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Cost-Benefit analysis for energy efficiency of existing hotel building

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Abstract. The purpose of establishing a hotel building itself is expected to get good financial benefits as much as possible. In order to increase the cost-benefit for the building, increasing the energy efficiency is a major way to save energy and thus reduce energy expenses from the existing building. This research aim is to analyze energy consumption and cost-benefit at repaired existing hotel building. The method that used in this research are existing building modeling, energy and cost simulation, provide repairmen alternatives to reduce energy consumption and cost, and determine the optimum alternative design. The simulation using Sefaira as a Sketchup Software plug-in. In this research, the object is hotel building that have 11 floor and 1 basement at Yogyakarta, Indonesia. The result show that the existing hotel building consume 977 kWh/m^2/year and energy cost IDR 2.994.403.821. The alternative for repairmen existing hotel building area the replacement of tint window, insulated wall application, skylight addition, and window addition at dismantle room area. For the selected alternative is the hybrid of window addition at dismantled room area and insulated wall that decrease energy consumption and cost into 871,06 kWh/m^2/year (12,16%) and IDR 2.346.637.473 respectively. It means the energy cost savings is IDR 272.042.266 (9,09%). Furthermore, from cost-benefit analysis resulted the economic internal rate of return (EIRR) 13,61%, payback period in 5,52 years. In 20 years, PV Cost IDR 14.493.532.315,84 and PV benefit IDR 16.422.494.153,10, resulted the NPV at IDR 1.928.961.837,26 and BCR value 1.13.

1 Introduction

The hotel industry is a commercial building that consumes quite a lot of energy. The purpose of establishing a hotel building itself is expected to get good financial benefits as much as possible. Energy consumption is one of the factors in saving expense of owner. One of the ways in order to increase benefit, is by reducing expenses itself, including operational costs (energy, maintenance, etc.) [1]. Increasing the energy efficiency is a major way to save energy and thus reduce energy expenses from the existing building. To limit

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the excessive energy consumption, the construction of hotel is expected to apply the green building method.

Green building method itself has an assessment criterion called Greenship. Greenship has been 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 [2]. Based on the description above, one aspect that has a very large impact on nature is Energy Efficiency and Conservation. Based on previous research, the U.S. The Green Building Council (USGBC) revealed that buildings are ranked number 1 in world energy consumption, which consumes as much as 41% of the world's energy [3]. Energy audits on infrastructure can be an option in efforts to reduce world energy consumption. This energy audit itself is an evaluation effort to find out the savings opportunities that can be made so that energy consumption can be reduced. An energy audit on infrastructure is carried out to find out and evaluate a building whether the building has optimized the minimum energy use or vice versa, so that later it is hoped that this method can reduce energy consumption in the building [4].

In this research is using Sefaira software is a web-based performance analysis platform from Sketchup to explicitly used for conceptual design. Energy analysis in this software includes annual energy performance, energy usage costloads using the ASHRAE 90.1-2019 standard. This software has also been used by previous researchers, including [5], on The Botani Museum, [6] on Lecture Building, [7] on Residential House Building, [8] on Resort Dome Building, and [9] Difference Building Shape Effect. In previous research using the Sefaira software, especially in hotel-type buildings [10], the researchers only did simulations and explored the direction of the building's orientation to solar radiation.

Apart from Sefaira software, in previous research about cost-benefit from energy efficiency topic, provides an opportunity to substantially reduce energy consumption and consequently. The topic of energy efficiency in hotel buildings has previously been discussed with previous researchers, such as [11], [12], [13], [14] and [15], provides an opportunity to substantially reduce energy consumption and cost efficiency for existing buildings.

Several studies have analyzed the potential energy savings and profitability from energy cost usage. Otherwise on previous research about hotel energy efficiency, mostly only makes savings from the existing building or changing types of equipment such as lights, air conditioners, and types of lights. It is still rare to make changes to building design to optimize natural lighting consumption. Besides saving energy, the hotels need to increase the cost-benefit for the building. The main intention of this research is to focus its activities in the line of reducing operating costs by giving recommendation designs that give an energy-efficient building.

2 MATERIAL AND METHOD

2.1 Modeling 3D existing design

The stages of the Sefaira software process itself began with conducting the modeling of the Hotel building in Yogyakarta, Indonesia 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, perform a natural lighting simulation of the buildings.

2.2 Room lighting classified

After performing the lighting simulation, the result of existing hotel building simulation will show the part of dark and glare sides. 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 **Fig. 1**, shows the lighting assessment indicator.

Fig. 1. Percentage of daylight illuminance indicator in Sefaira.

After determining which room is glare and dark, proceed to the calculation of Energy Use Intensity (EUI) on the existing design. The standard used for EUI itself refers to Table 1 Indonesian EUI Standard Based on Building Type and Function [16].

Table 1. Indonesia EUI Standard Based on Building Type and Function.

