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Analysis of Energy-Saving Opportunities at SMKN 3 Kuningan

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ABSTRACT

This research presents the results of an energy audit at SMKN 3 Kuningan, which aims to identify energy saving opportunities in the school's electrical system. The audit focused on two main energy consumption systems, lighting and air conditioning (AC). The analysis was conducted based on electricity consumption data and Energy Consumption Intensity (IKE) standards. The results show that the lighting system still uses conventional TL and incandescent lamps, which waste energy. Replacing with energy-saving LED lamps can save around 571 kWh per month. In addition, the AC units used mainly have low efficiency. Replacing with energy-saving AC and adjusting operating hours results in additional savings of 5,718.29 kWh per month. Overall, the school has the potential to reduce electricity consumption by 6,289.29 kWh per month. The implementation of this recommendation is also able to reduce the IKE value from 105,321 kWh/m²/year to 103,924 kWh/m²/year, closer to the national efficiency standard according to SNI 03-6197-2000 and the regulations of the Ministry of Energy and Mineral Resources. This research emphasizes the importance of regular energy audits in educational institutions as a strategic step in operational cost efficiency and contribution to environmental sustainability.

1. Introduction

The increasing demand for electrical energy in educational environments is driven by the growing use of electronic devices in daily activities. Classrooms, laboratories, and administrative offices rely heavily on lighting systems, air conditioning, and other devices to create a comfortable and productive learning environment. However, this dependency often leads to energy waste if not managed efficiently, ultimately increasing operational costs.

In this research, energy audits in educational buildings, such as those conducted at SMKN 2 Pontianak and Politeknik Negeri Semarang, are highly relevant because they found that lighting and air conditioning systems contribute significantly to energy consumption [1] [2]. Additionally, analysing power quality in government buildings provides deeper insights into energy management in educational institutions [3].

As a solution to this issue, energy audits have become an essential tool for identifying inefficiencies within a building's electrical system. By analysing energy usage patterns and comparing them with national standards like the Energy Consumption Intensity (IKE), institutions can identify opportunities to reduce waste and improve energy efficiency.

Based on SNI 03-6197-2000 [4], which regulates energy conservation for lighting systems, and SNI 03-6390-2000 [5], which governs air conditioning systems in buildings, various energy-saving strategies can be implemented without compromising comfort. SMKN 3 Kuningan, as a vocational school, has experienced a 24.39% increase in electricity bills over the past three months.

This situation highlights the need for an energy audit, especially on the two major energy-consuming systems: lighting and air conditioning (AC) (figure 1). Air conditioning systems in educational buildings are known to be a major contributor to excessive energy consumption [6].

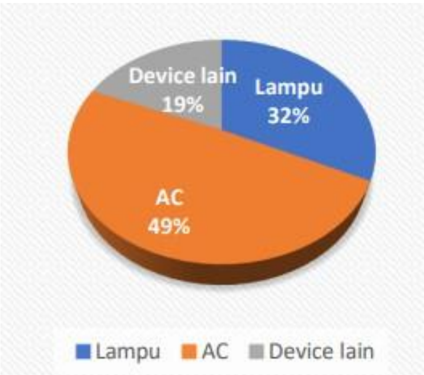

Figure 1: Power consumption of electrical devices.

These two systems significantly contribute to the total electricity consumption in schools, with 32% coming from lighting and 49% from air conditioning (AC). This research refers to SNI 03-6197-2000 to identify energy-saving strategies that can be implemented without reducing comfort and effectiveness in schools' teaching and learning process.

Energy-saving through the use of energy-efficient lighting (LED) and more efficient air conditioning systems are steps identified in various studies, such as those conducted at Universitas Diponegoro and in office and residential buildings [7] [8]. These strategies are highly relevant to efforts to reduce energy consumption that can be implemented at SMKN 3 Kuningan. The energy audit aims to identify areas of energy waste and implement energy-saving strategies per SNI standards, as outlined in the research [9]. These steps are expected to reduce energy waste and lower school operating costs while ensuring comfort and the effectiveness of the learning environment.

2. Methods

The quantitative approach is applied by collecting measurable data related to the use of electrical energy. Through the implementation of an energy audit process that is systematically arranged as described in the figure 2.

