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Energy Analysis of the Educational Building in Palembang Indonesia

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Abstract The issues of global warming and the greenhouse effect are of enormous concern today for most people. With increased demand for energy and a reduction in existing energy resources, demands for more energy efficient buildings within the construction industry are growing rapidly. Buildings are one of the largest energy consumers and account for about 40% of total energy consumption. This study aims to investigate the energy consumption of existing building located in Palembang as compared to the benchmark of Indonesian Standard for educational buildings. This paper also develops an energy analysis model with BIM integration to produce accurate predictions of the educational building performance with better scenarios. The EUI calculations were carried out in two ways. First, the electrical usage used in the building was calculated and then compared with the SNI 03-6196-2000 standard. Secondly, a 3D model was developed by redrawing the building object using BIM Revit application which follows the ASHRAE 90.1 benchmark standards. It was found that HVAC dominated for about 69% of the total energy consumption for the first floor, whereas electronic appliances contributed to the highest proportion of energy consumption, which was about 66%, for the second floor. The EUI value for the first floor was 22.43 kWh/m^2/month, while the second floor was about 45.56 kWh/m^2/month, resulting in an average EUI of around 33.99 kWh/m^2/month. The existing building was then classified as a very inefficient building in terms of energy consumptions. Based on the renovation designs, 9 scenarios were then developed to measure potential energy savings generated by the building using the Insight 360 web-based energy analysis tool. In the last scenario, considering a building installed with solar panels with a time limit of 30 years, 90% of surface coverage resulted in an EUI value of -6.49 kWh/m^2/year with 102.10% of energy efficiency. This building scenario could provide energy export and save the energy excess. It can also be concluded that there was a significant improvement on energy use reduction and a substantial increase in energy savings under different renovation design scenarios. Finally, the results will help the decision makers identify the potential for energy savings in all energy-consuming facilities and equipment in the building as well as develop strategies for energy conservation.

Keywords Global Warming, BIM, Energy Analysis, Building Performance, EUI, HVAC

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1. Background

The issue of sustainability and energy conservation has become an important topic in today's world community. With an increasing demand for energy consumption, demands for more energy efficient buildings within the construction industry are growing rapidly. Buildings are one of the largest energy consumers and account for about 40% of total energy consumption [1]. According to the Green Building Guidelines [2] in the Jakarta green building standards, most buildings in Indonesia normally use the HVAC (Heating, Ventilation and Air Conditioning) system and contribute to 47%-65% of the total building energy consumption.

The analysis of energy performance in buildings is important to discuss because of the demands for energy savings and their impacts on the environment. Several studies have been conducted to optimize the use of building energy, including the use of energy efficient technology and recommending various strategies in energy conservation [2-5]. Bergin et al [6] used BIM as a digital method and process for building performance analysis. Solla et al [7] examined the various possibilities for integrating BIM into green building performance assessment tools. A study by Fitriani [8] evaluated the efficiency of electrical energy in hospital buildings using the Ecotect software. Energy analysis is still mostly carried out only with statistical estimates or using simple static calculations. For this reason, it is necessary to develop an energy analysis for buildings using dynamic energy simulation software in order to predict energy consumption more accurately.

Building energy analysis must meet cost and project schedule requirements. According to Azhar et al [9], cost savings can reach more than 10 times the initial investment value by using the concept of sustainable design. Energy simulation tools are increasingly used for building energy performance analysis such as Ecotect, Energy Plus and others [10]. However, most of the specific building element information required for energy simulations can be done by using Building Information Modeling (BIM), thus integration is needed with the design process and BIM technology [11-13]. The integration of BIM in the assessment of energy performance in buildings makes a major contribution to reducing energy consumption and CO_2 emissions. This study aims to investigate the energy consumption of a building located in Palembang as compared to the benchmark of Indonesian Standard for educational buildings. The initial energy audit was also conducted to determine the value of Energy consumption intensity (EUI) of the buildings using the SNI 03-6169-2000 guidelines and using ASHARE 90.1 benchmarks. Energy audits were carried out to identify the potential for energy savings in all energy-consuming facilities and equipment. Energy audits were also carried out to determine patterns of energy use and potential energy savings. This paper also develops an energy analysis model with BIM integration to produce accurate predictions of the educational building performance with better scenarios. The models can help improve the design decision-making process. The 3D building model was developed with several energy efficiency design strategies.