Building Type	EUI Range (kWh/m2/yr)			Reference Operating Time
	Lower Limit	Reff	Upper Limit	
Office	210	250	285	10h/d,5d/w,52w/yr=2600h/yr
Hotel	290	350	400	24h/d,7d/w,52w/yr=8736h/yr
Apartment	300	350	400	24h/d,7D/W,52W/Yr=8736H/Yr
School	195	235	265	8H/D,5H/W,52W/Yr=2080H/Yr
Hospital	320	400	450	24H/D,7H/W,52W/Yr=8736H/Yr
Shops	350	450	500	12H/D,7D/W,52W/Yr=4368H/Yr

Source: [5] Indonesia Energy Use Intensity Classified.

Energy Consumption Intensity (EUI) itself is a way of calculating to find out the energy consumption needs of a building by means of kWh consumption of electrical energy in the last one year divided by the total area of the building in m2. After knowing the lighting conditions and EUI value of the building, then it is determined whether the energy-wasting building or energy-efficient building. If the hotel building is classified as an energy-wasting building, then the next stage is to giving alternative designs for the manufacture of energy-efficient buildings.

Then the next step is giving an a few alternative designs for making the energy-efficient building. Afterwards providing several design alternatives, the next step is giving which design is the recommendation design simulation based on the optimum EUI reduction and cost-benefit consideration.

2.3 Economic analysis of alternative major design

After obtaining the cost-benefit budget value for all alternative design, an economic analysis is needed, the main objectives of the economic analysis itself are to:

1. Identify the level of project feasibility.
2. Evaluate how much profit will be obtained.
3. Justify the costs required for the construction of the project and the possibility of return on investment.
4. Identify the risks that might become obstacles for the project.
5. Identify the impact of the project.

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Calculation methods in economic analysis that are commonly used are as follows:

1. Net Present Value Method

The cost component and the benefit component are calculated as present value based on a predetermined interest rate. Net Present Value is obtained by subtracting the present value of the benefit component from the present value of the cost component.

NPV = PVbenefit - PVcost

where:

NPV = Net Present Value

PV = Present Value

This Net Present Value price is the price of the present value of profits. If the Net Present Value price has a positive sign or > 0, it means that the project under review can be classified as economical and feasible to build.

2. Benefit Cost Ratio Method

The comparison between benefits and costs is calculated by dividing the present value of the benefit component by the present value of the cost component. If the price B/C ratio > 1.0 then the project is said to be economical and feasible to build.

BCR = PVbenefit : PVcost

where:

BCR = Benefit Cost Ratio

PV = Present Value

3. Internal Rate of Return Method

If all the cost and benefit components have been obtained, then cash flow can be made from all these components according to the estimated economic life of the project. From this economic cash flow, the amount of economic net benefit for each year is then calculated, which is the basis for calculating the IRR value. IRR calculation is done by finding the value of the discount rate so that the present value of the benefit is equal to the value of the present value of cost, or the net present value is equal to zero. If the applicable discount rate is greater than the IRR value, then the project is feasible to implement.

IRR = I1+ NPV1/(NPV1-NPV2) (I2 – I1)

where:

I1 = interest rates give a positive NPV

I2 = interest rates give a negative PV value

NPV = the difference between the present value of benefits and the present value of costs

NPV1 = positive NPV

NPV2 = negative NPV

After economic analysis from all alternative design, the next step is giving which design is the most feasible to become the recommendation design.

3 RESULTS AND DISCUSSION

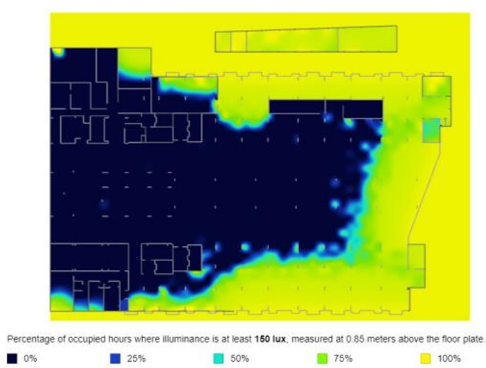
3.1 Existing Hotel Building Modeling

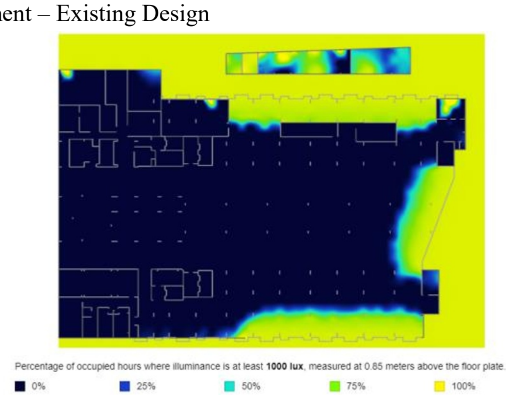
From the 3D model of existing building that show on Fig. 2, the next step is running simulation from natural daylight simulation, the result from simulation shows on Table 2.

Fig. 2. Existing 3D model.

