Energy Audit For Energy Efficiency and Cost on Hospital Buildings

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ABSTRACT

Hospitals are social facilities that operate publicly for 24 hours/day. The energy consumption of hospital buildings is among the highest, compared to commercial and residential buildings. Energy efficiency can be achieved after implementing a process called energy auditing and planning. The purpose of this study is to determine the EUI (Energy Use Intensity) of electricity for energy and cost savings, without reducing the productivity and comfort of the occupants. The method used in this research is the calculation of the EUI of the entire equipment, comparison of calculating the existing EUI with the Standard, simulation of existing conditions, redesign, modeling and simulation analysis of redesign results, calculation of EUI after redesign, and calculation of energy costs before and after redesign. The results of this study obtained the EUI value in the air-conditioned room on the 1st floor of 15.14 kWh/m^2/month included in the category Sufficient efficient from previously Wasteful, 2nd floor of 7.53 kWh/m^2/month included in the category Fully Efficient and 3rd floor of 7.97 kWh/m^2/month included in the category Fully Efficient. As for the non-AC room, the 1st floor of 2.27 kWh/m^2/month is included in the Fully Efficient category, the 2nd floor of 2.50 kWh/m^2/month is included in the Fully Efficient category from the previous Efficient, and the 3rd floor of 2.50 kWh/m^2/month is included in the Fully Efficient category from the previous Efficient. Meanwhile, the calculation of energy costs after design recommendations were obtained at IDR 976.219.477,27 decreased by 21.56%.

Keywords: EUI; hospital; energy efficiency; redesign; sefaira.

INTRODUCTION

Hospitals or healthcare buildings are social facilities designed to provide care to patients, which operate in general over 24 days (Nourdine & Saad, 2019) The energy consumption of hospital buildings is among the highest, compared to commercial and residential buildings. Energy Audit and Planning for both existing and new-to-build buildings has been of increasing interest during the last years due to growing environmental concerns. Energy efficiency could be achieved after applying a process called energy audit and planning. According to this process, all energy consumptions would be defined and possibilities to reduce them would be explored (Doukas & Bruce, 2017)

A technique used to calculate the amount of energy consumption in buildings and identify ways to save it. EUI value is an energy efficiency indicator parameter used to determine the amount of electrical energy consumption in the building sector. EUI analysis is carried out so that there is no waste of electrical energy consumption. The data used to calculate the EUI value is taken from the energy audit data on the building. This data is subjected to statistical analysis to determine the efficiency of electrical energy consumption in a building and the parameters that affect the EUI value (Purnami et al., 2022). Energy-saving actions should be developed to decrease the energy consumption. Therefore, commercial buildings have enormous energy-saving potential. Energy conservation generally includes actions to reduce the amount of energy end use (Joshi et al., 2023). One measure of whether a building is efficient in using energy is the EUI based on SNI 03-6196-2011 on energy audit procedures in buildings.

Energy consumption optimization can be more challenging as any of the energy reduction measures(Qiang et al., 2023). Proposed measures should ensure minimal or no adverse effect on the

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daily operations and productivity of the plant. Generally, energy efficiency is associated with cost savings. The purpose of this study is to determine the EUI of electricity for energy and cost savings without reducing the productivity and comfort of the occupants.

RESEARCH METHODS

Materials

The energy auditing process can be undertaken successfully based on specific guidelines (Purnami et al., 2022). In this study using data on floor plans and electrical equipment. The energy auditor is required to have some preliminary ideas on the facility's energy consumption capacity.

Calculation EUI

Based on SNI 03-6169-2011 on building energy audit procedures, the energy consumption intensity in each room can be calculated using the following equation:

$$EUI = \frac{Pk}{A}$$

by:

EUI = Energy Use Intensity (kWh/m^2/year)

Pk = total electrical consumption (kWh)

A = area (m^2)

To categorize a building as wasteful or economical in energy use, both for air-conditioned and non-air-conditioned rooms based on the guidelines for the implementation of electrical energy conservation and supervision, in determining energy saving achievements (Fitriani et al., 2017) As a guideline, the EUI standard value for buildings in Indonesia has been set according to the Ministry of ESDM No. 13 of 2012 shows Table 1.