2. Literature Review

Studies on energy consumption have been emerging. The efficiency of energy use for educational buildings based on LEED Building Rating Systems and the influence of LEED certification to building energy performance were studied [4]. This study recognized impending issues related to attaining sustainable energy policies. A study by Ouf et al [15] also highlighted the energy use of school buildings based on historical energy consumption for a ten-year period as compared to the benchmark. It was found that the age of school buildings had a significant impact on energy consumption, and that new schools consumed more electricity than old ones. The research of [16] examined the standard for energy performance in high school building design and concluded that energy use can be identified based on building design, services design and occupant behavior.

The energy use characteristics for different types of higher education buildings were presented by [17] and also stated that the buildings used for research had a higher Energy Use Intensity (EUI) rather than the academic offices. A study by [18] highlighted the energy performance of different types of school buildings and found that universities consumed more electricity than elementary schools in Taiwan. Moreover, it was also found that the air-conditioning and lighting strongly influenced the energy consumption of school buildings. The research of [19] performed the energy use analysis for educational buildings specifically in humid areas and assessed the material construction, cooling load and lighting that all had/resulted in significant effects on energy consumption. The energy performance of universities accommodation based on the number of electrical appliances used as well as equipment and machinery was also evaluated by Dzulkefli et al [20].

A study by [21] examined the evaluation of building performance on energy consumption in the school buildings in Ecuador using the Autodesk Revit 2017 software. The research presented the comparisons of various building components that produce optimum energy use. The study by Shoubi et al [22] examined energy performance in several cases/scenarios for building, climate, and environmental conditions as well as HVAC systems by involving various information models and building physical conditions. The study by Kamaruzzaman et al [23] analyzed energy and cost savings by controlling daylight in historical buildings in tropical areas. This study stated that lighting consumption in buildings can be influenced by building use, daytime electricity usage, lighting levels and hours of use. The natural and artificial lighting using the Ecotect software was investigated by Chandra et al [24] and it was concluded that the natural lighting entering the room was influenced by the location and the size of the windows, as well as the direction of the sun's trajectory. The study of Shandilya et al [25] presented the optimization of thermal behavior of residential houses under different climates and proposed a retrofitting strategy by keeping the thermal comfort. A study by Yang et al [26] conducted an energy analysis of house buildings and developed data conservation strategies related to the local environment by analyzing several factors such as building orientation, building daylight hours, and natural ventilation conditions. Energy-efficient design is defined as the design of buildings to minimize energy use without limiting the function of the building or the comfort or productivity of its occupants. Designing an energy-efficient building is one aspect of achieving sustainable buildings.

According to SNI-03-6196-2000 [27], Energy Use Intensity (EUI) is the ratio between energy consumption and building area unit which is used as an indicator for energy savings in a building. The value of EUI is explained by the amount of energy consumption (kW) per square meter area (m^2) per month. Table 1 shows the EUI value standard for educational buildings in Indonesia with its classifications for rooms both with and without air conditioning [28]. The EUI value will determine whether a building is classified as highly efficient, efficient, simply efficient or inefficient. Standard criteria for EUI value can be seen as follows.

Table 1. EUI Standard based on the Educational Building Standards (2006) [28]

Criteria	EUI for Room with AC ($kWh/m^2/month$)	EUI for Room without AC ($kWh/m^2/month$)
Very Efficient	4.17 - 7.92	0.84 – 1.67
Efficient	7.92 - 12.08	1.67 – 2.50
Simply Efficient	12.08 - 14.58	-
Tends to be inefficient	14.58 - 19.17	-
Not efficient	19.17 - 23.75	2.50 – 3.34
Very Inefficient	- 37.50	- 4.17

3. Research Methodology

The research was conducted in Palembang by utilizing a two-story educational building. This research used a field survey and measurement method as well as quantitative analysis by comparing the existing measurements to the Indonesian standards for educational buildings. A field survey was performed to investigate the energy consumption in buildings which include the numbers of electrical equipment, equipment operational process mechanisms, hours of use of electrical equipment and the technology used. Since the buildings were built in 1957, the as-built drawings are no longer available. Therefore, direct measurement of the buildings was conducted to determine floor area and the total area of the building. Based on an interview with the manager of the buildings, the hours of operation can be determined. Meanwhile the number of AC points, light points and other electronic loads can be determined from direct observation.