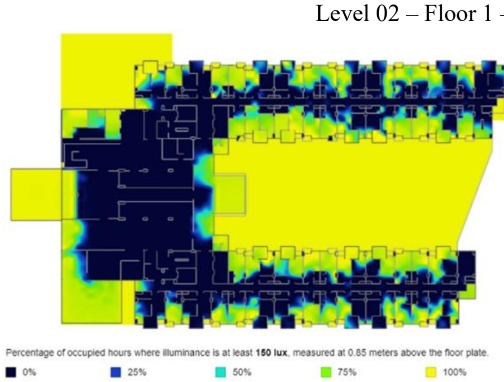
Daylight analysis in Sefaira can be performed in various method. Annual daylight analysis was performed to shows daylight condition of all area in the building. Annual daylight analysis in Sefaira performed in two boundary, 150 lux daylight illumination to represent dark area and 1000 lux illumination to represent glare area. Sefaira daylight analysis results can be seen in the Table 2.

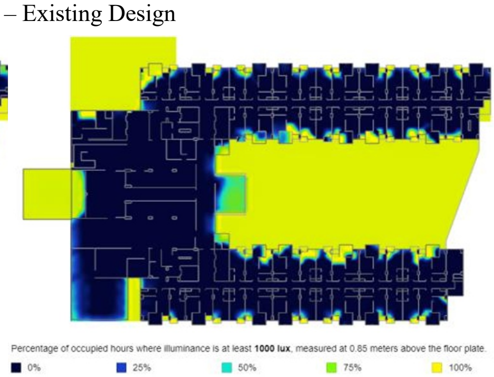
Level 01 – Area Basement – Existing Design