Table 1. EUI Value Standard Criteria

No	Criteria	AC Room (kWh/m^2/month)	Non-AC room (kWh/m^2/month)
1.	Fully Efficient	< 8,5	< 3,4
2.	Efficient	8,5 – 14	3,4 – 5,6
3.	Sufficient efficient	14 – 18,5	5,6 – 7,4
4.	Wasteful	> 18,5	> 7,4

Methods

The first step in this research is the calculation of the overall EUI of the equipment. The second step is to compare the results of the existing EUI calculation with the EUI Standard which is a regulation of the Ministry of Energy and Mineral Resources. If the results of the existing EUI calculation do not meet the standard, then the hospital building needs to be redesigned for energy optimization. Furthermore, the third step is the simulation of existing conditions to analyze energy consumption for one year. In this simulation, sefaira plug-in is used for skethcup by estimating based on ASHRAE 90.1. 2019. The fourth step is redesign modeling and simulation analysis of redesign results. Next, the fifth step is the calculation of EUI after redesign. The last step is the calculation of energy costs before and after redesign.

RESULT AND DISCUSSION

Calculation EUI

EUI is a term used to express the amount of energy used per square meter of gross building area in a certain period (Kurniawati & Mamok Suprapto, 2017). A calculated EUI of the building also give by research of (Biantoro & Permana, 2017). Based on existing data, the building area in this hospital building is 6.156 m^2 consisting of 3rd floors. Table 2 is the building area of the AC and non-AC room hospital buildings used. Lighting usage in hospitals for 14 hours

Table 2. Hospital Building Area

Floor	Area		Total Area (m²)
	AC room (m²)	Non AC room (m²)	
1st	1605	447	2052
2nd	1698	354	2052
3rd	1702	350	2052
Total	5005	1151	6156

Calculating the EUI in AC and non-AC rooms based on electrical load data such as the type of electrical equipment load installed in hospital buildings can be seen in Table 3.

Table 3. Calculation of Electricity Load on the Building

Floor	AC room (m²)	Non-AC room (m²)	AC room (kWh/day)	Non-AC room (kWh/day)	AC room (kWh/month)	Non-AC room (kWh/month)
1st	1.605	447	1.001,12	45,62	30.033,60	1.368,60
2nd	1.698	354	536,22	42,69	16.086,54	1.280,58
3rd	1.702	350	600,93	43,75	18.027,78	1.312,50
Total	5.005	1.151	2.138,26	132,06	64.147,92	3.961,68

Table 3 shows the details of the electricity load for each floor, so the above calculations can be used to obtain the IKE value for one year using the formula in the following equation.

$$IKE = \frac{Pk}{A} = \frac{((64.147,92 + 3.961,68)\ X\ 12)}{(5005 + 1151)} = 132,77 \text{ kWh/m}^2\text{/year}$$

Energy audit efforts for each air-conditioned and non-air-conditioned room can also calculate the EUI value on each floor using the same equation and compared with the Ministry of ESDM No. 13 of 2012, the value on each floor is obtained in Table 4 as follows:

Table 4. EUI Value of Each Floor

Floor	AC Room EUI Criteria (kWh/m²/month)	Non-AC Room EUI Criteria (kWh/m²/month)	EUI AC Room (kWh/m²/month)	EUI Non-AC Room (kWh/m²/month)	AC Room Criteria	Non-AC Room Criteria
1st	> 18,5	< 3,4	18,71	3,06	Wasteful	Fully Efficient
2nd	8,5 – 14	3,4 – 5,6	9,47	3,65	Efficient	Efficient
3rd	8,5 – 14	3,4 – 5,6	10,59	3,75	Efficient	Efficient

Table 4 shows the EUI value in the air-conditioned room on the 1st floor of 18.71 kWh/m²/month falls into the Wasteful category, the 2nd floor of 9.47 kWh/m²/month falls into the Efficient category and the 3rd floor of 10.59 kWh/m²/month falls into the Efficient category. Whereas for non-air-conditioned rooms on the 1st floor of 3.06 kWh/m²/month falls into the Fully Efficient category, the 2nd floor of 3.65 kWh/m²/month falls into the Efficient category, and the 3rd floor of 3.75 kWh/m²/month falls into the Efficient category. The calculation results show the inequality of categories in one building, so improvements and energy savings are needed in the building. In current energy auditing practice, this information is obtained from existing building documentation and surveys, whereas missing information is usually supplemented by standard values (Spudys et al., 2023).