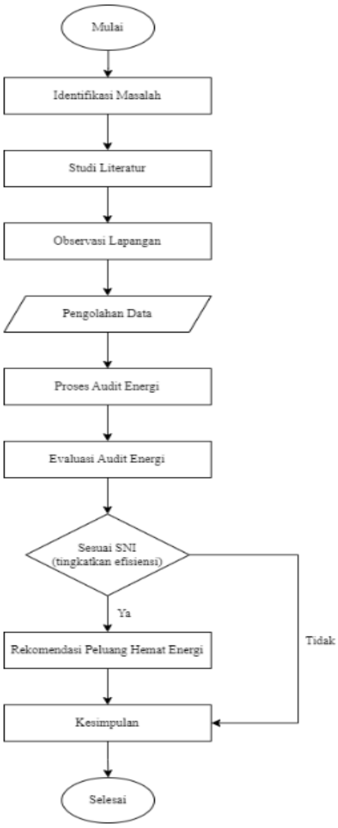

Figure 2: Flowchart of research.

The research objectives and identifying the main problems, the increasing consumption of electrical energy at SMKN 3 Kuningan. A literature review was conducted to understand relevant concepts and standards, such as Energy Consumption Intensity (IKE) and guidelines from SNI 03-6197-2000 and the Ministry of Energy and Mineral Resources (ESDM).

Observations were conducted to assess the actual conditions of energy use in classrooms, laboratories, and administrative offices. Primary data were obtained through direct measurements on the electrical distribution panel, while secondary data included electricity bills, building plans, and technical specifications of electrical equipment.

The collected data is analysed to calculate the actual energy consumption and IKE value. The audit process focuses on the power consumption of the lighting and air conditioning (AC) systems, which are the main contributors to the most significant electrical load. The efficiency level is then evaluated by comparing the IKE value to the national standard. If the calculation results show that IKE exceeds the efficiency limit, then the simulation identifies energy-saving opportunities by comparing the values before and after the simulation.

Preparation of energy-saving recommendations, such as replacing conventional lamps with LED lamps, increasing the efficiency of AC units, and regulating equipment operating times to implement of efficient energy management in educational environments.

2.1. Simulation with DiaLux Evo

This simulation can display the light distribution in each room so that it follows the rules of SNI 03-6197-2000. The time in the simulation is set at night because in the morning or afternoon, it will be helped by natural light.

2.1.1. Headmaster's Room

This room has an area of 69 m2 with 7 light points with a power of 30 watts and 4200 lumens.

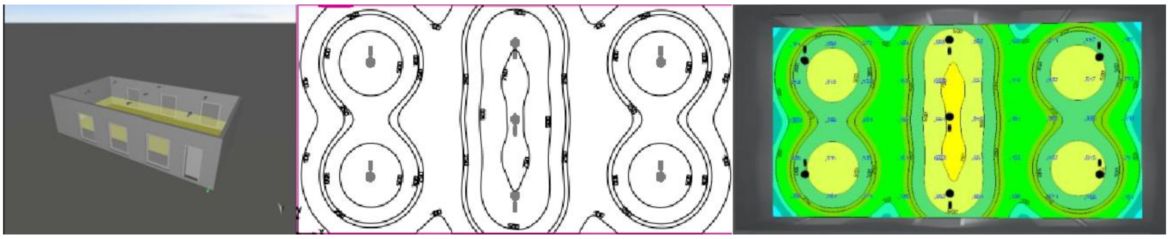

Figure 3: Light distribution of headmaster's room.

Based on the figure 3, the light produced averages 350 Lux according to SNI 03-6197-2000.

2.1.2. Physics Laboratory

This room has an area of 152 m2 with 14 light points with a power of 110 watts and 7249 lumens.

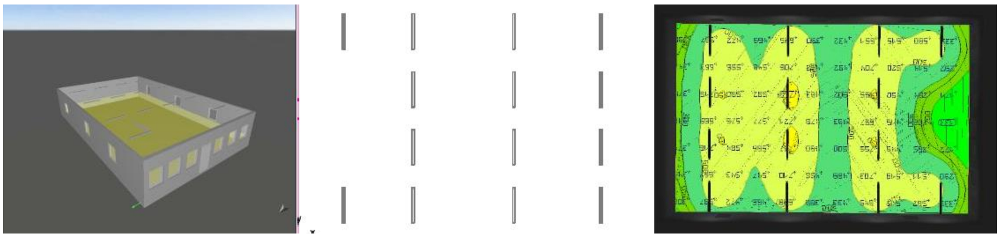

Figure 4: Light distribution of physics laboratory.