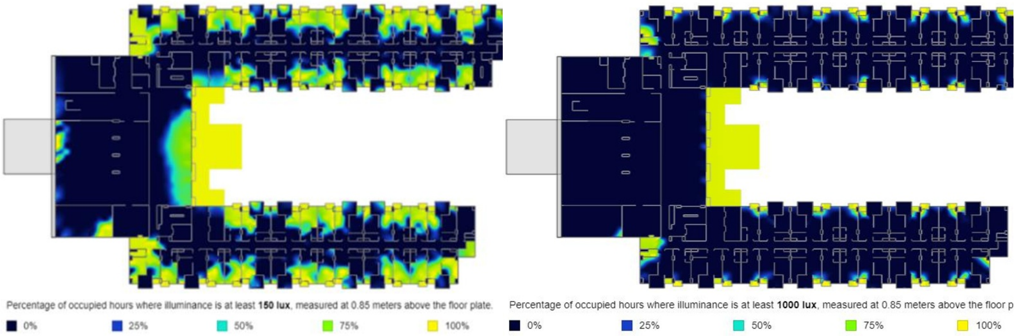


Level 02 – Floor 1 – Existing Design

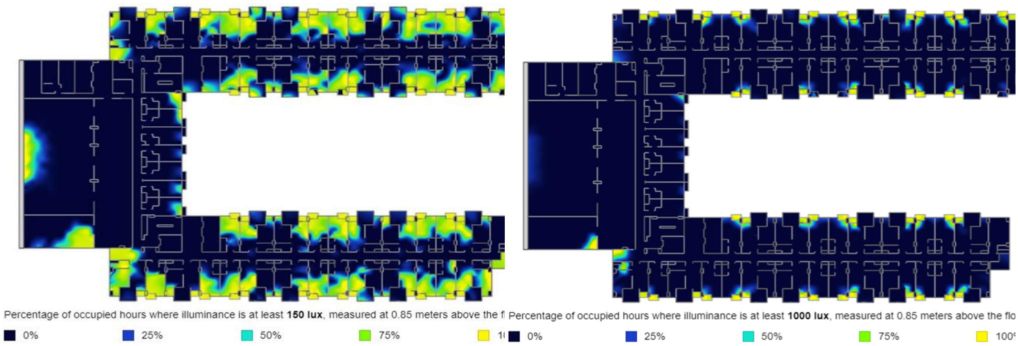




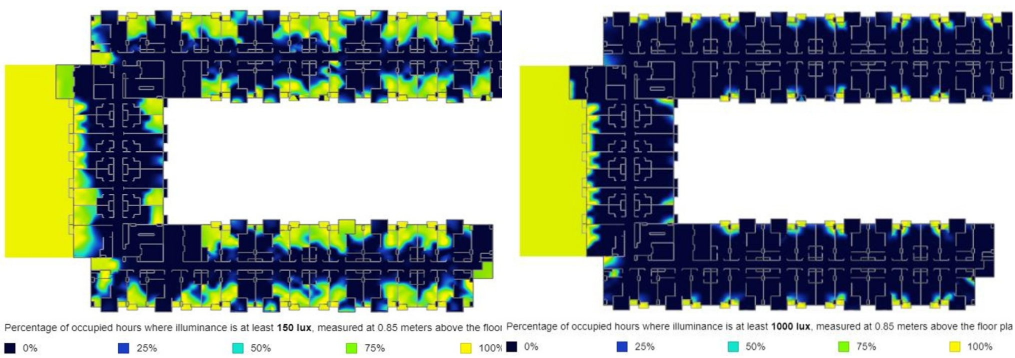
Level 03 – Floor 2 – Existing Design



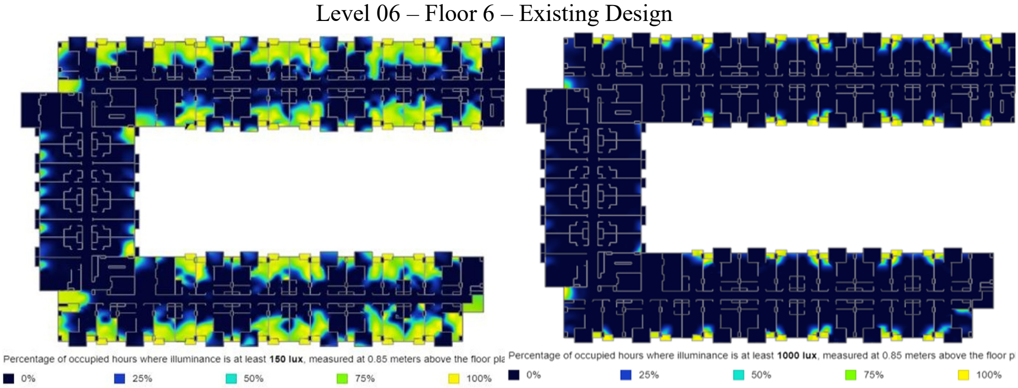
Level 04 – Floor 3 – Existing Design



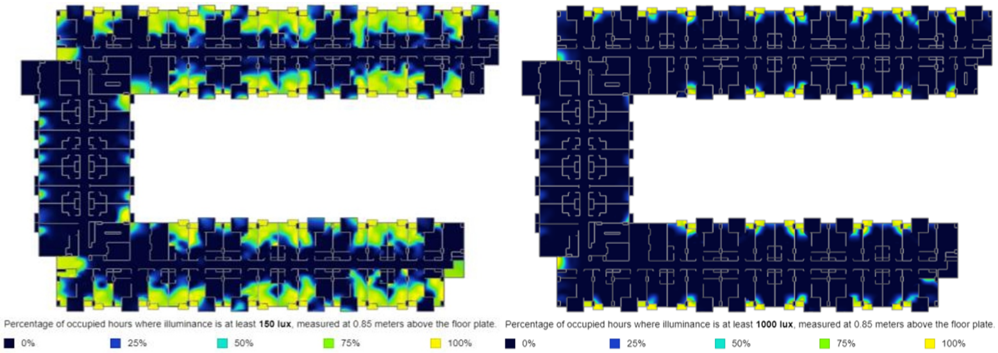
Level 05 – Floor 5 – Existing Design



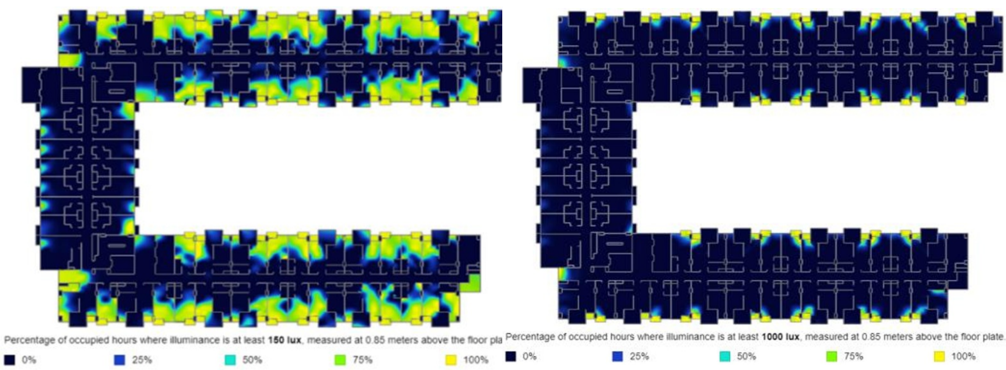
Level 06 – Floor 6 – Existing Design



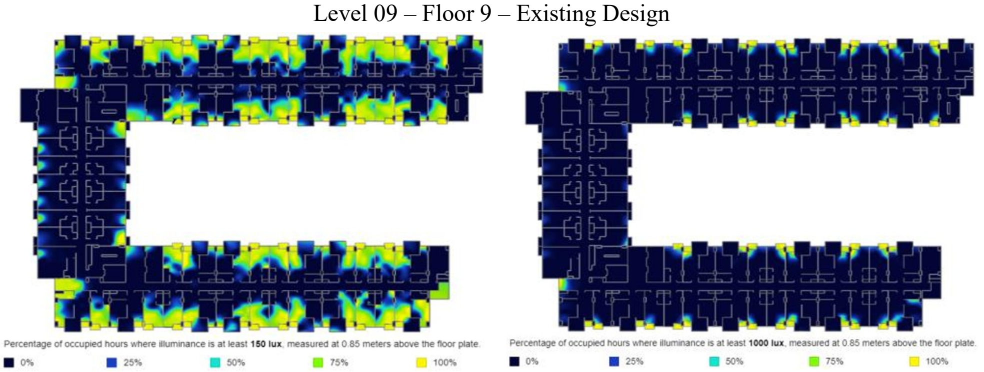
Level 07 – Floor 7 – Existing Design



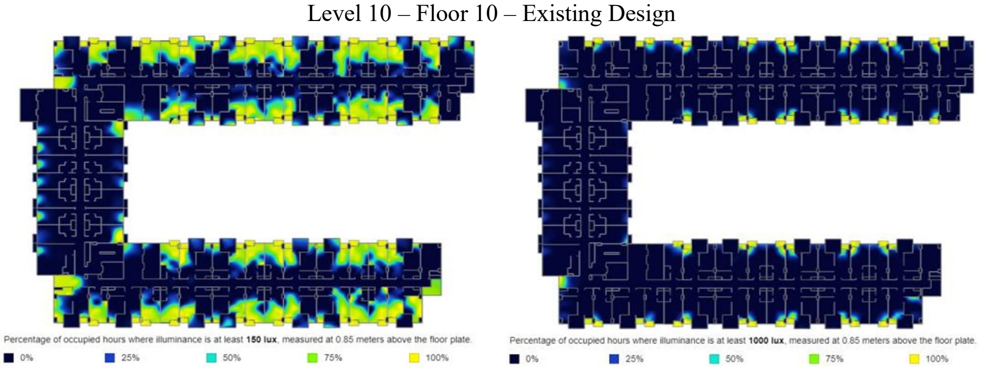
Level 08 – Floor 8 – Existing Design



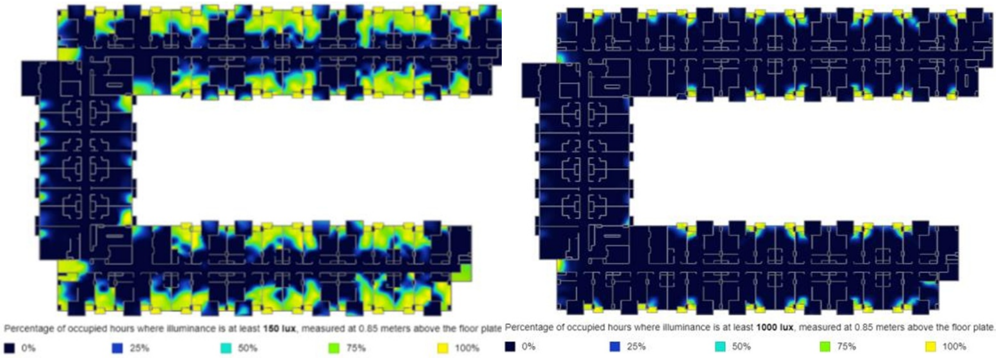
Level 09 – Floor 9 – Existing Design