Natural lighting analysis using sefaira

Sefaira is a web-based performance analysis platform specifically built for conceptual design. The software is useful for designing sustainable buildings and optimising their energy efficiency and

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carbon footprint (Paramita, 2019). The simulation reviewed the amount of natural lighting entering the building. The simulation results can be seen in Figure 1.

Figure 1. Natural lighting simulation of existing hospital Floor 1, (b) Floor 2, (c) Floor 3

Figure 1 shows the existing natural lighting of the hospital on the 1st floor shows an average lighting factor result of 4.56%, the 2nd floor is 5.91% and the 3rd floor is 4.19%.This shows a lack of natural lighting in the building, so there is a need for design changes for energy savings. Energy saving opportunities are still very open, by improving energy consumption behavior patterns and implementing energy-saving technologies (Sunarto, 2018).

Design Recommendation

Building design should consider the function and needs so that occupants can feel comfortable. Lighting levels can be achieved by utilizing natural and artificial lighting, ensuring visual comfort (Hesti et al., 2015). Alternative design provides the addition of skylights on the roof, so that more light enters and can reduce the use of lights during the day.

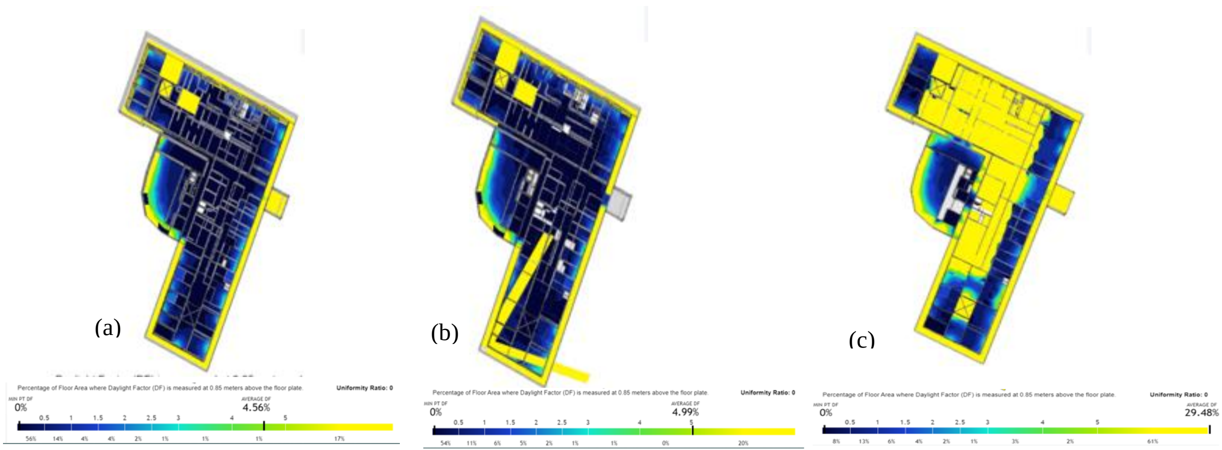

Figure 2. Natural lighting simulation of redesign hospital Floor 1, (b) Floor 2, (c) Floor 3

In Figure 2, the results of the daylight factor simulation of the alternative design above can be seen on the 3rd floor there is a change in natural lighting conditions, which is 29.45%. Meanwhile, for the 1st and 2nd floors there is a change of 4.56% and 4.99%. This can be a recommendation for recalculating EUI to meet the criteria of the ESDM ministry regulations.

EUI Calculation after Design Recommendation

The distinguishes EUI calculation after this recommendation is changing the type of lamp from TL and fluorescent lamps to LED according to the lumen of the lamps used previously on all floors, and changing the use of lights on the 3rd floor to 11,5 hours because on the 3rd floor there is additional natural light from the skylight.

