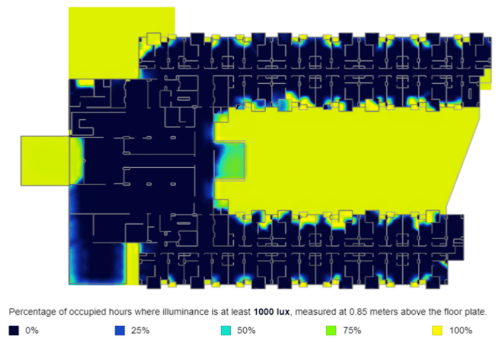
<tr><td>
</td><td>
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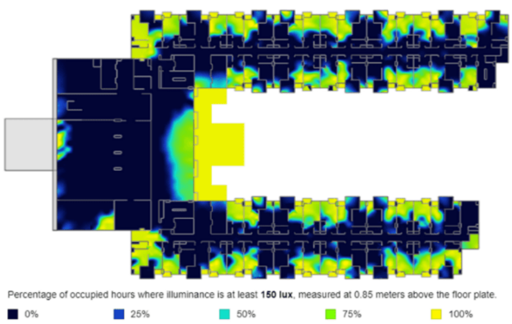
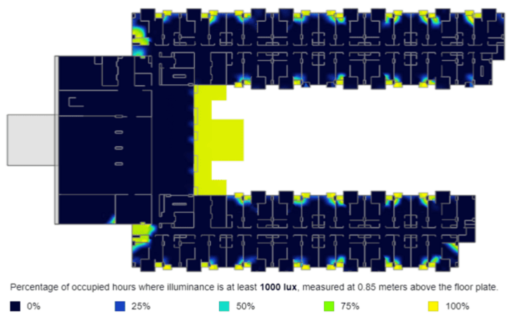
<tr><td>
</td><td>
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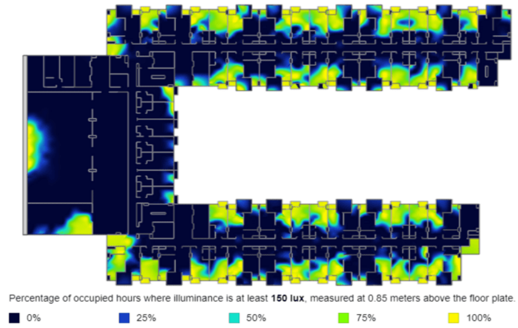

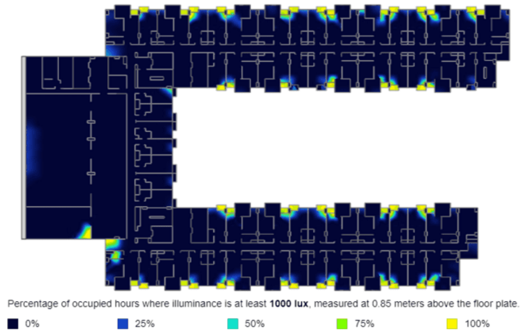

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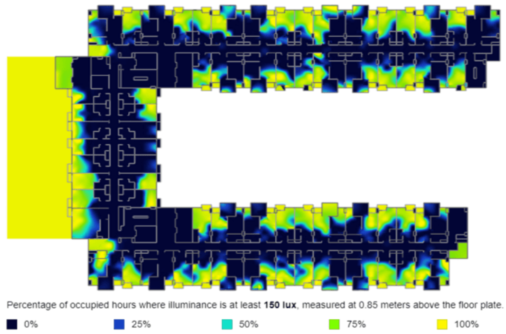

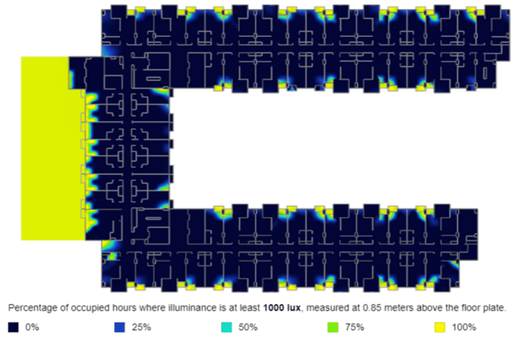

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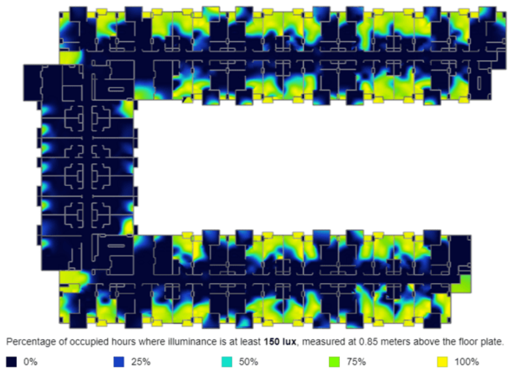