The EUI value can be determined by using the equation as follows:

$$EUI = \frac{Pk}{A} \tag{1}$$

Which:

EUI = Energy Use Intensity ($kWh/m^2/month$)
Pk = Total Energy Consumptions (kWh/month)
A = Total area (m^2)

The energy consumption of the existing building was determined based on the formula given in equation (1). In addition, 3D building modeling was also performed with BIM Revit software, weather data and building data based on specifications and materials to be simulated in the BIM Revit 2020. The building energy analysis was carried out with the Green Building Studio (GBS) and then the scenario development was conducted using Insight 360 using the DOE 2.2 and Energy Plus simulation engine. The simulation modeling can produce multiple outputs. The maximum EUI value was obtained and then compared with the applicable ASHRAE and SNI standards. Table 2 presented the material characteristics based on the existing data and Table 3 displayed the material characteristics after retrofitting was conducted.

Table 2. Material characteristics of the Existing Building

Building Material	Types	Thickness (mm)	Heat transfer coefficient (U) (W/m2.K)	Solar Heat Gain Coefficient
Roof	Multiroof/zink	375	5728.57	-
Wall	Light brick	150	5.5102	-
Floor	Ceramics	210	4.8382	-
Ceiling	2’ x 4’ ACT System	57.2	3. 5906	-
Window glass	1/2 in Pilkington single glazing	5	6.2426	0.81

Table 3. Material characteristics After Retrofitting

Building Material	Types	Thickness (mm)	Heat transfer coefficient (U) (W/m^2.K)	Solar Heat Gain Coefficient
Roof	Multiroof/zink	375	5728.57	-
Wall	Light brick	150	5.5102	-
Floor	Ceramics Floor	210	4.8382	-
Ceiling	2' x 4' ACT System	57.2	3.5906	-
Window glass	Large double-glazed windows (reflective coating)	60	2.914	0.13

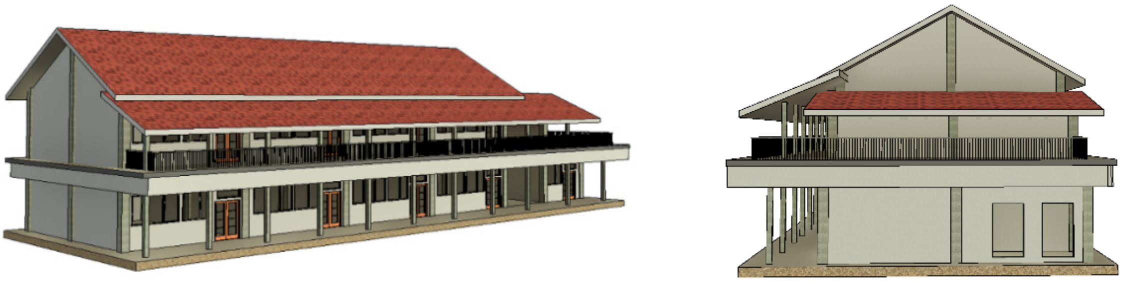

(a) (b)

Figure 1. 3D Perspective (a) from North, (b) from West

Table 4. Total Area of computer lab (m^2)

Location	Air-conditioned room area (m^2)	Non-AC Room Area (m^2)	Total Floor Area (m^2)
1st floor	285.20	120.15	405.35
2nd Floor	261.20	96.96	358.16
Total	546.40	217.12	763.52

In order to overview the energy consumption under different scenarios, several scenarios were developed by modifying some variables such as using renovation designs and other scenario combinations. All scenarios were performed to determine the best model with maximum energy efficiency.

4. Results and Discussion

This study was conducted at the SMKN 2 Palembang, a vocational high school located in Palembang City, Indonesia. The school was founded in 1957 and has an area of 4.53 Ha, consisting of eleven different engineering majors. Each department has a building that is used as a workshop/laboratory. The computer engineering program is one of the departments in the school of SMKN 2 Palembang and has the biggest computer laboratory compared to the other departments. The energy audit was performed at the computer laboratory building to determine the Energy Use Intensity (EUI) and then compared the results with the EUI benchmark of Indonesian Standard for educational buildings.

