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Potential Electrical Saving and Efficiency in Lighting and Cooling Systems in Car Dealership Building

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Abstract

An energy audit is an activity to determine the pattern of energy consumption and consumption to identify various potential energy savings that are feasible and can be carried out legally without compromising comfort and health. The location of the work is the building of the car dealership. Several works are carried out to measure, calculate and analyze data to get the Energy Consumption Intensity or ECI of the building. In the next step of the research, preliminary calculations and analysis are used to look for technical improvement steps to increase the low Energy Consumption Intensity value in certain rooms. The technical improvement steps are then reviewed to obtain the necessary recommendations to achieve a specific efficiency score. The electricity efficiency audited according to the standard is 2,698.65 kWh/ month. High-purity hydrocarbon refrigerant is suggested to use directly to replace synthetic refrigerants in chillers. This refrigerant has various advantages including 20% energy saving, no ozone causing damage, and greenhouse gas effects. Lighting software is used to simulate the number of light points. The advantage of this software is that it not only focuses on the engineering side but also in terms of visualization. By using Lighting software we can simulate a room with lamps that are available in the worldwide lighting industry.

Keywords

Energy Consumption Intensity, Artificial Lighting, Department of Energy and Natural Resources Standards, Lighting Software, Refrigerant Hydrocarbon

INTRODUCTION

An increase in energy consumption in developing countries, especially China and India, accounted for the bulk of global energy consumption growth in recent years, at a rate of 11.37% per year in the last 20 years [1]. However, with the increasing number of electrical devices in the municipality, the consumption of electrical energy is also increasing. This increase in power consumption is not proportional to the power supply of the power plant. To avoid wasting electrical energy[2]. The Ministry of Energy and Natural Resources has issued energy-saving guidelines for buildings that consume large amounts of energy, such as offices, hospitals, supermarkets, and others [3]. Energy audits in buildings are carried out to determine the level of energy consumption and energy-saving opportunities in buildings to increase the efficiency of energy use in the buildings concerned. So that energy use in these buildings becomes more efficient and cost-effective [4]. An energy audit is the process of energy assessment and identification of energy-saving opportunities and recommendations to improve efficiency in a company. An energy audit is the first step toward good energy management. Concrete data on the condition of existing devices in the building or buildings, operating costs for energy requirements, and the energy management used in buildings or buildings are obtained from the electricity bill data [5]. The results of the data can be analyzed and energy-saving opportunities and energy-saving measures can be identified. Energy-saving opportunities are implemented through simulations to determine the extent to which energy savings can be achieved and how much money can be saved. The results of this energy audit are in the form of recommendations that must be made for good energy management to increase efficiency and ultimately reduce the operating costs of electrical energy. The energy audit at PT Nasmoco Majapahit was carried out due to the large number of costs incurred to pay electricity bills before the Covid-19 pandemic and from the results of the Energy Consumption Intensity calculations following ESDM Ministerial Regulation No. 13 of 2012 before the Covid-19 Pandemic, including the wasteful category. The data collected when submitting the thesis is from February 2021 to January 2022, from the Energy Consumption Intensity calculation results, it can be seen that the results are quite efficient, because in this month the electricity bill is quite low and there is still no implementation of homework with it all employees work or carry out activities in the office, Therefore, it is necessary to conduct an energy audit. The audit process includes an audit of the lighting system and an audit of the cooling system, as well as performing a simulation using the software to determine the number of light points needed in each room [6].

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RELATED THEORY

An indicator of whether a structure is suitable for using energy is the Energy Consumption Intensity (ECI). Based on SNI 03-6197-2000 on Energy Conservation in Lighting Systems is a term used to determine the magnitude of energy consumption per square meter [7]. The Energy Consumption Intensity value is important as a benchmark to determine the energy-saving potential that can be used in any room or entire building area. Comparing a building's Energy Consumption Intensity to national standards can usually tell whether a room or the entire building is energy efficient or not. Energy Consumption Intensity (ECI) is the split between energy use and the unit area of the building. Determining the intensity of electrical energy consumption for buildings can use kWh/m² /month or with Equation 1 is used

$$\text{ECI}=\frac{\text{kWh}}{\text{m}^2}=\frac{\text{Total energy consumption (kWh)}}{\text{Total floor area (m}^2\text{)}} \quad (1)$$

The amount of energy consumed by a building expands the conditioned area in a month or a year. The conditioned area is an area where the room temperature is controlled to meet the comfort standard with cool air supplied by the building's air conditioning system as detailed in Figure I.