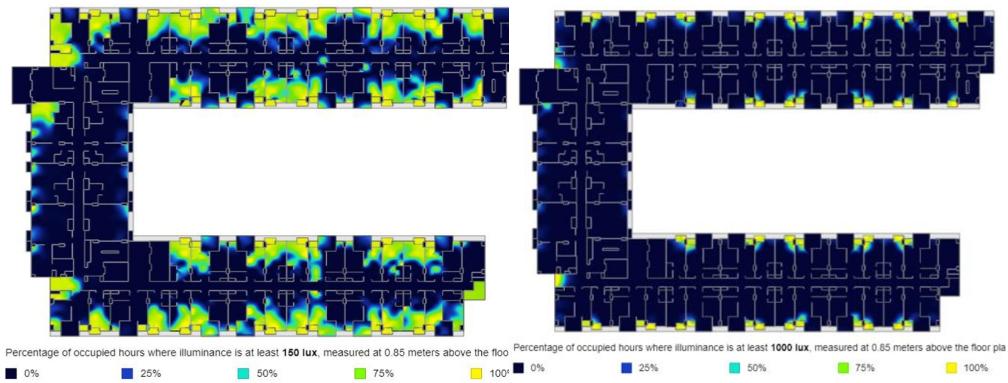
Level 10 – Floor 10 – Existing Design



Level 11 – Floor 11 – Existing Design



Level 12 – Floor 12 – Existing Design



3.2 Alternative 1 – Minor – replacing window film

In the existing conditions, it can be seen from the analysis of each room, it is obtained that rooms facing west, north and south mostly experience glare on the side near the window, but when reading the lux value, the condition of the room is considered dark because the middle side and the end of the room experience lack of light, then an analysis of alternative design 1 is then carried out by changing the type of VLT window film and the VLT illustration is on Fig. 3.