The reason to conduct the energy audit in this building is because the computer lab produced the highest energy consumption compared to the other buildings. This building is mostly used for students' purposes and is commonly used for the civil servants entrance examination program in the South Sumatra Province. Figure 1 also shows 3D building perspectives viewed from the North and West side.

The analysis was performed by calculating the EUI value of rooms with air conditioning (AC). Before calculating the EUI, it is necessary to calculate the areas of the building both served by AC and not served by AC on each floor. This building consists of two floors with a total building area about 750.59 square meters as seen in Table 4. The first floor has a total area 405.35 m^2 and the second floor has 358.16 m^2. The total area for rooms with air conditioning is 546.40 m^2, while those not served by AC are 217.12 m^2.

The EUI was estimated for each floor by collecting data on the electrical equipment installed in the room along with the installed power capacity in Watt-hours. Based on the observation and measurement, the load types for each floor were divided into 3 types: 1) lighting 2) heating, ventilation, and air-conditioning (HVAC), and 3) electrical equipment (appliances). Table 5 and Table 6 presented the load types for each floor along with value of total power produced or total energy consumed. The total energy consumed was calculated by multiplying the number of units used for each item of electrical equipment, power used and duration of energy consumption.

Table 5. Load Types for First Floor

Load Type		Description	Unit Number	Power (Watt)	Duration of Use (Hours)	Total Energy (Watt)	Room Type
(1)		(2)	(3)	(4)	(5)	(6 = 3x4x5)	
1	Lighting	LED light	4	40	9	1,440	Lab. 1
		LED light	4	40	9	1,440	Lab. 2
		LED light	4	40	9	1,440	Lab. 3
		LED light	5	40	9	1,800	Teacher room
		LED light	1	40	9	360	Counseling room
		LED light	2	40	9	720	WC
		LED light	8	40	9	2,880	Terrace
					Total =	**10,080**	
2	HVAC	AC (2PK)	2	1,920	9	34,560	Lab. 1
		Fan	5	85	9	3,825	Lab. 1
		AC (2PK)	2	1,920	9	34,560	Lab. 2
		Fan	5	85	9	3,825	Lab. 2
		AC (2PK)	2	1,920	9	34,560	Lab. 3
		Fan	5	85	9	3,825	Lab. 3
		AC (2PK)	2	1,920	9	34,560	Teacher room
		Fan	2	85	9	1,530	Teacher room
		AC (2PK)	1	1,920	9	17,280	Counseling room
		Fan	1	85	9	765	Counseling room
					Total =	**169,290**	
3	Electronic Equipment	Computer	2	450	9	8,100	Lab. 1
		Laptop	17	60	9	9,180	Lab. 1
		Projector	1	100	5	500	Lab. 1
		Printer	1	50	5	250	Lab. 1
		Computer	2	450	9	8,100	Lab. 2
		Laptop	17	60	9	9,180	Lab. 2
		Projector	1	100	5	500	Lab. 2
		Printer	1	50	5	250	Lab. 2
		Computer	2	450	9	8,100	Lab. 3
		Laptop	17	60	9	9,180	Lab. 3
		Infocus	1	100	5	500	Lab. 3
		Printer	1	50	5	250	Lab. 3
		Computer	1	450	9	4,050	Teacher room
		Laptop	11	60	5	3,300	Teacher room
		Projector	1	100	5	500	Teacher room
		Printer	1	50	5	250	Teacher room
		Computer	1	450	9	4,050	Counseling room
		Laptop	1	50	5	250	Counseling room
					Total =	**66,490**	
Total (1+2+3)						**245,860**	