TABLE I
CRITERIA FOR ENERGY CONSUMPTION INTENSITY FOR AIR-CONDITIONED BUILDINGS ACCORDING TO MINISTER OF ENERGY AND NATURAL RESOURCES NO. 13 OF 2012

Criteria	Index of Energy Consumption Intensity (ECI) (kWh/m2/month)
Excellent	ECI < 8,5
Moderate	8,5 ≤ ECI < 14
Adequate	14 ≤ ECI < 18,5
Wasteful	ECI ≥ 18,5

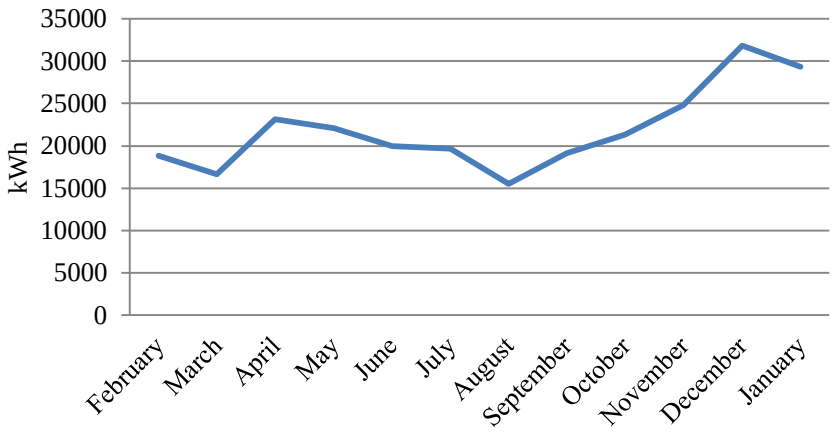

Figure 1. Trend of Electrical Bill of Car Dealership during period of February 2021 - January 2022

From February 2021-January 2022 in Figure 1, the energy released every month varies depending on the use of electricity consumption each month, the largest energy output is obtained in December 2021, which is 31,837 kWh, because the electricity consumption in December 2021 is very large. is the effect of very crowded dealer conditions so that a lot of energy consumption is released, while in August 2021 the energy released is 15,535 kWh, this is due to dealer conditions that are less crowded due to the covid-19 pandemic effect, which affects total energy consumption in February 2021.

PROCEDURE

Energy Audit

An energy audit is a strategy used to determine energy consumption in buildings and find ways to save it. Energy audit activities are regular inspection activities to ensure that energy is used appropriately and effectively. Energy identification is used to find out if there is a leak or wasted energy that can be tracked and then decide on corrective action.

The scope of energy audit activities includes the following as given in Figure 2:

1. Identify energy usage, specifically in terms of energy types, components of energy usage, system usage, and energy costs.
2. Consideration of the use of energy according to the condition of the building and type of use.
3. Knowing where the greatest potential for improving the efficiency of energy use lies.
4. How to improve efficiency. Auditing is defined as the process of evaluating a building in use and identifying opportunities to reduce energy consumption.

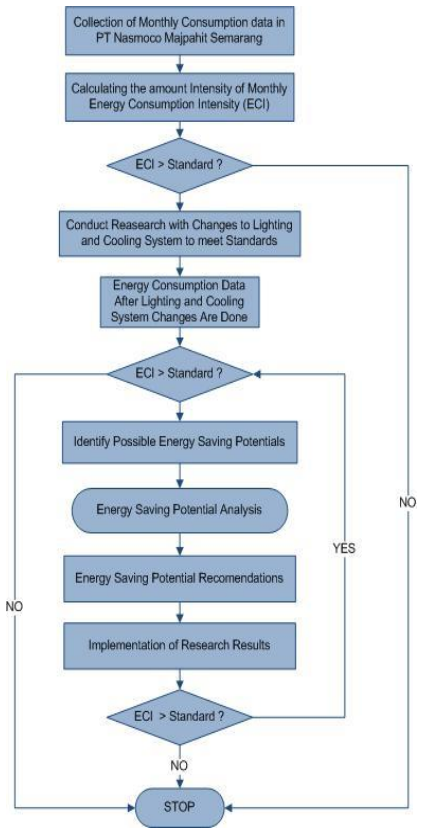

Figure 2. Flow of Energy Audit Activities

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Lighting System

To calculate lighting requirements in the building must pay attention to the following:

1. Safety.
2. Increased accuracy.
3. Good health and a more comfortable atmosphere.

Energy audit lighting systems aim to find out the high level of lighting in a room. The strong level of light in a room must be adapted to the type of activity in the room. If the activity requires high accuracy, the required level of lighting is also greater. Energy audit lighting systems also aim to determine the efficiency of energy consumption for lighting systems in a room as listed in Table II and Table III.

TABLE III
HORIZONTAL ILLUMINATION RECOMMENDATION BASED ON THE NATIONAL STANDARDIZATION AGENCY SNI-03-6197-2000.

Type of Lighting System	Illumination Level (lux)	Place ir Type of Activity
General Lighting for a Room or Area with simple Activities	20	Minimum free area
	30	Warehouse/shop
	50	Car park areas
	75	Dock
	100	Hall
	150	Stock Room
	200	Minimum on work piece
General Lighting for indoor workspace	300	Rough workspace, Machine
	500	motor vehicle assembly office
	750	Office space with special machines.
Additional Information for Illumination type Localized	1000 or Higher	Smooth workspace
	2000 or Higher	Surgery room

TABLE IIIII
MAXIMUM LIGHTING POWER STANDARD OF THE ROOM ACCORDING TO THE NATIONAL STANDARDIZATION AGENCY SNI-03-6197-2000

Location	Maximum Lighting Power Watt/m²
Office room	15
Auditorium	25
Common area	15
Warehouse	5
Garage	2
Ladder	10

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Parking Space	5
Busy Traffic	30
Road Vehicle	1.5
Parking lot	2

The maximum power calculation for each room at Car Dealership can be found with Equation 2 is used.

$$\frac{W}{m2} = \frac{\text{Installed (W)}}{\text{Room Size (m2)}} \quad (2)$$

- Finding the number of light points using software

Software to determine the number of light points is Dialux in Figure 3. The advantage of this software is that it does not only rely on the engineering side, but also in terms of visualization. We can simulate a room using lamps that are available in the world's lighting industry, Therefore the calculation and rendering results will resemble the actual situation. In this software, we can also choose the specifications of the lamps we want, both in terms of light distribution.

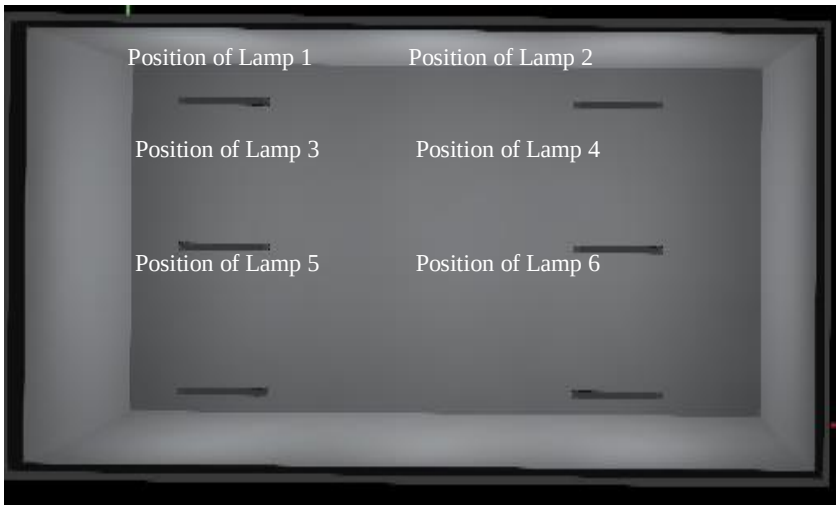

Figure 3. Canteen room Simulation of Using Software to Determine the Number of Light Points Needed in each room.