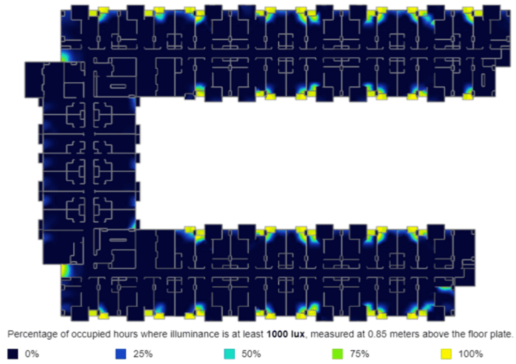

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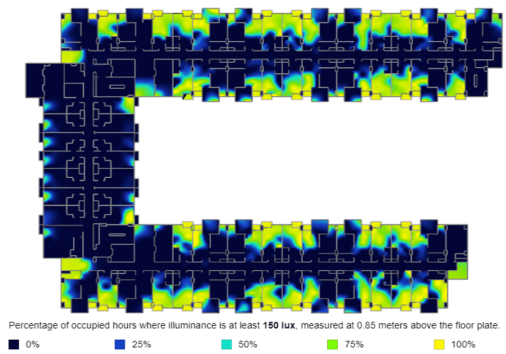

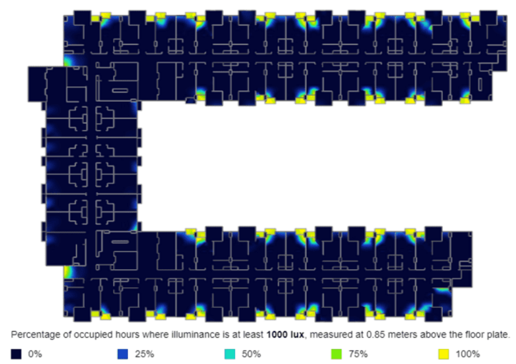

pISSN 2302-4240
eISSN 2655-2086
Volume 13, Issue 1, February 2024, pp.212-224
DOI: http://dx.doi.org/10.32832/astonjadro.v13i1
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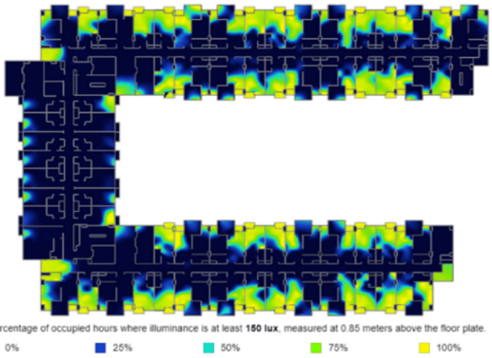
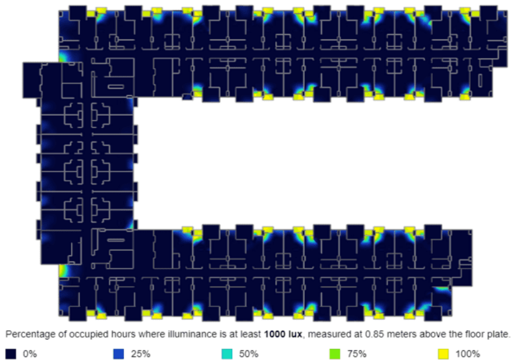
Level 08 – Floor 8 – Existing Design





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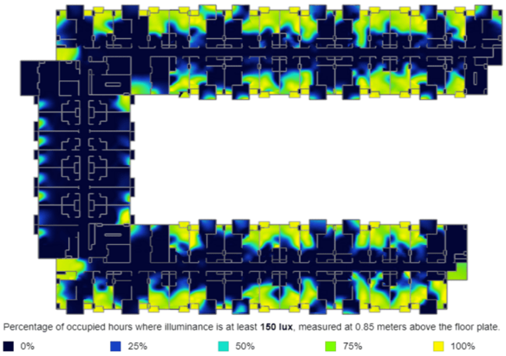

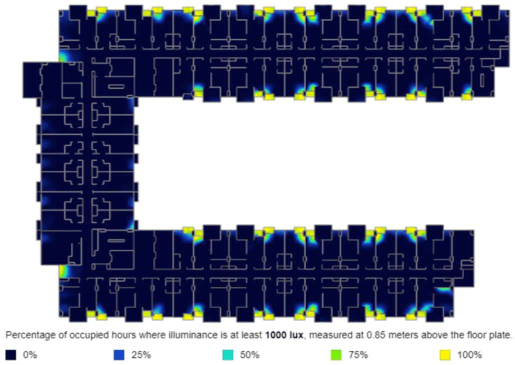

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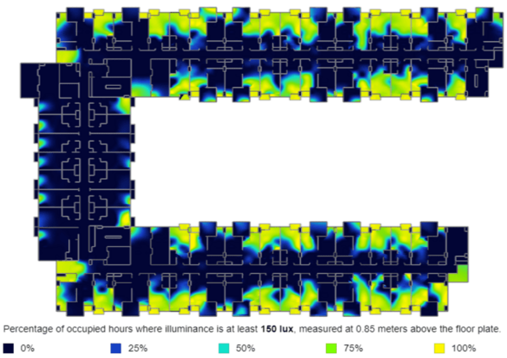