Table 6. Load Types for Second Floor

Load Type		**Description**	**Unit Number**	**Power (Watt)**	**Duration of Use (Hours)**	**Total Energy (Watt)**	**Room Type**
(1)		(2)	(3)	(4)	(5)	(6 = 3x4x5)	
1	Lighting	LED light	6	60	9	3,240	Lab. 4
		LED light	6	60	9	3,240	Lab. 5
		LED light	6	60	9	3,240	Lab. 6
		LED light	6	60	9	3,240	Teacher room
		LED light	8	40	9	2,880	Terrace
					Total =	**15,840**	
2	HVAC	AC (2PK)	2	1,920	9	34,560	Lab. 4
		AC (2PK)	2	1,920	9	34,560	Lab. 5
		AC (2PK)	2	1,920	9	34,560	Lab. 6
		AC (2PK)	2	1,920	9	34,560	Teacher room
		Fan	1	85	9	765	Teacher room
					Total =	**139,005**	
3	Electronic Equipment (appliance)	Computer	23	450	9	93,150	Lab. 4
		Projector	1	100	5	500	Lab. 4
		Printer	1	50	5	250	Lab. 4
		Computer	23	450	9	93,150	Lab. 5
		Projector	1	100	5	500	Lab. 5
		Printer	1	50	5	250	Lab. 5
		Computer	23	450	9	93,150	Lab. 6
		Projector	1	100	5	500	Lab. 6
		Printer	1	50	5	250	Lab. 6
		Computer	4	450	9	16,200	Teacher room
		Projector	1	100	5	500	Teacher room
		Printer	1	50	5	250	Teacher room
		Laptop	13	60	5	3,900	Teacher room
					Total =	**302,550**	
Total (1+2+3)						**457,395**	

The LED lights were commonly used for lighting since LED was considered to be more economical and efficient than incandescent light bulbs. In addition, AC using 2 PK (1 PK horse power = 9,000 BTU) and fans are the types of electronic devices for HVAC used in this building. Other electronic equipment in the laboratory comprised of personal computers, laptops, in-focus, projectors, and printers. The total energy consumption for the first floor consists of lighting (10,080 watts), HVAC (169,290 watts)), and electronic equipment (66,490 watts). Meanwhile for the second floor, lighting (15,840 watts), HVAC (139,005 watts), and electronic equipment (302,550 watts). The average computer usage in a day was approximately 9 hours from Monday to Saturday and the number of effective days in a month was 26 days. The total energy consumed per day for the first floor was around 245,860 watts and 457,395 watts for the second floor. Since the operation days per month were just 26 days, the total consumptions were 6,393,360 watts per month or 6,392 kWh/month. The energy consumptions for the second floor were 11,892,270 watts per month or 118,892 kWh/month.

The distribution of the loads for each floor can be seen in Figure 2. HVAC dominated for about 69% of the total energy consumption for the first floor, whereas electronic appliances contributed the highest proportion for about 66%.

Figure 2. Distribution of load types for the first and second floor

Table 7. EUI Average air-conditioned room

Location	Total area (m^2)	Air-conditioned area (m^2)	Energy Consumption (Watt/day)			Total Energy (Watt Per day)	Total Energy (kWh/ month)	EUI (kWh/m^2/month)
			Lighting	HVAC	Electronic Equipment			
1st floor	405.35	285.20	10,080	169,290	66,490	245,860	6,392	22.43
Second Floor	358.16	261.20	15,840	139,005	302,550	457,395	11,892	45.56
Total	763.52	546.40	19,440	308,295	369,040	**Average =**		**33.99**

In order to determine the EUI value for each floor, the total energy consumption per month was divided into the total area in square meters which represented the room with AC only. It was found that the EUI for the first floor was 22.43 kWh/m^2/month, while the second floor was about 45.56 kWh/m^2/month. Based on the EUI values for each floor, the average EUI can be calculated as the summation of EUI divided by 2. Therefore, the average EUI was 33.99 kWh/m^2/month as seen in Table 7.