Cooling System

The calculation of the cooling load is shown in Equation 3 is used [6].

$$\text{Cooling Load} = \frac{(Lx3.28)\ x(\ Wx3.28)\ x\ (Tx3.28) x\ Ix\ E}{60} \quad (3)$$

1 m = 3.28 feet
L = Room width
T = Room height
I = If the ground floor Value = 10
= If the top floor Value = 18

E = AC placement direction

a) North = 16

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b) East = 17
c) South = 18
d) West = 20

The air conditioner used at Car Dealership still uses a refrigerant in the form of Refrigerant R-22. This can be done by replacing the Refrigerant in the AC used with the Musicool or refrigerant hydrocarbon MC-22. The advantages are

a. Environmentally friendly and comfortable, refrigerant MC-22 is non-toxic, does not form bubbles, comfortable and its release into the wild will not damage the ozone layer and does not cause global warming effects.

b. Saving Electricity/Energy, refrigerant MC-22 has better thermodynamic properties so it can save energy/electricity consumption by up to 20% - 30% compared to refrigerant Hydrocarbon at the same capacity of the refrigeration machine.

c. More efficient, refrigerant MC-22 has low-density properties so it only requires about 30% of the use of refrigerant at the same capacity as the refrigeration machine.

d. Replacement for all, refrigerant MC-22 can replace the refrigerant used so far without changing or replacing components or lubricants.

Analysis of Energy-Saving Opportunities

The results of the measurements carried out are then followed up to the calculation of the amount of Energy Consumption Intensity (ECI) and electrical profiling energy use at Car Dealership and recommend opportunities to save electricity by not neglecting quality, quantity, comfort, and health of the building itself. If the opportunity to save is known, then there is a need to be real action taken by the parties involved in the order to achieve energy savings. Equation (4) is used [10].

$$\text{Payback period} = \frac{\text{Required Investment Cost (IDR)}}{\text{Possible Savings (IDR)}} \quad (4)$$

RESULTS

The intensity of energy consumption in a building or building can be used as a reference to determine the coefficient of energy use in the building or building. The standard used is the standard of energy consumption intensity according to the Minister of Energy and Mineral Resources Regulation No. 13 of 2012.

Energy Consumption Intensity

The amount of energy used by a building expands the conditioned area in one month or one year. The conditioned area is an area where the room temperature is regulated in such a way that it meets the comfort standard with cool air supplied from the building's air conditioning system as in Table IV.

TABLE IVV
ENERGY CONSUMPTION INTENSITY AT CAR DEALERSHIP BEFORE SAVINGS

Year	Month	kWh	Wide (m^2)	ECI	ESDM Criteria
2021-2022	February	18,850	1842.5	10.23	Moderate
	March	16,600	1842.5	9.00	Moderate
	April	23,140	1842.5	12.55	Moderate
	May	22,100	1842.5	11.99	Moderate
	June	19,955	1842.5	10.83	Moderate

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	July	19,695	1842.5	10.68	Moderate
	August	15,535	1842.5	8.43	Excellent
	September	19,110	1842.5	10.37	Moderate
	October	21,328	1842.5	11.57	Moderate
	November	24,842	1842.5	13.48	Moderate
	December	27,837	1842.5	15.10	Adequate
	January	26,453	1842.5	14.35	Adequate

Lighting System

TABLE V
REPLACEMENT OF EXISTING LAMPS WITH LED LAMPS

Existing		LED		Number of lamps	Existing power (Watt)	LED Power (Watt)
Type	Power (Watt)	Type	Power (Watt)			
TL 36	36	LED T8	16	368	13,248	5,888
SL 18	18	LED SL 7	6	180	3,240	1,08
Amount					16,488	6,968

The lighting system at Car Dealership uses TL and SL lamps, more details can be seen in the appendix. To save more energy, it is possible to replace existing lamps by using LED lamps. LED lamps absorb less power than conventional lamps. The following is the calculation of the replacement of existing lamps using Led lamps as provided in Table V and Table VI.