Based on the figure 4, the light produced averages 500 Lux according to SNI 03-6197-2000.

2.1.3. Carpenter's Workshop

This room has an area of 144 m2 with 14 light points with a power of 110 watts and 7249 lumens.

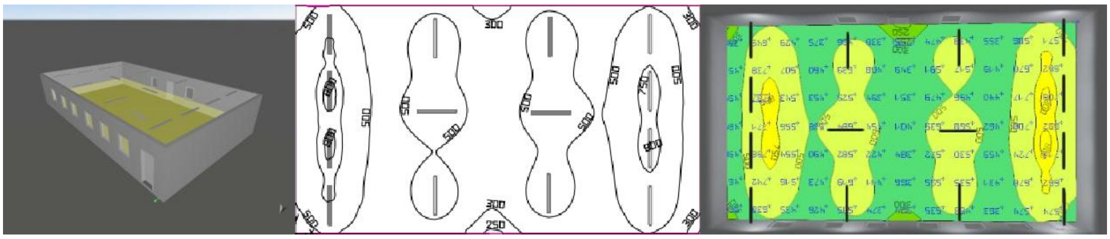

Figure 5: Light distribution of carpenter's workshop.

Based on the figure 5, the light produced averages 510 Lux according to SNI 03-6197-2000.

2.1.4. Chemistry Laboratory

This room has an area of 72 m2 with 14 light points with a power of 72 watts and 4628 lumens.

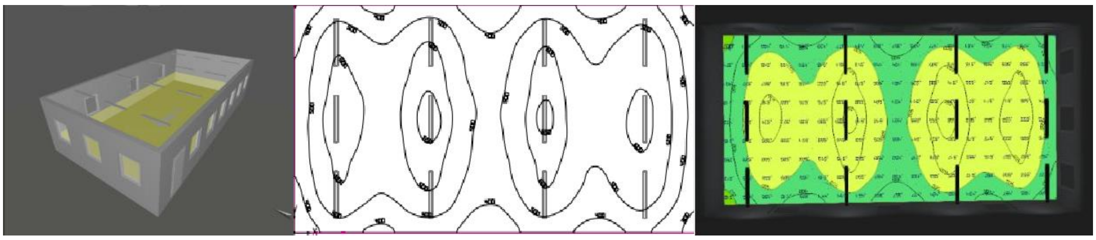

Figure 6: Light distribution of chemistry laboratory.

Based on the figure 6, the light produced averages 510 Lux according to SNI 03-6197-2000.

2.1.5. Computer Laboratory

This room has an area of 152 m2 with 14 light points with a power of 110 watts and 7249 lumens.

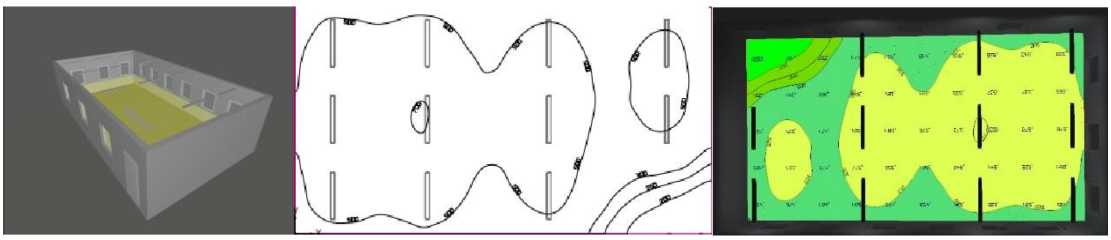

Figure 7: Light distribution of computer laboratory.

Based on the figure 7, the light produced averages 510 Lux according to SNI 03-6197-2000.

2.1.6. Electrical Installation Laboratory

This room has an area of 72 m2 with 12 light points with a power of 72 watts and 4628 lumens.