$$EUI(1) \ = \frac{Pk}{A} = \frac{6393}{285.20} = 22.43\ kWh/m^2/month$$

$$EUI(2) = \frac{Pk}{A} = \frac{11,892}{261.20} = 45.56\ kWh/m^2/month$$

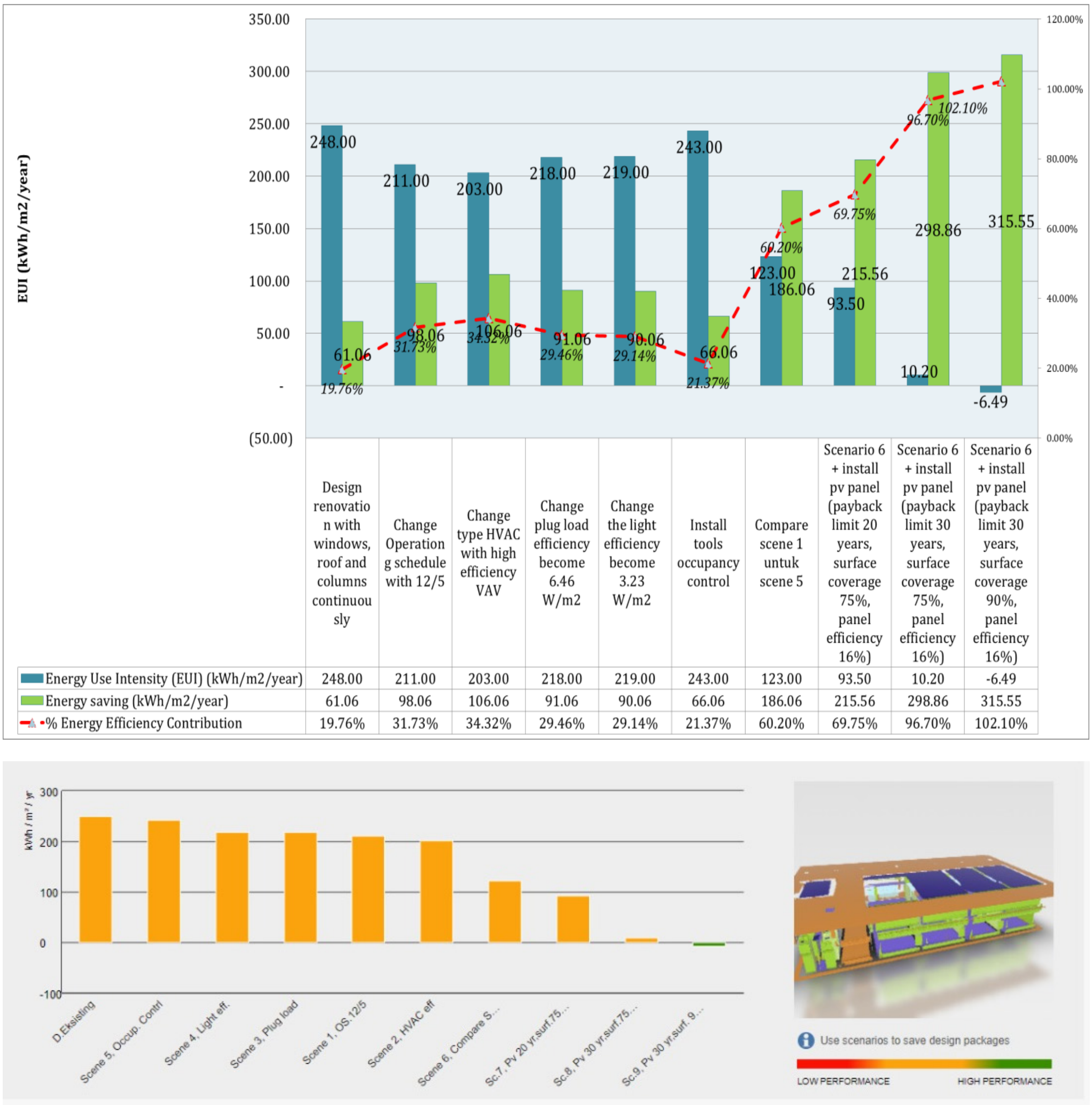
By comparing the average value of EUI (33.99 kWh/m^2/month) to the national standard for building guidelines, the computer laboratory can be classified as a very inefficient building in terms of energy consumption. The category of very inefficient building is/lie within the range of 23.75 – 37.50 kWh/m^2/month of energy consumption.

In this study, EUI calculations were carried out in two ways. First, the electrical data used in the building was calculated and then compared with the SNI 03-6196-2000 standard. Secondly, a 3D model was developed by redrawing the building object using the BIM Revit application which follows the ASHRAE 90.1 benchmark standards. Revit Insight 360 was used to simulate the data and calculate the electrical energy consumption using the SNI 03-6169-2000 guidelines and using ASHARE 90.1 benchmarks.