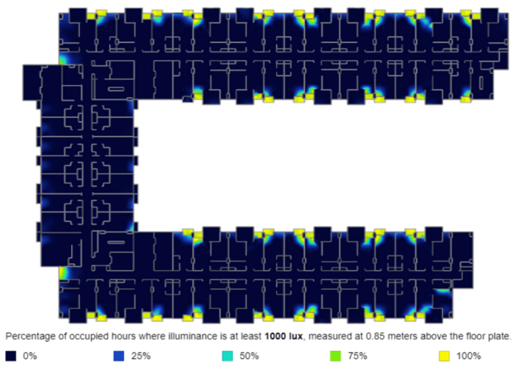

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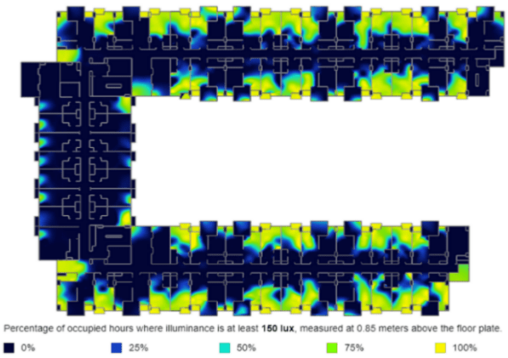

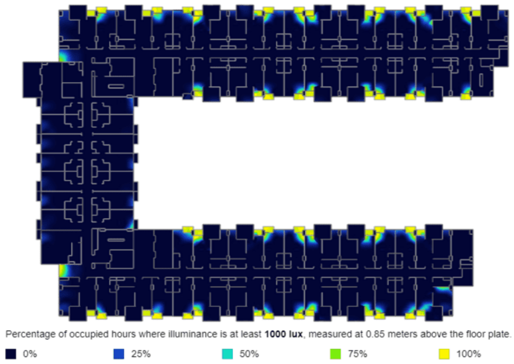

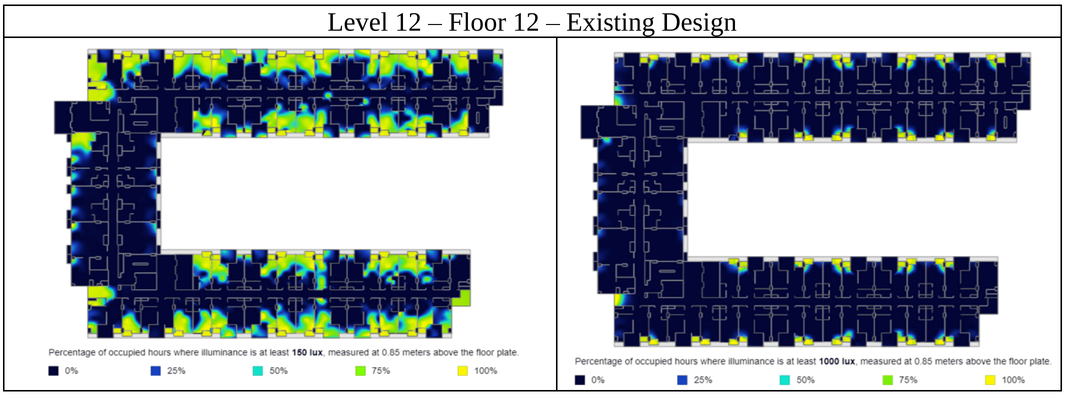

Figure 3. Annual Daylight Analysis in Sefaira – Existing Design

The results of the color reading on the existing design, there is the same tendency, each room experiences glare around the window, while at the end of the room there is a lack of light or dark, while in the corridors of each floor there was a lack of light, so that almost all of the corridors in the hotel became dark. From the results of the existing design simulation, the next step is to recapitulate energy consumption, IKE and CO_2 emissions in Table 1.