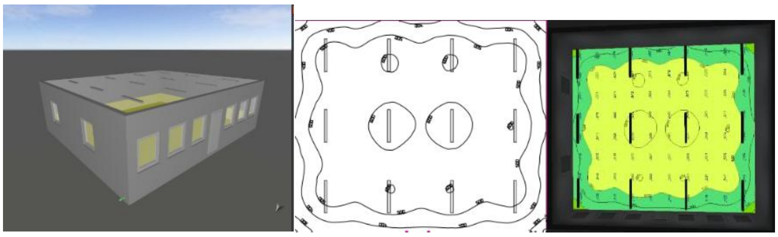

Figure 8: Light distribution of electrical installation laboratory.

Based on the figure 8, the light produced averages 510 Lux according to SNI 03-6197-2000.

2.1.7. Motorbike Workshop

This room has an area of 72 m2 with 12 light points with a power of 72 watts and 4628 lumens.

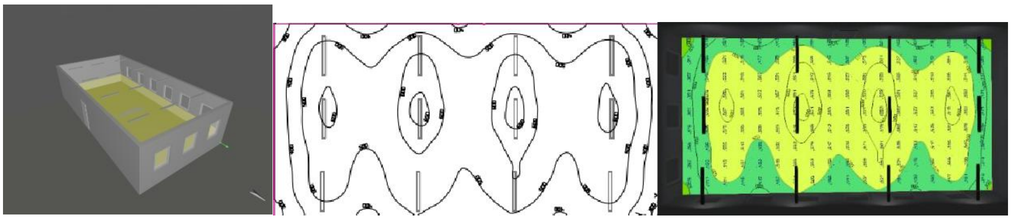

Figure 9: Light distribution of motorbike workshop.

Based on the figure 9, the light produced averages 510 Lux according to SNI 03-6197-2000.

2.1.8. Multimedia Room

This room has an area of 72 m2 with 11 light points with a power of 72 watts and 4628 lumens.

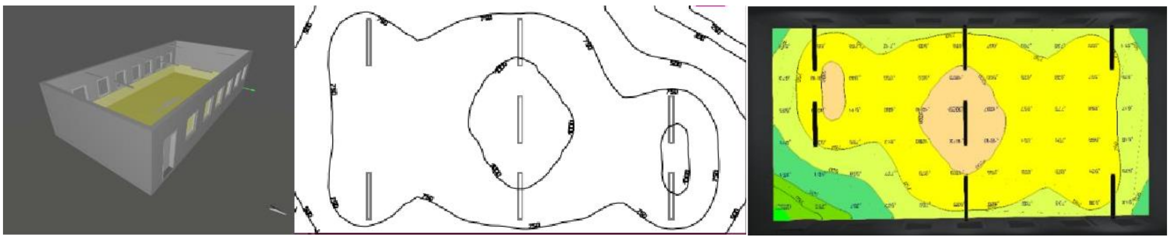

Figure 10: Light distribution of multimedia room.

Based on the figure 10, the light produced averages 510 Lux according to SNI 03-6197-2000.

2.1.9. Drawing Room

This room has an area of 24 m2 with 5 light points with a power of 9 watts and 802 lumens.

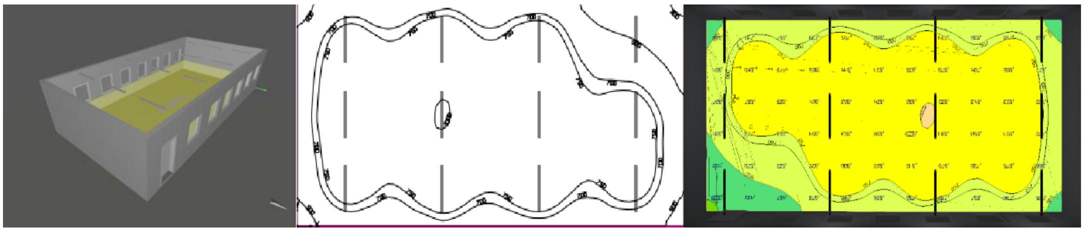

Figure 11: Light distribution of drawing room.

Based on the figure 11, the light produced averages 751 Lux according to SNI 03-6197-2000.

2.1.10. Office Room

This room has an area of 72 m2 with 11 light points with a power of 23 watts and 2997 lumens.