Fig. 3. VLT percentage illustration

Visible Light Transmission (VLT) is how much light is able to penetrate the glass. In percentage form, the greater the VLT number, the greater the incoming light, making it more glare. Conversely, the smaller the VLT number, the less light will penetrate. In the existing design, which has a VLT value of 30%, it is changed to 50% so that it becomes a bit brighter.

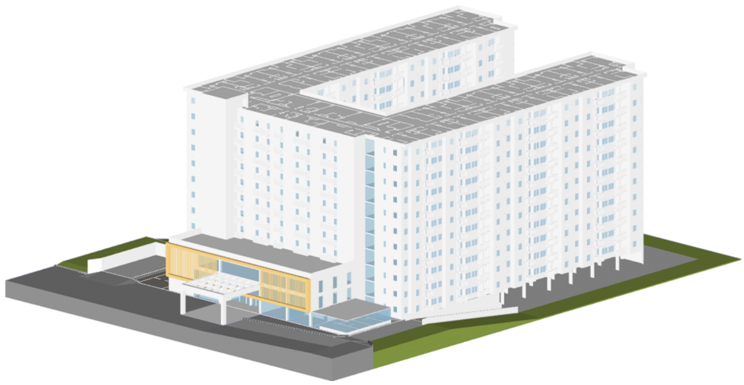


Fig. 4. Alternative 1 3D model

3.3 Alternative 2 – Minor – insulated paint

In the minor alternative design 2, changes were made to the color and type of paint for the entire building. Improvements for energy savings in this study were carried out by changing the paint color from white and brown to paper lace cream. The insulation paint itself has a function as a reflector and insulator which can reduce the temperature by 10-20 degrees Celsius, as well as the addition of insulation on the wall with a typical U-Value value on the wall after adding insulation to 0,3 W/m^{2}k where the typical U-Value value on the wall before adding insulation in the existing conditions of 2,2 W/m^{2}k.

Fig. 5. Alternative 1 3D model

Based on both simulation results of alternatives minor, various cost reduction results were obtained and the EUI reduction was recapitulated in Table 3.

In the recapitulation above, alternative 2 by changing the color and type of paint, was chosen to be a minor change because it got the greatest reduction in energy consumption, namely 1.98%, because the alternatives given had less impact on energy savings, the next step is to provide a major design alternative (big changes) that are expected to have a greater impact on energy savings. The major alternative itself is a change made by changing

the layout of the existing building design, and a combination of the selected minor alternative designs (insulation paint replacement) and major alternatives.

Table 3. Minor alternative energy use comparation

Information	Existing	Alt 1 Tint Window	Alt 2 Insulated Paint
EUI (kWh/m^2/yr) =	977,00	976,25	958,04
EUI Reduction =	0,00	0,75	18,96
Decrease Percentage =	0,00 %	0,08 %	1,98 %

3.4 Alternative Major – window addition

In the alternative major change, the alternative that will be carried out is to dismantling 2 rooms on the north side and 2 rooms on the south side of each hotel floor, the use of glass corridors aims to provide lighting for hotel corridors which are considered dark or lack of light, so that from the addition of a corridor glass aims to increase the level of lighting in floor corridors so that it is expected to save energy consumption in buildings, the following is a simulation of a glass corridor design in Sefaira.

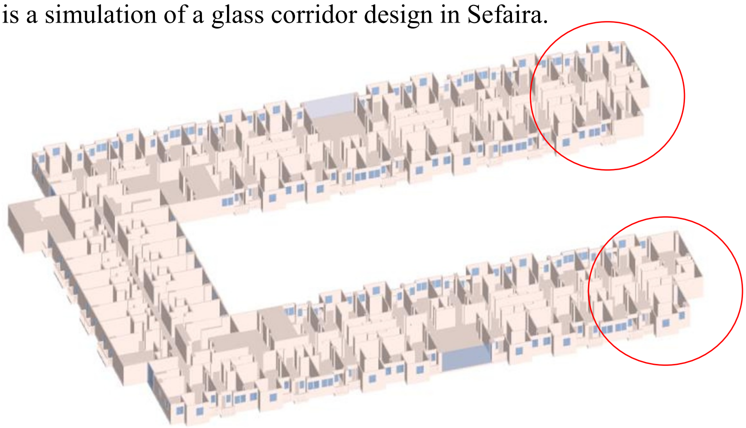


Fig. 6. Alternative Major 3D model

Based on Fig. 6 the addition of the glass corridor itself, so that the application of the glass corridor reduces a total of 4 units of rooms per floor. Next, a lighting simulation is carried out to find out whether the addition of glass corridors has the effect of providing lighting on floor corridors that experience a lack of lighting. Fig. 7 shows the simulation results of the major alternative glass corridors.