Table 1. Recapitulation of Energy Use and Emission CO_2 Existing Design

Floor	Annual Net Energy Use	EUI	Annual Net CO_2e Emissions
	kWh/yr	kWh/m²/yr	CO_2e
Level 01 – Basement	431,920	79,79	308.823
Level 02 - Floor 1	314,526	79,13	224.886
Level 03 - Floor 2	210,273	80,20	150.345
Level 04 - Floor 3	200,974	80,42	143.697
Level 05 - Floor 5	200,116	80,08	143.083
Level 06 - Floor 6	175,431	80,36	125.433
Level 07 - Floor 7	183,584	84,10	131.263
Level 08 - Floor 8	175,461	80,38	125.454
Level 09 - Floor 9	175,459	80,38	125.453
Level 10 - Floor 10	175,456	80,37	125.451
Level 11 - Floor 11	187,557	85,92	134.103
Level 12 - Floor 12	187,484	85,88	134.051
Total	**2,618,241**	**977,00**	**1.872.042**

Based on Table 1, the annual EUI calculation obtained is 977 kWh/m^2/year > 400.00 kwh/m^2/year, meaning that the hotel is above the upper limit range so that the hotel building is categorized as an energy-intensive building. So it needs improvement or an effort to reduce energy consumption and CO_2 emissions.

Design Recommendation

Redesign of existing hotel building is conducted by dismantling 2 rooms on the north side and 2 rooms on the south side of each hotel floor, the use of additional window corridors aims to provide lighting for hotel corridors which are considered dark or lack of light, so that from the recommendation design is to increase the level of lighting in floor corridors, so that it is expected to reduce energy consumption in buildings, the following is a simulation of a additional window corridor design in Sefaira:

pISSN 2302-4240
eISSN 2655-2086
Volume 13, Issue 1, February 2024, pp.212-224
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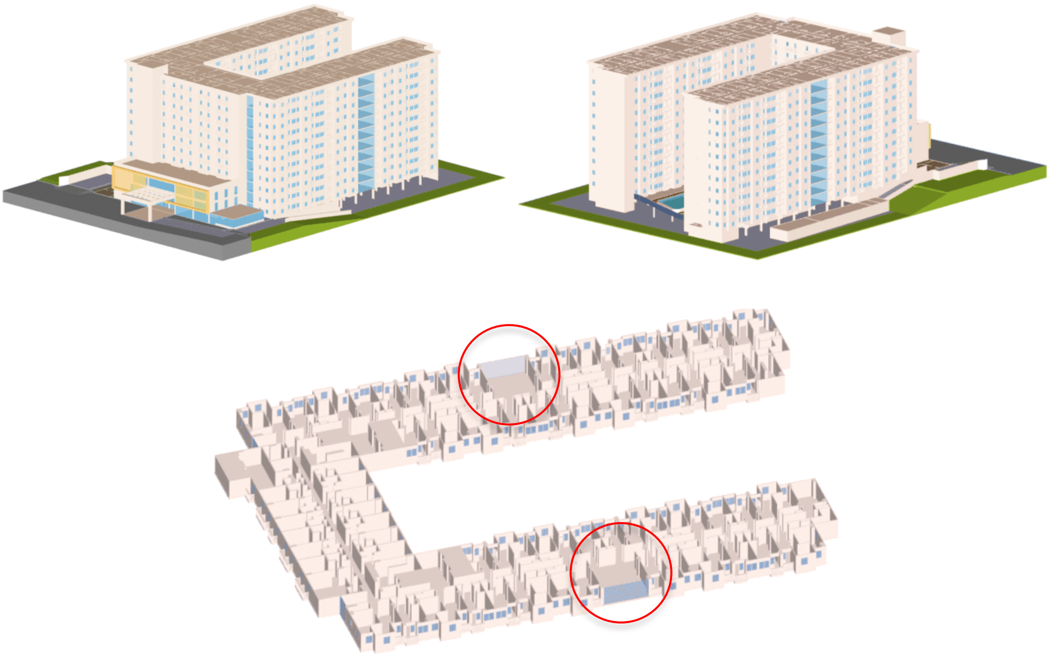

Figure 4. Recommended Design 3D Model

According to Figure 4, the addition window corridor reduces the total number of rooms each floor. Next, a lighting simulation is conducted to determine if the addition of window addition has the effect of illuminating floor corridors with natural lightning in Table 2.