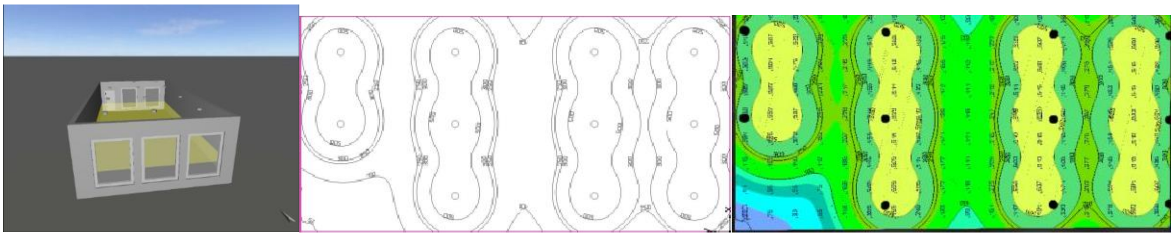

Figure 12: Light distribution of office room.

Based on the figure 12, the light produced averages 360 Lux according to SNI 03-6197-2000.

2.1.11. Classroom

This room has an area of 72 m2 with 6 light points with a power of 19 watts and 1110 lumens.

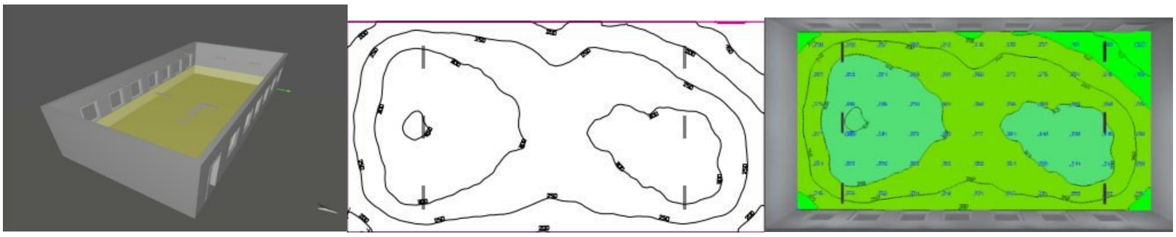

Figure 13: Light distribution of classroom.

Based on the figure 13, the light produced averages 255 Lux according to SNI 03-6197-2000.

2.1.12. Meeting Room

This room has an area of 195 m2 with 23 light points with a power of 23 watts and 3198 lumens.

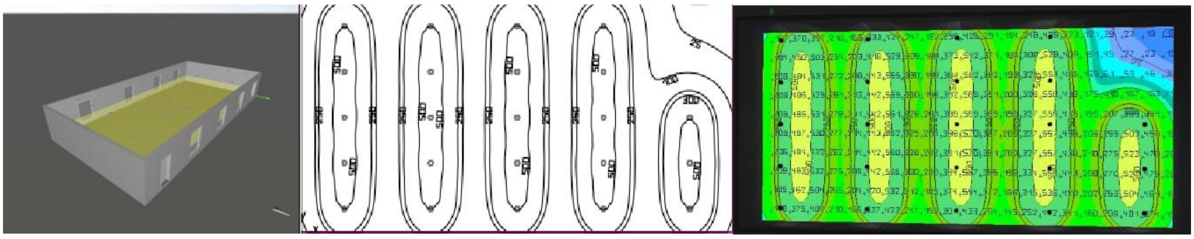

Figure 14: Light distribution of meeting room.

Based on the figure 14, the light produced averages 308 Lux according to SNI 03-6197-2000.

2.1.13. Toilet

This room has an area of 16 m2 with 2 light points with a power of 23 watts and 3198 lumens.

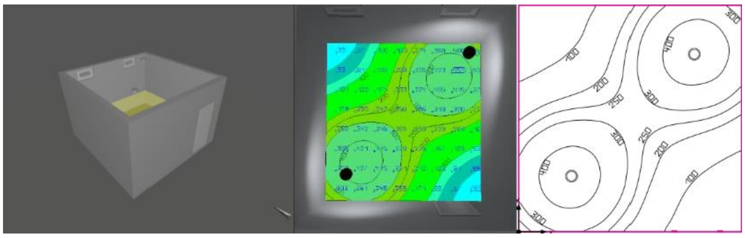

Figure 15: Light distribution of toilet.

Based on the figure 15, the light produced averages 250 Lux according to SNI 03-6197-2000.