Table 4. Calculation of Electricity Load on the Building After Recommendation

Floor	AC room (m^2)	Non-AC room (m^2)	AC room (kWh/day)	Non-AC room (kWh/day)	AC room (kWh/month)	Non-AC room (kWh/month)
1st	1.605	447	809,77	33,75	24.292,98	1.012,56
2nd	1.698	354	426,34	29,54	12.790,20	886,32
3rd	1.702	350	452,19	29,15	13.565,78	874,56
Total	5.005	1.151	1.688,30	92,45	50.648,96	2.773,44

Table 4 shows the details of the electricity load for each floor, so the above calculations can be used to obtain the IKE value for one year using the following formula.

$$IKE = \frac{Pk}{A} = \frac{((50.648,96 + 2.773,44)\ X\ 12)}{(5.005+2.773,44)} = 104,14 \text{ kWh/m}^2\text{/year}$$

From the results of the above calculations, the IKE value obtained after the recommendation is 104.14 kWh/m2 / year. From the initial IKE calculation, it was reduced by 28.63 kWh/m2 / year or by 21.56%. Based on the regulation of the Ministry of Energy and Mineral Resources No.13 of 2012, the value of each floor is obtained in Table 5 as follows:

Table 5. EUI Value of Each Floor After Recommendation

Floor	AC Room EUI Criteria (kWh/m^2/month)	Non-AC Room EUI Criteria (kWh/m^2/month)	EUI AC Room (kWh/m^2/month)	EUI Non-AC Room (kWh/m^2/month)	AC Room Criteria	Non-AC Room Criteria
1st	14 - 18,5	< 3,4	15,14	2,27	Sufficient efficient	Fully Efficient
2nd	< 8,5	< 3,4	7,53	2,50	Fully Efficient	Fully Efficient
3rd	< 8,5	< 3,4	7,97	2,50	Fully Efficient	Fully Efficient

Table 5 shows that the EUI value in the air-conditioned room on the 1st floor of 15.14 kWh/m^2/month falls into the category of Efficient enough from the previous wasteful, the 2nd floor of 7.53 kWh/m^2/month falls into the category of Fully Efficient and the 3rd floor of 7.97 kWh/m^2/month falls into the category of Fully Efficient. The non-air-conditioned room on the 1st floor at 2.27 kWh/m^2/month is categorized as Fully Efficient, the 2nd floor at 2.50 kWh/m^2/month is categorized as Fully Efficient from the previous Efficient, and the 3rd floor at 2.50 kWh/m^2/month is categorized as Fully Efficient from the previous Efficient. The calculation results show the similarity of categories on each floor and only on the 1st floor of the air-conditioned room which falls into the category of quite efficient but still acceptable.

Energy Cost

Energy costs use the results of the initial EUI calculation in this study. For Hospital building, the monthly usage cost is IDR 1.522,80 because it is included in Group P-2 / TM power above 200 kVA. The calculation of energy costs is as follows.

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Energy cost = P x t x Rp/kWh
= 2.270,32 x 30 x 1.522,80
= IDR 103.717.299,88 /month
Meanwhile, the total energy cost per year
Energy cost = 103.717.299,88 x 12
= IDR 1.244.607.587 /year

The calculation of energy costs uses the results of the EUI calculation after the following recommendations.

Energy cost = P x t x Rp/kWh
= 1780,75 x 30 x 1.522,80
= IDR 81.251.632,11 /month
Meanwhile, the total energy cost per year
Energy cost = 81.251.632,11 x 12
= IDR 976.219.477,27 /year
The calculation of the initial EUI energy costs above, the costs incurred each year amounted to IDR 1.244.607.587 /year, and for EUI after the design recommendations obtained results of IDR 976.219.477,27 /year. The calculation of energy costs is decreased by IDR 268.388.109,29 /year or 21.56%.

CONCLUSION

The results of this study obtained the EUI value in the air-conditioned room on the 1st floor of 15.14 kWh/m^2/month included in the category Sufficient efficient from previously Wasteful, 2nd floor of 7.53 kWh/m^2/month included in the category Fully Efficient and 3rd floor of 7.97 kWh/m^2/month included in the category Fully Efficient. As for the non-AC room, the 1st floor of 2.27 kWh/m^2/month is included in the Fully Efficient category, the 2nd floor of 2.50 kWh/m^2/month is included in the Fully Efficient category from the previous Efficient, and the 3rd floor of 2.50 kWh/m^2/month is included in the Fully Efficient category from the previous Efficient. Meanwhile, the calculation of energy costs after design recommendations was obtained at IDR 976.219.477,27 decreased by 21.56%.

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