Table 2. Annual Daylight Analysis in Sefaira – Recommended Design

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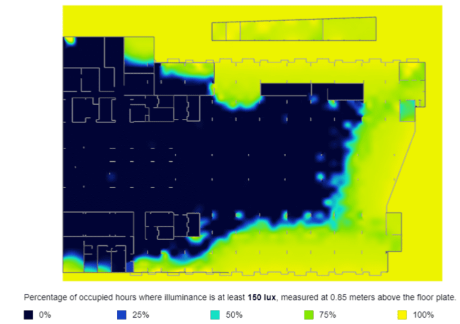
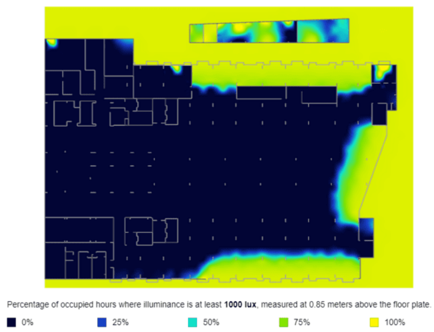
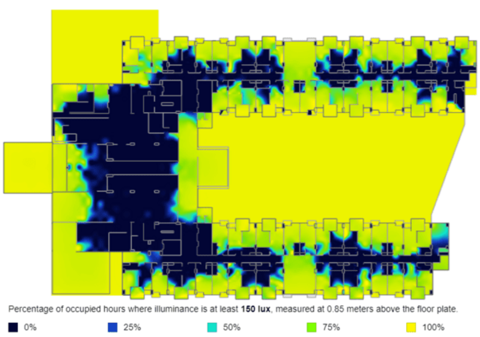
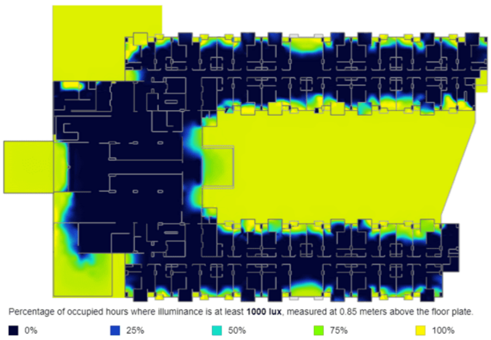
	
Level 02 – Floor 1 - Recommended Design	
	
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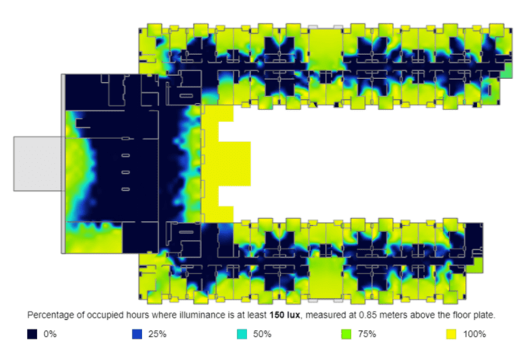
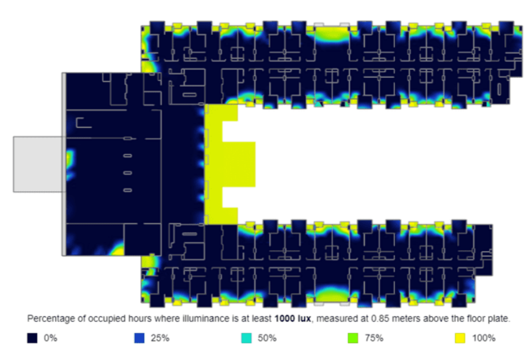
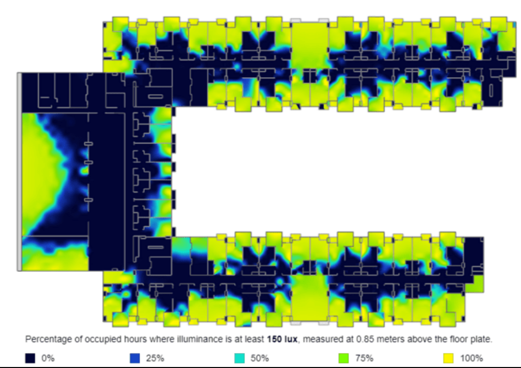
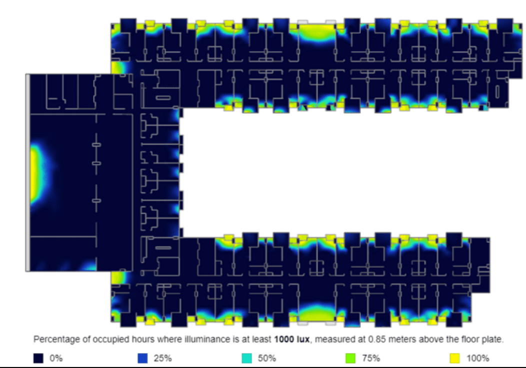




Level 04 – Floor 3 - Recommended Design





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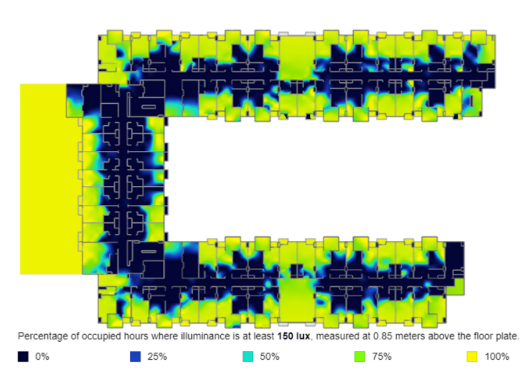