2.1.14. Generator and Water Pump Room

This room has an area of 24 m2 with 5 light points with a power of 9 watts and 802 lumens.

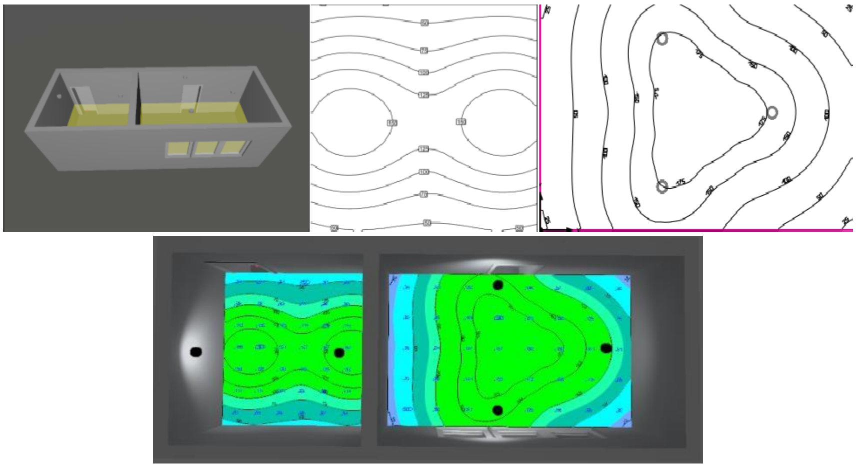

Figure 16: Light distribution of generator and water pump room.

Based on the figure 16, the light produced averages 106 Lux according to SNI 03-6197-2000.

3. Results and Discussion

3.1. Results

This research provides a comprehensive overview of actual energy consumption and potential savings that can be achieved by optimizing lighting and air conditioning (AC) systems. Measurement results, field observations, and technical simulations are used to formulate realistic energy efficiency strategies.

3.1.1. Lighting System

Table 1: Energy on Lighting System used before.

Location	Load	Qty.	Load Power (Watt)	Total Power (Watt)	Time (Hours)	Energy Used (kWh)
Staffroom's Panel	TL Lamp	350	24	10800	12	129,6
	Spotlight Lamp	20	100	6000	10	60
	TL Lamp Surface	150	36	432	12	5,184
Workshop's Panel	TL Lamp	150	24	4584	13	59,52
	TL Lamp Surface	80	36	720	14	10,8
Generator's Panel	TL Lamp	24	24	576	12	6,91
Laboratory's Panel	TL Lamp	200	24	5568	12	66,86
	TL Lamp Surface	25	36	900	12	10,8
Total				29580		349,674

Table 2: Energy on lighting system used after.

Lamp	Power (Watt)	Lamp Qty.	Total Power	Time (Hours)	Energy Used (kWh)
LED Philips Coreline Trunking Gen2	72	102	7.344	12	88,128
LED Philips Luxspace 2 Downlight	30	7	210	12	2,52
Philips Lineco TL	110	28	3.080	12	36,96
LED Philips Lifemax TL	19	180	3.420	12	41,04
LED Philips Magneos Downlight	9	7	63	12	0,756
LED Philips Essential Downlight	23	66	1.518	12	18,216
LED Philips Lifemax	36	14	504	12	6,048
LED Philips Spotlight	100	20	2.000	12	24
LED Philips Sitrang Helix	55	10	550	12	6,6
Total Power used			18.689		224,268

Table 3: Comparing total energy used in lighting system.

Buildings	Power Before (Watt)	Energy Used Before (kWh)	Power After (Watt)	Energy Used After (kWh)
Staffroom	13.532	194,784	9.444	113,328
Workshop	6.480	70,32	2.129	25,548
Laboratory	5.700	77,66	6.081	72,972
Generator	252	6,91	45	0,54
Total	25.964	349,674	18.689	224,268

Energy savings of lamps by replacing units from the simulation results per day are obtained around 224,268 kWh, while the total amount of all kWh before the savings are made is 349,674 kWh. Therefore, the calculation is as follows:

$$= \sum Energy\,used - \sum Energy\,saving \quad (1)$$
$$= \sum 349{,}674\ kWh - \sum 224{,}268\ kWh \quad (2)$$
$$= 125{,}406\ kWh \quad (3)$$

From the calculation, the energy used for one day is 125,406 kWh. This method has proven effective for long-term savings.