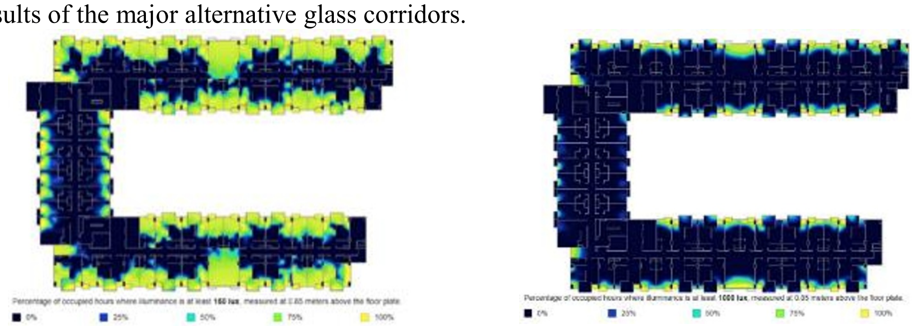


Fig. 7. Annual Daylight Analysis in Sefaira – Major Alternative

The main alternative of glass corridors is 2 different types of implementations, the first is glass corridors applied on floors 3,6,8,10, and 12. Meanwhile, the second glass corridor is installed on floors 1-12. From two alternative types of glass corridor installation, which one is the most effective and optimal will be chosen because the glass corridor is taken from a reduction in the number of rooms, so if there are too many rooms dismantle, it can reduce financial income for the owner of the hotel building, so the design chosen must consider the IRR and the BCR of the repairment alternative.

3.5 Alternative 3 – Major – Floor 3,6,8,10, and 12

In Alternative 3, the addition of glass corridors is implemented on floors 3,6,8,10, and 12. This addition aims to find out how much affect the glass corridor has on saving costs, and energy in one building, here is a schematic drawing and recapitulation analysis results of adding glass corridors on floors 3,6,8,10, and 12. The 3D model of Alternative 3 show on **Fig. 8**.

Fig. 8. Alternative 3 3D Model

3.6 Alternative 4 – Major – All Floor (1-12)

In Alternative 4, the addition of glass corridors is implemented on floors 1 to 12. This addition also aims to find out how much influence the glass corridor has on saving costs, and energy one building. The following is a schematic image and the results of the recapitulation analysis of adding a glass corridor on the 1st floor up to the 12th floor. The 3D model of Alternative 4 show on **Fig. 9**.

Fig. 9. Alternative 4 3D model

3.7 Recapitulation of alternative result

Based on minor and major simulation results, various cost reduction results were obtained and the EUI reduction was recapitulated in **Table 4**.

Table 4. Major alternative energy use comparison.

Alternative	Annual Net Energy Use	EUI	Energy Saving	Annual Energy Cost
	(kWh/yr)	(kWh/m²/yr)	(%)	(IDR)
Existing	2.578.528	977,00	0,00	2.994.403.821
Alternative 3	2.531.778	871,05	12,16	2.722.361.555
Alternative 4	2.051.849	744,22	31,28	2.346.637.473

From the simulation results, obtained cost savings from alternative 3 to the existing conditions of IDR 272.042.266 and alternative 4 cost savings IDR 647.766.348. The simulation results show that alternative 4 has the biggest percentage of energy reduction and energy-cost, but the selection of the optimal design must also consider economic analysis, whether implementing this alternative can be considered feasible, because reducing too many rooms can disrupt financial income.

In the economic analysis calculation, room loss is added if there is 100% occupancy, based on the Indonesia holiday calendar, it can be seen that the total national holidays and joint leave are 30 days, while the room rate per day is IDR. 600.000,00 multiplied by the number of room units replaced as glass corridors (4 room units / floor). Based on the explanation above, here are the major alternative economic analysis. The following in Table 5 and Table 6 are alternative 4 and alternative 5 economic analysis.