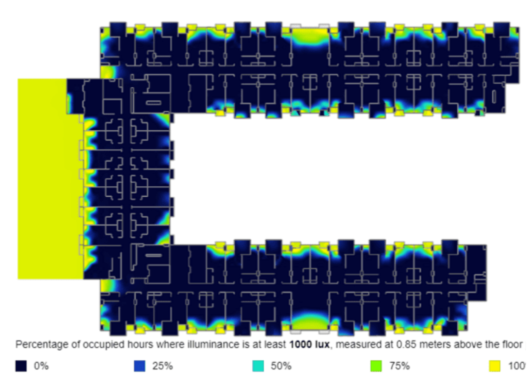

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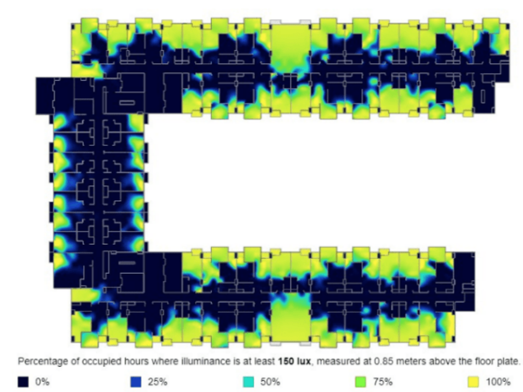

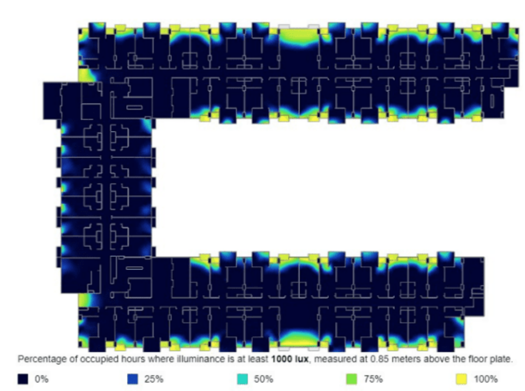

Level 07 – Floor 7 - Recommended Design

pISSN 2302-4240
eISSN 2655-2086
Volume 13, Issue 1, February 2024, pp.212-224
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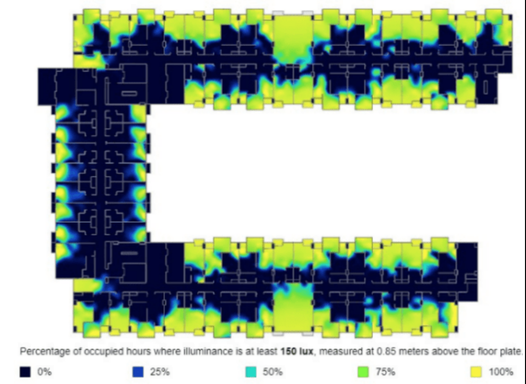
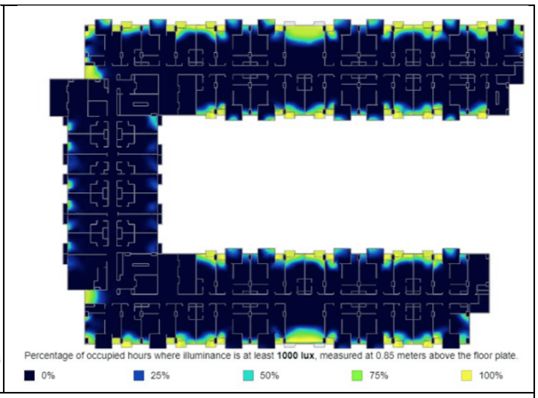
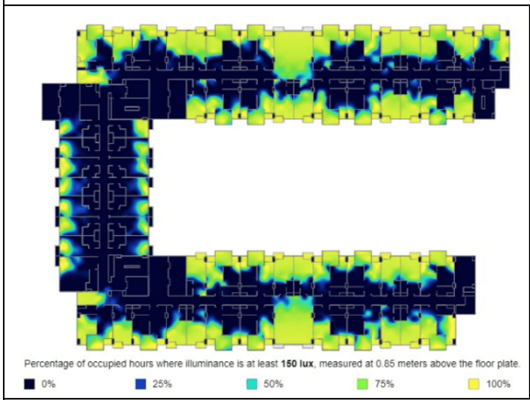
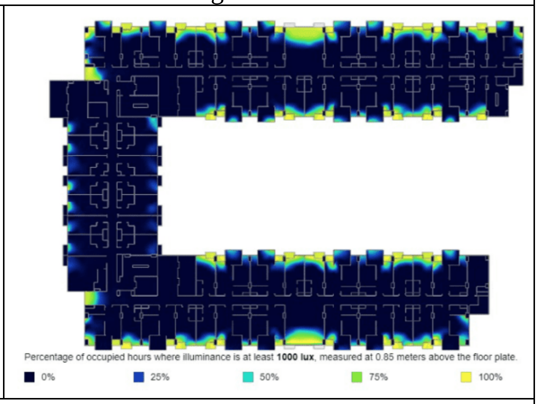