3.1.2. Air conditioning System

Table 4: Energy on air conditioning system used before.

Rooms	Brand	Power (Watt)	PK	Qty.	Total Power (Watt)	Time (Hours)	Energy Used (kWh)
Office Room	Sharp	701	1	2	1.402	5	7,01
Headmaster's Room	Panasonic	718	1	1	718	3	2,154
Staffroom	Daikin	958	1 ½	2	1.916	6	11,496
Committee Room	Sharp	701	1	1	701	3	2,103
Counselling Room	Daikin	958	1 ½	1	958	3	2,874
Meeting Room	Daikin	1901	2	2	3.802	6	22,812
Physics Lab.	Daikin	980	1 ½	4	3.920	6	23,52
Chemistry Lab.	Daikin	980	1 ½	2	1.960	6	11,76
Computer Lab.	Panasonic	638	1	8	5.104	6	30,624
Electrical Installation Lab.	Panasonic	638	1	6	3.828	6	22,968
Industrial Automation Lab.	Daikin	980	1 ½	1	980	6	5,88
	Panasonic	638	1	1	638	6	3,828
Multimedia Room	Midea	698	1	1	698	5	3,47
	Sharp	701	1	1	701	5	3,505
Digital System Room	Daikin	958	1 ½	2	1.916	5	9,58
Drawing Room	Daikin	958	1 ½	1	958	5	4,79
	Sharp	701	1	1	701	5	3,505
Electric Workshop Vehicle	Daikin	950	1 ½	2	1.900	6	11,4
Automation Industrial Room	Panasonic	1450	2	1	1.450	6	8,7
Audio-visual Room	Daikin	950	1 ½	2	1.900	6	11,4
Motorbike Room	Daikin	950	1 ½	1	950	6	5,7
Lobby	Sharp	701	1	1	701	6	4,206
Library	Daikin	958	1 ½	2	1.916	5	9,58
Total Power					39.718		222,865

Table 5: Energy on air conditioning system used after.

Rooms	Brand	Power (Watt)	PK	Qty.	Total Power (Watt)	Time (Hours)	Energy Used (kWh)
Office Room	Sharp	701	1	2	1.402	3	4,206
Headmaster's Room	Panasonic	718	1	2	1.436	1	1,436
Staffroom	Daikin	958	1 ½	2	1.916	3	5,748
Committee Room	Sharp	701	1	2	1.402	1	1,402

Counselling Room	Sharp	701	1	1	701	1	0,701
Meeting Room	Daikin	1901	2	2	3.802	3	11,406
Physics Lab.	Daikin	980	1 ½	2	1.960	4	7,84
Chemistry Lab.	Daikin	920	1 ½	2	1.840	4	7,36
Comupter Lab.	Daikin	930	1 ½	8	7.440	4	29,76
Electrical Installation Lab.	Daikin	890	1 ½	6	5.340	4	21,36
Industrial Automation Lab.	Daikin	980	1 ½	2	1.960	3	5,88
Multimedia Room	Daikin	930	1½	2	1.860	3	5,58
Digital System Room	Daikin	958	1½	2	1.916	3	5,748
Drawing Room	Daikin	958	1½	2	1.916	3	5,748
Electric Workshop Vehicle	Daikin	950	1½	2	1.900	3	5,7
Automation Industrial Room	Sharp	950	1½	2	1.900	3	5,7
Audio-visual Room	Daikin	950	1½	2	1.900	3	5,7
Motorbike Room	Daikin	950	1½	2	950	3	2,85
Lobby	Sharp	701	1	1	701	1	0,701
Library	Daikin	1901	2	2	3.802	1	3,802
Total Power					**45.990**		**138,628**

Table 6: Comparing total energy used in air conditioning system.