TABLE VI
COMPARISON OF THE USE OF TL 36 EXISTING LAMPS WITH T8 LED LAMPS

TL 36 Mounted Existing Lamp	Replacement with T8
Type lamp = TL 36 Watt	Type Lamp = LED T8
Lumen=2500	Lumen = 2500
The ultimate lux =476	The ultimate lux=482
Room Size=40m^2	Room Size = 40 m^2
10 light point	10 light point
36 W x 10 light point=360 Watt	16 W x 10 light point = 160

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	Watt
360 Watt : 40m^2= 9W/m^2	160 W : 40m^2 = 4 W/m^2

Efficiency =360 Watt-160 Watt
=200 Watt

- Simulation Results Finding the Number of Light Points

In the simulation results in Figure 4 by taking into account Fig. 3 for the canteen room using LED lights, there are 6 light points are needed to meet the SNI standard of 250 lux. The simulation results show that on average when using 6 light points using Philips T8 lamps, the average lux is 248 lux, the divergent of lux mostly strongly in the middle.

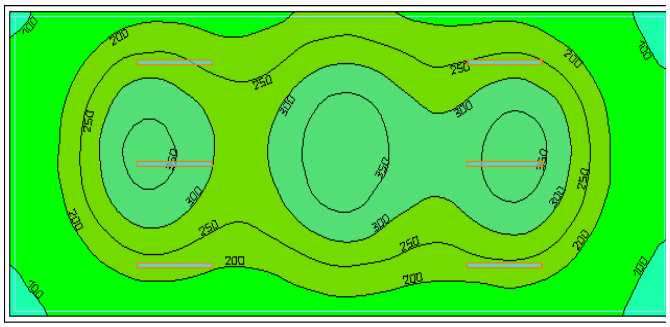

Figure 4. The distribution of lux when simulated using the software to determine the number of light points

- Calculation to find the number of light points according to SNI. The Equation 5 is used

$$\text{Lux} = \frac{\text{lumen}}{\text{m2}} \quad (5)$$

Existing TL (36 W)
Lumen =2500

Wide =40 m^2

$$=\frac{2500}{40} = 62.5 \text{ lux} = 62.5 \text{ lumen/m}^2$$

$$=\frac{\text{lux SNI lighting level}}{\text{Lux or Lumen/m}^2}$$

$$=\frac{250}{62.5}$$

= 4 Point Lamp

LED T8 (16 W)
Lumen =2500

Wide =40 m^2

$$=\frac{2500}{40} = 62.5 \text{ lux} = 62.5 \text{ lumen/m}^2$$

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$$=\frac{\text{lux SNI lighting level}}{\text{Lux or Lumen/m}^2}$$

$$=\frac{200}{62.5}$$

=4 Point Lamps

The payback period will be implemented when:

- Savings Lighting System
  Exterior Lamp Energy Consumption-Led Lamp Energy Consumption = 73.48 kWh/day – 30.01 kWh/day
  = 43.47 kWh/ day
  Savings/day = 43.47 kWh/day

  The effective working day in 1 month is 27 days, so the energy savings that can be done for 1 month are:

  Savings/month = 43.47 kWh/day x 27 day

  = 1,173.69 kWh/ month

  The savings in electricity bill payments that can be made in one month are:

  Savings = Total kWh x Electricity Tariff January

  = 1,173.69 kWh x IDR. 1,444.70

  = IDR. 1,695,629.94

  Payback period $= \frac{\text{IDR. } 25{,}280{,}000}{\text{IDR. } 1{,}695{,}629.94} = 1.2$ Year

Cooling System

- An example of an appropriate calculation is taken from the Technician Room on the 2nd floor and the direction of the AC placement is facing west. As it is written in Eq. (3)
  Technician Room
  $\frac{(12\text{x } 3.28)\text{ x } (3\text{x } 3.28)\text{ x } (2{,}3\text{ x } 3.28)\text{ x } 18\text{x } 20}{60} = 17{,}530$ BTU/ h

The results of the calculation of the AC capacity requirement in the Technician Room with a room size of 36 m2 of 17,530 BTU/h. The AC available in the Technician's Room is 2 PK (± 18,000) then the AC is available in the Lab Room. Waste Treatment Engineering meets the AC capacity requirement for the space. The results of the AC calculations for each room can be seen in the appendix in full.