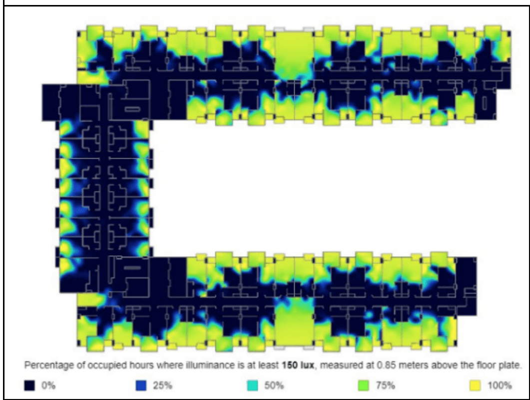


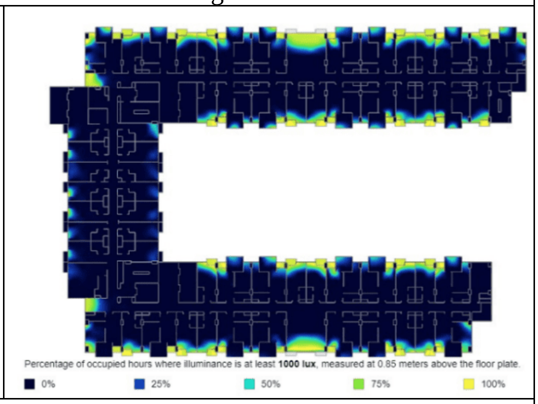
Level 08 – Floor 8 - Recommended Design



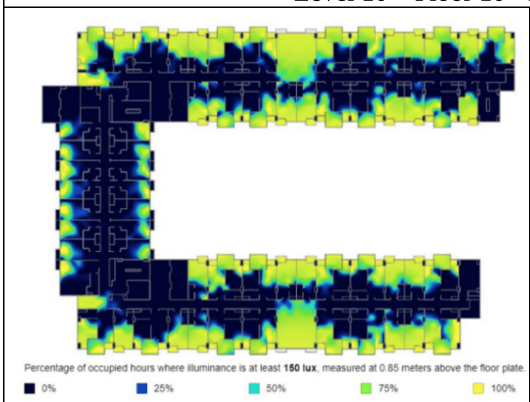


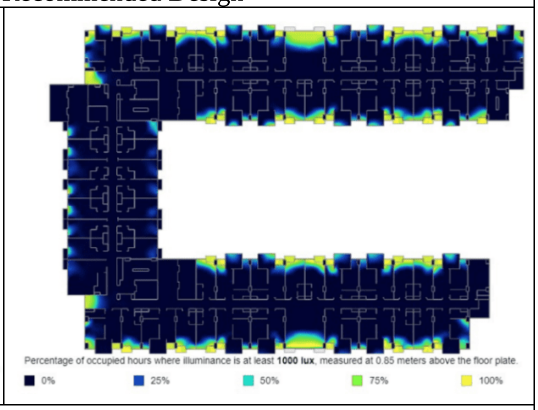
Level 09 – Floor 9 - Recommended Design





Level 10 – Floor 10 - Recommended Design





Level 11 – Floor 11 - Recommended Design

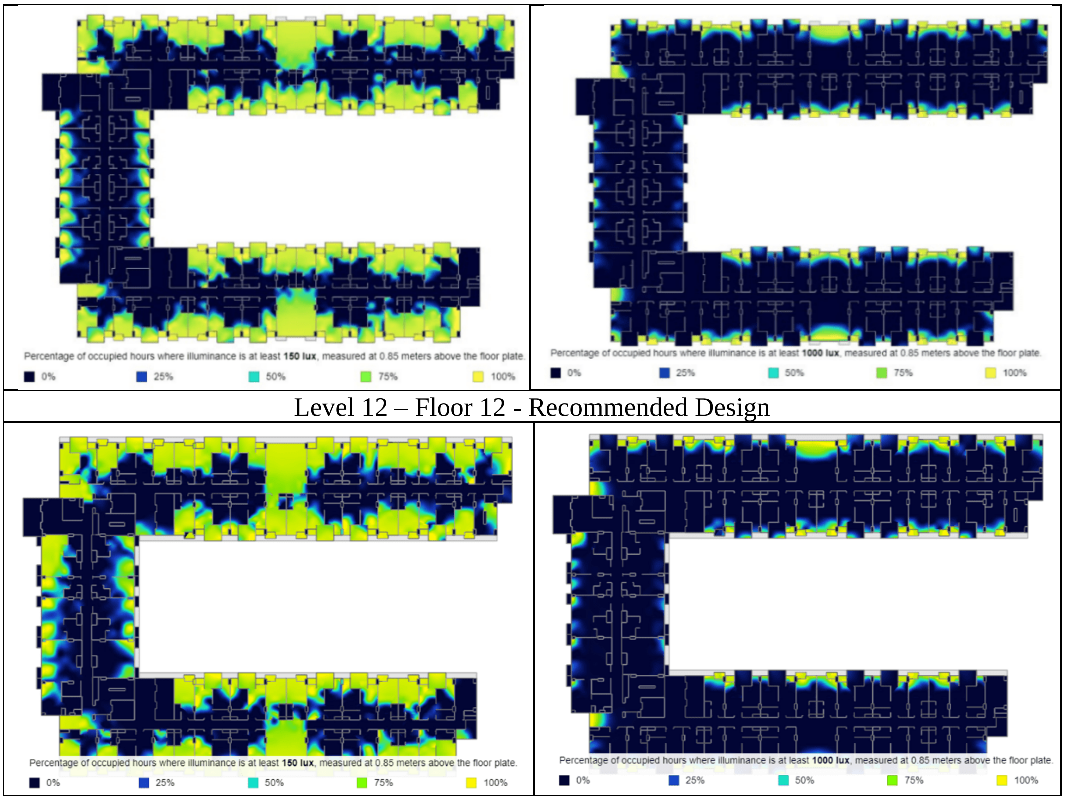


Figure 5. Annual Daylight Analysis in Sefaira – Recommended Design

As shown in figure 5, the additional window corridors on all floors significantly reduces the number of dark corridors in the existing design, so it expected that the additional window corridors can reduce energy consumption in the building, as summarized in Table 3 of recommended design simulation results:

Table 3. Recapitulation of Energy Use and Emission CO_2 Recommended Design

Floor	Annual Net Energy Use	EUI	Annual Net CO_2e Emissions
	kWh/yr	kWh/m²/yr	CO_2e
Level 01 – Basement	431.920	79,79	308.823
Level 02 - Floor 1	234.546	59,01	167.700
Level 03 - Floor 2	155.984	59,49	111.529
Level 04 - Floor 3	149.007	59,63	106.540
Level 05 - Floor 5	148.572	59,45	106.229
Level 06 - Floor 6	130.129	59,61	93.042
Level 07 - Floor 7	136.037	62,32	97.266
Level 08 - Floor 8	130.091	59,59	93.015
Level 09 - Floor 9	129.383	59,27	92.509
Level 10 - Floor 10	129.379	59,27	92.506
Level 11 - Floor 11	138.469	63,43	99.005
Level 12 - Floor 12	138.332	63,37	98.908
Total	**2.051.849**	**977,00**	**1.467.072**

pISSN 2302-4240
eISSN 2655-2086
Volume 13, Issue 1, February 2024, pp.212-224
DOI: http://dx.doi.org/10.32832/astonjadro.v13i1 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