The renovation designs were suggested to improve the energy performance by developing different scenarios. Figure 3 presented the view of the building before and after the renovation designs suggested. In this paper, 9 scenarios were developed as presented in Figure 4 and Table 8. The renovation designs were made by changing the facade of the building, beginning with changing the shape of the roof, making windows wider and higher, and adding continuous columns from bottom to top to support the roof. The result indicates that the EUI value is around 248 kWh/m^2/year, 61.06 kWh/m^2/year for total energy savings and 9.76% for energy efficiency.

Before Renovation	After Renovation
	

Figure 3. Building views before and after renovation design



	Design renovation with windows, roof and columns continuously	Change Operationg schedule with 12/5	Change type HVAC with high efficiency VAV	Change plug load efficiency become 6.46 W/m2	Change the light efficiency become 3.23 W/m2	Install tools occupancy control	Compare scene 1 untuk scene 5	Scenario 6 + install pv panel (payback limit 20 years, surface coverage 75%, panel efficiency 16%)	Scenario 6 + install pv panel (payback limit 30 years, surface coverage 75%, panel efficiency 16%)	Scenario 6 + install pv panel (payback limit 30 years, surface coverage 90%, panel efficiency 16%)
🟦 Energy Use Intensity (EUI) (kWh/m2/year)	248.00	211.00	203.00	218.00	219.00	243.00	123.00	93.50	10.20	-6.49
🟩 Energy saving (kWh/m2/year)	61.06	98.06	106.06	91.06	90.06	66.06	186.06	215.56	298.86	315.55
% Energy Efficiency Contribution	19.76%	31.73%	34.32%	29.46%	29.14%	21.37%	60.20%	69.75%	96.70%	102.10%

Figure 4. Energy Consumption and Energy Savings based on different scenarios

Based on the renovation designs, 9 scenarios were developed to measure the amount of potential energy savings generated by the building using the Insight 360 web-based energy analysis tool. Scenario 1 was developed by changing the operating schedule from 12/6 to 12/5, indicating 12 hours in 5 days. Scenario 1 resulted in an EUI value of 211.00 kWh/m^2/year with an energy efficiency of 31.73%. The second scenario was to change the cooling system that previously used Split AC to a VAV central AC type with high efficiency for educational buildings, resulting in an EUI value of 203.00 kWh/m^2/year and 34.23% for energy efficiency. The third scenario was that the building served with electrical equipment with a high efficiency up to 6.46 W/m^2, resulting in an EUI value of 218.00 kWh/m^2/year and 29.46% of energy efficiency.

In the fourth scenario, the building was served with special energy-efficient lighting equipment and had a high efficiency up to 3.23 W/m^2, resulting in an EUI of 219.00 kWh/m^2/year with a total energy efficiency of 29.14%. In the fifth scenario, the building was installed with light sensors from outside and occupancy control resulting in an EUI value of 243.00 kWh/m^2/year and an energy efficiency of 21.37%. The sixth scenario was a combination of scenarios 1 through scenario 5, which had an EUI value of 123.00 kWh/m^2/year with an energy efficiency of 60.20%. The seventh scenario was that the building was installed with solar panels with a time limit of 20 years, and 75% of surface coverage resulting in the EUI value of 93.50 kWh/m^2/year and an energy efficiency of 69.75%. In the eighth scenario, the building was installed with solar panels with a time limit of 30 years and a surface coverage of 75%, producing an EUI value of 10.20 kWh/m^2/year and an energy efficiency of 96.70%. In the last scenario, the building was installed with solar panels with a time limit of 30 years, and 90% of surface coverage, and the resulting EUI is -6.49 kWh/m^2/year with an energy efficiency of 102.10%.