- An example of an inappropriate calculation is taken from the Instructor Room of Car Dealership Semarang on the 1st floor and the direction of the AC placement is facing west.
  Instructor Room:

$\frac{(9.84\text{x}9.84\text{x}7.544\text{x}10\text{x}20)}{60} = 2{,}434$ BTU/ h

The results in Table VII of the calculation of the need for AC capacity in the Instructor Room with a room size of 9 m2 of 2,434 BTU/h. The AC available in the Instructor's Room is 2 PK (± 18,000), so the AC available in the Instructor's Room is too sufficient for the AC capacity of the room. The results of the AC calculation for the Laboratory Lecturer Room should be sufficient to use an AC capacity of 1/2 PK (± 5,000).

TABLE VII
INVESTMENT IN AC REPLACEMENT USING REFRIGERANT HYDROCARBON MC-22

No	AC Capacity	MC- 22 price	Number of AC	Investment (IDR)
1	2 PK	505000	24	12,120,000

Payback period will be implemented when:

- Savings on cooling system
  AC with refrigerant R22 - AC refrigerant MC-22

282.4 kWh/day–225.92 kWh/day = 56.48 kWh/ day

Savings/day = 56.48kWh/ day

The effective working day in 1 month is 27 days, so the energy savings that can be done for 1 month are:

Savings/month = 56.48 kWh/ day x27 day

= 1,524.96 kWh/ month

The savings in electricity bill payments as illustrated in Figure 5 and Table VIII that can be made in one month are:

Savings = Total kWh x Electricity Tariff January

= 1,524.96 kWh x IDR. 1,444.70

= IDR. 2,203,109.712

Payback Period= $\frac{\text{IDR. } 12,120,000.00}{\text{IDR. } 2,203,109.71}$ = 5.5 month

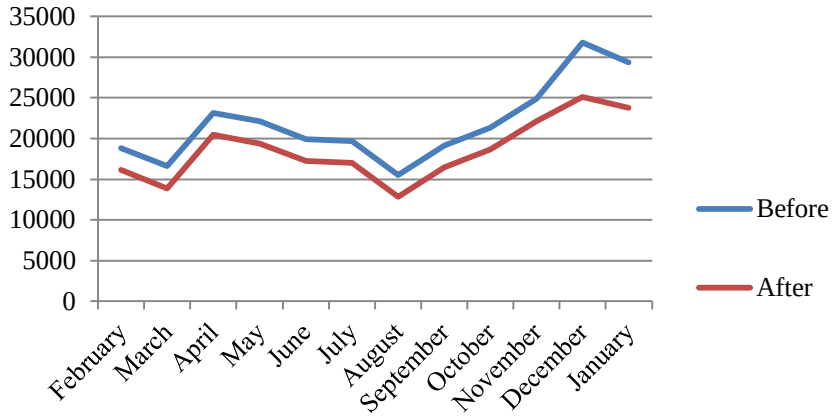

Figure 5. Comparison Trend of Electrical Bill of Car Dealership from February 2021 to January 2022 Before and After Audits

TABLE VIII
ENERGY CONSUMPTION INTENSITY AFTER SAVINGS

Year	Month	Before Savings (kWh)	After Savings (kWh)	ECI	ESDM Criteria
2021-2022	February	18,850	16,151.35	8.76	Moderate
	March	16,600	13,901.35	7.54	Excellent
	April	23,140	20,441.35	11.09	Moderate
	May	22,100	19,401.35	10.52	Moderate
	June	19,955	17,256.65	9.36	Moderate
	July	19,695	16,996.35	9.22	Moderate
	August	15,535	12,836.35	6.96	Excellent
	September	19,110	16,441.35	8.92	Moderate
	October	21,328	18,629.35	10.11	Moderate
	November	24,842	22,143.35	12.01	Moderate
	December	27,837	25,138.35	13.64	Moderate
	January	26,453	23,754.35	12.89	Moderate

CONCLUSION

The Energy Audit conducted is an energy survey at the Car Dealership building is how energy is used. Based on the analysis of the data, it raises energy conservation opportunities at Car Dealership buildings reducing waste power more effectively. Implementing energy conservation measures such as replacing energy-saving lamps (LED) and refrigerant MC-22, with the replacement of energy-saving lamps (LED) and refrigerant MC-22 at the Car Dealership building can save total energy of 2,698.65 kWh per month. The payback period with the Refrigerant MC-22 refrigerant is 5.5 months after installation and the payback period for replacing existing lamps with Led lamps is 1.2 years from the installation of Led lamps to replace existing lamps.

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