Energy use intensity (EUI) in this alternative at 744,22 kWh/m^2/year is still 344,22 kWh/m^2/year above the EUI standard for hotels in Indonesia, and the building layout limits alternatives for building repairment option. But 31,28% reduction of EUI by only using additional window corridors on each floor has already significantly reduce the existing condition.

Simulation Summary

Based on Sefaira simulation results on existing and recommendation designs, a summary of energy use, EUI, and carbon emissions is listed in Table 4 below.

Table 4. Energy Use and CO_2e Emissions Simulation Summary

Alternative	Annual Net Energy Use	EUI	Energy Saving	Annual Net CO_2e Emissions	Emission Reduction
	kWh/yr	kWh/m^2/yr	(%)	KgCO_2e	(%)
Existing	2,578,528	977,00	0,00	1.872.042	0,00
Alternative	2.051.849	744,22	31,28	1.467.072	27,60

Based on the simulation result, it can be seen the recommended design provides annual net energy use of 2.051.849 kWh/yr and 977 kWh/m^2/year values of EUI which gives a 31,28% reduction of EUI into 744,22 kWh/m^2/year. Meanwhile the carbon emission reduced into 1.467.072 kgCO_2e/year (27,60%) from the existing design.

CONCLUSION

Energy consumption is an essential and vital issue for commercial hotel buildings. The simulation in this research indicates that poor daylighting consumed more energy and CO_2 emissions. By using additional window in all the corridors each floor reduced 31,28% of EUI and 27,60% of CO_2 emissions. But to build additional window in corridors, some rooms must be dismantled. So, further research is recommended to gives the feasibility of financial aspect from less occupation.

ACKNOWLEDGEMENT

Authors would like to thank Universitas Brawijaya, My Family, and My Friend who have helped in carrying out this research.

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