Table 5. Economic analysis alternative 3

Year	Benefit		Cost		Cash Flow	Cash Flow Comulative
	Painting Fund Allocation from O&M	Energy Cost Savings	Repairment Cost	Dismantling Room Loss		
	(IDR)	(IDR)	(IDR)	(IDR)	(IDR)	(IDR)
1	2.745.412.208,27	272.042.266,00	3.681.894.710,05	360.000.000,00	(1.024.440.235,78)	(1.024.440.235,78)
2	-	272.042.266,00		360.000.000,00	(87.957.734,00)	(1.112.397.969,78)
3	-	272.042.266,00		360.000.000,00	(87.957.734,00)	(1.200.355.703,78)
4	-	272.042.266,00		360.000.000,00	(87.957.734,00)	(1.288.313.437,78)
5	-	272.042.266,00		360.000.000,00	(87.957.734,00)	(1.376.271.171,78)
6	2.745.412.208,27	272.042.266,00		360.000.000,00	2.657.454.474,27	1.281.183.302,50
7	-	272.042.266,00		360.000.000,00	(87.957.734,00)	1.193.225.568,50
8	-	272.042.266,00		360.000.000,00	(87.957.734,00)	1.105.267.834,50
9	-	272.042.266,00		360.000.000,00	(87.957.734,00)	1.017.310.100,50
10	-	272.042.266,00		360.000.000,00	(87.957.734,00)	929.352.366,50
11	2.745.412.208,27	272.042.266,00	3.611.637.605,78	360.000.000,00	(954.183.131,51)	(24.830.765,01)
12	-	272.042.266,00		360.000.000,00	(87.957.734,00)	(112.788.499,01)
13	-	272.042.266,00		360.000.000,00	(87.957.734,00)	(200.746.233,01)
14	-	272.042.266,00		360.000.000,00	(87.957.734,00)	(288.703.967,01)
15	-	272.042.266,00		360.000.000,00	(87.957.734,00)	(376.661.701,01)
16	2.745.412.208,27	272.042.266,00		360.000.000,00	2.657.454.474,27	2.280.792.773,26
17	-	272.042.266,00		360.000.000,00	(87.957.734,00)	2.192.835.039,26
18	-	272.042.266,00		360.000.000,00	(87.957.734,00)	2.104.877.305,26
19	-	272.042.266,00		360.000.000,00	(87.957.734,00)	2.016.919.571,26
20	-	272.042.266,00		360.000.000,00	(87.957.734,00)	1.928.961.837,26
Total	**10.981.648.833,10**	**5.440.845.320,00**	**7.293.532.315,84**		**1.928.961.837,26**	**9.045.216.014,87**
***Economic Internal Rate of Return* (EIRR)**						**13,61%**
***Payback Period* (PP) Year**						**5,52**
	PV Cost	**PV Benefit**			**NPV**	**BCR**
	14.493.532.315,84	16.422.494.153,10			1.928.961.837,26	1,13

Table 6. Economic analysis alternative 4.

Year	Benefit		Cost		Cash Flow	Cash Flow Comulative
	Painting Fund Allocation from O&M	Energy Cost Savings	Repairment Cost	Dismantling Room Loss		
	(IDR)	(IDR)	(IDR)	(IDR)	(Rp)	(IDR)
1	2.745.412.208,27	647.766.348,00	3.766.203.235,17	864.000.000,00	(1.237.024.678,90)	(1.237.024.678,90)
2	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(1.453.258.330,90)
3	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(1.669.491.982,90)
4	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(1.885.725.634,90)
5	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(2.101.959.286,90)
6	2.745.412.208,27	647.766.348,00		864.000.000,00	2.529.178.556,27	427.219.269,38
7	-	647.766.348,00		864.000.000,00	(216.233.652,00)	210.985.617,38
8	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(5.248.034,62)
9	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(221.481.686,62)
10	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(437.715.338,62)
11	2.745.412.208,27	647.766.348,00	3.611.637.605,78	864.000.000,00	(1.082.459.049,51)	(1.520.174.388,13)
12	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(1.736.408.040,13)
13	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(1.952.641.692,13)
14	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(2.168.875.344,13)
15	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(2.385.108.996,13)
16	2.745.412.208,27	647.766.348,00		864.000.000,00	2.529.178.556,27	144.069.560,14
17	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(72.164.091,86)
18	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(288.397.743,86)
19	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(504.631.395,86)
20	-	647.766.348,00		864.000.000,00	(216.233.652,00)	(720.865.047,86)
Total	**10.981.648.833,10**	**12.955.326.960,00**	**7.377.840.840,95**		**(720.865.047,86)**	**(19.578.897.267,52)**
***Economic Internal Rate of Return* (EIRR)**						**-7,69%**
***Payback Period* (PP) Year**						**5,83**
		PV Cost	**PV Benefit**		**NPV**	**BCR**
		24.657.840.840,95	23.936.975.793,10		(720.865.047,86)	0,97

Based on the calculations of the Technical Economic Calculation Analysis in Table 9, an IRR value of 13,61% and a BCR value of 1,13 for alternative 3 are obtained and for alternative 4 an IRR value of -7,69% and an IRR value of -7,69% are obtained. BCR 0,97. With a general IRR target of 12% and BCR > 1, alternative 4 can be declared not feasible to be implemented in study locations. In order to achieve greater energy savings and be economically feasible, it can be concluded that alternative 3 is the best alternative to be recommended in terms of technical economic analysis.

4 CONCLUSION

The lowest cost and energy consumption based on the Sefaira simulation results, are in alternative 3 with improvement by using insulated walls and with additional window corridor for 5 levels (floor 3,6,8,10,12). In alternative 3, the annual energy cost reduction is IDR 272.042.266,27 or around 12% of the existing design value. Decrease in value of annual energy consumption of 237.868 kWh. Apart from the energy aspect, alternative 3 also includes improvements to daylighting, and has 13.61% of the economic internal rate of return (EIRR) which gives estimated payback period in 5,52 years. With PV Cost in 20 years IDR 14.493.532.315,84, PV benefit IDR 16.422.494.153,10 and NPV at IDR 1.928.961.837,26 gives BCR value 1,13 which indicates that improvement with insulated wall and 5 level additional window corridor combined has good value of benefit. So, in this study, it is recommended to use alternative 3 to improve the study site-building and a suggestion for further research to encourage improvement innovations and major improvement that can significantly impact saving cost and energy consumption.

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