Buildings	**Power Before (Watt)**	**Energy Used Before (kWh)**	**Power After (Watt)**	**Energy Used After (kWh)**
Office Room	1.402	7,01	1.402	4,206
Headmaster's Room	718	2,154	1.436	1,436
Staffroom	1.916	11,496	1.916	5,748
Committee Room	701	2,103	1.402	1,402
Counselling Room	958	2,874	701	0,701
Meeting Room	3.802	22,812	3.802	11,406
Physics Lab.	3.920	23,52	1.960	7,84
Chemistry Lab.	1.960	11,76	1.840	7,36
Comupter Lab.	5.104	30,624	7.440	29,76
Electrical Installation Lab.	3.828	22,968	5.340	21,36
Industrial Automation Lab.	1.618	9,708	1.960	5,88
	1.399	6,975	1.860	5,58
Multimedia Room	1.916	9,58	1.916	5,748
	1.659	8,295	1.916	5,748
Digital System Room	1.900	11,4	1.900	5,7
Drawing Room	1.450	8,7	1.900	5,7
	1.900	11,4	1.900	5,7
Electric Workshop Vehicle	950	5,7	950	2,85
Automation Industrial Room	701	4,206	701	0,701
Audio-visual Room	1.916	9,58	3.802	3,802
Total Energy	39.716	222,865	45.990	138,628

Air conditioning energy savings by recommending unit replacement from the simulation results per day obtained around 222,865 kWh, while the total amount of all kWh before the savings were made was 138,628 kWh. Therefore, the calculation is as follows:

$$= \sum Energy\,used - \sum Energy\,saving \tag{4}$$

$$= \sum 222{,}865\ kWh - \sum 138{,}628\ kWh \tag{5}$$

$$= 84{,}237\ kWh \tag{6}$$

From the calculation, the energy used for one day is 84.237 kWh if accumulated in a whole month to 2,527.11 kWh/month. This method has proven effective for long-term savings.

3.1.3. Total Energy Saving

Energy saving opportunities in the lighting system 3,762.18 kWh/month with recommendations for calculating lighting system by means of DiaLux simulation and reducing usage time. Then recommendations on the air conditioning system produce 2,527.11 kWh with recommendations for replacing AC units according to BTU and reducing operational time in each room.

Total savings obtained from the energy saving:

$$ES\ Lighting\ System\ +\ ES\ Air\ Condition\ System \tag{7}$$

$$= 3.762{,}18\ +\ 2.527{,}11\ =\ 6.289{,}29\ kWh/\ month \tag{8}$$

Energy saving costs :

$$6.289{,}29\ x\ 1.114{,}74\ = 7.010.923{,}11 \tag{9}$$

The initial total IKE is 107,697.2 kWh/month, while the IKE after savings is 6,289.29 kWh/month, which if accumulated in one year, the IKE before savings is 1,292,366.4 kWh/year and the IKE after savings is 75,471.48 kWh/year. So, the total calculation of the IKE difference:

$$\frac{(IKEi) - (IKEa)}{Area\ of\ Buliding} \tag{10}$$

$$= \frac{1.292.366{,}4 - 75.471{,}48}{Area\ of\ Buliding} \tag{11}$$

$$= 103.924\ kWh/m^2/year \tag{12}$$

3.2. Discussion

SMKN 3 Kuningan has significant potential to improve energy efficiency through relatively simple but strategic interventions. Simulation of replacing conventional lamps with LED technology which generally has a longer service life and lower power compared to TL and incandescent lamps is a long- term cost-effective solution and can be implemented without disrupting school operational activities.

By replacing old Air conditioning with energy-efficient inverter types and setting more efficient operating schedules, schools can significantly reduce electricity usage without compromising thermal comfort in classrooms and offices. This adjustment of usage times ensures that ACs only operate during active school hours, so efficiency can be maximized.

The total energy savings of 6,289.29 kWh per month is quite a significant achievement when viewed from the long-term operational cost perspective. This finding emphasizes the importance of conducting periodic energy audits.

4. Conclusion

Based on the results of the energy audit conducted at SMKN 3 Kuningan, the opportunity for energy savings to increase efficiency through electrical device replacement and proper operational schedule management has proven to be very effective. The lighting system with LED lights can save energy by 571 kWh per month. The air conditioning system saves energy by 5,718.29 kWh per month by replacing several old ACs and managing operational schedules. Overall, these savings have the potential to save 6,289.19 kWh per month. In addition to reducing energy consumption, the implementation of this recommendation also reduces the Energy Consumption Intensity (IKE) value from 105,321 kWh/m²/year to 103,924 kWh/m²/year, which is close to the national efficiency standard. The results of this research emphasize the importance of implementing periodic energy audits in educational environments to reduce the operational cost efficiency of electrical devices.

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