Table 8. Energy Use Intensity and Energy Efficiency based on Scenario Development

No	Scenario Development	Variables	Existing variables	Energy Use Intensity (EUI) (kWh/m^2/year)	Energy saving (kWh/m^2/year)	Energy Efficiency (%)
1	Existing building	Design before renovation	Existing building	309	0.00	0%
2	Renovation design	Design renovation with windows, roof and columns continuously	-	248	61.06	19.76%
3	Scenario 1	Change Operation schedule with 12/5	Operation 12/6	211	98.06	31.73%
4	Scenario 2	Change type HVAC with high efficiency VAV	AC Split	203	106.06	34.32%
5	Scenario 3	Change plug load efficiency become 6.46 W/m^2	13.99 W/m^2	218	91.06	29.46%
6	Scenario 4	Change the light efficiency become 3.23 W/m^2	11.84 W/m^2	219	90.06	29.14%
7	Scenario 5	Install tools daylight and occupancy control	No installation	243	66.06	21.37%
8	Scenario 6	Combination scene 1 until scene 5	-	123	186.06	60.20%
9	Scenario 7	Combination Scenario 6 + install pv panel (payback limit 20 years, surface coverage 75%, panel efficiency 16%)	-	93.5	215.56	69.75%
10	Scenario 8	Combination Scenario 6 + install pv panel (payback limit 30 years, surface coverage 75%, panel efficiency 16%)	-	10.2	298.86	96.70%
11	Scenario 9	Combination Scenario 6 + install pv panel (payback limit 30 years, surface coverage 90%, panel efficiency 16%)	-	-6.49	315.55	102.10%

An EUI value of -6.49 kWh/m^2/year indicated that there was almost no energy consumed. This building scenario could provide energy export and save the energy excess. This may be caused by the decrease in building energy and the installation of photovoltaic panel devices that can produce energy. The building based on this scenario was classified as an energy efficient building with high performance and can save energy, if needed, at any time. Thus, it can be concluded that the ninth scenario produced the best scenario with the least amount of energy consumption. This also implies that the EUI values based on the simulation were much lower than the existing EUI calculated based on the equation 1. It can also be concluded that there was a significant improvement on the energy use reduction and a substantial increase for energy savings under different renovation design scenarios. The renovation designs could significantly improve potential energy savings. Insight 360 results can be used as a temporary reference for preliminary design because they allow the analysis of building models quickly and accurately. However, the drawback is that not all design factors can be used in Indonesia because there are variables such as wall/roof seal that are not the same as those provided in Insight 360. Finally, the results will help decision makers identify the potential for energy savings in all energy-consuming facilities and equipment in the building as well as develop strategies to save energy.

5. Conclusions

This study aims to investigate the energy consumption of an existing educational building located in Palembang as compared to the benchmark of Indonesian Standard for educational buildings. The research was conducted in Palembang by utilizing a two-story educational building to determine the value of Energy Use Intensity (EUI) and then to compare the results to the benchmark. It was found that HVAC dominated for about 69% of total energy consumption for the first floor, whereas electronic appliances contributed the highest proportion for about 66% for the second floor. The EUI value for the first floor was 22.43 kWh/m^2/month, while the second floor was about 45.56 kWh/m^2/month, resulting in an average EUI around 33.99 kWh/m^2/month. The building was then classified as a very inefficient building in terms of energy consumption. The renovation designs were then suggested to improve the energy performance by developing 9 different scenarios.

The last scenario in which the building installed with solar panels with a time limit of 30 years and 90% of surface coverage produced the EUI value -6.49 kWh/m^2/year with an energy efficiency of 102.10%. This building scenario could provide energy export and save energy excess. This was influenced by the decrease in building energy and the installation of photovoltaic panel devices that can produce energy. The building based on this scenario was classified as an energy efficient building with high performance and able to save energy if needed at any time. Thus, it can be concluded that the ninth scenario produced the best scenario with the least energy consumption. This also implies that EUI values based on the simulation were much lower than the existing EUI calculated based on equation 1. Thus, it can be concluded there was a significant improvement in energy use reduction and a substantial increase for energy savings under renovation design scenarios. The renovation designs could significantly improve potential energy savings. Insight 360 results can be used as a temporary reference for preliminary design because it allows the analysis of building models quickly and accurately. However, the drawback is that not all design factors can be used in Indonesia because there are variables such as wall/roof seal that are not the same as those provided in Insight 360. Finally, the results will help the decision makers identify the potential for energy savings in all energy-consuming facilities and equipment in the building as well as develop strategies for energy conservation.

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