

Day Lighting Strategy in Education Complex for Electrical Energy Saving

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Abstract

Buildings consume more energy which lead to more production and environmental pollution compared to other enterprises or industries. Daylighting has recognized potential for electrical energy saving when used complementary to artificial lighting. Present study reviews the daylight performance implemented for energy saving at an educational complex in UniKL MITEC. Lack of awareness and moral obligation among staff and students are the factors associated with electrical energy wastage in the complex. A lighting schedule was set up and made publicly acknowledge by a total of 124 staff and students involved in this study. Electrical energy consumption was calculated for three months consecutively. It was found that the set up procedure effectively reduced electricity consumption and eventually minimized cost. With proper practice and wider implementation to other buildings and complexes in the campus, it is targeted that the overall energy cost to be reduced by 26 percent.

Keywords: Daylighting, Energy saving, Occupants' behavior

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1. Introduction

With the growing global population, it is expected that more and more commercial buildings to be developed and constructed. Almost 50 percent of the electricity generated in Malaysia is distributed and consumed by three major consumers; industries, residences, and commerce, as shown in Figure 1[1].

Final electricity consumption (percent)

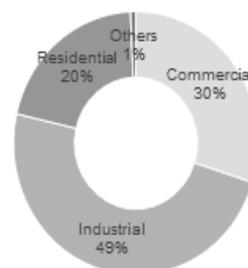


Figure 1: Final electricity consumption in local buildings for the year 2017 with total consumption of 12,606 ktoe[1], which made of almost half of the entire electricity produced in the same year

In 2014, Hassan et al. [2] highlighted how four major categories of contributing factors [3] influence the use of energy in local buildings. Typical weather in Malaysia recorded variation in temperature ranged from 22 °C to 32 °C with high humidity due to abundant rainfall throughout the year. This kind of climate tends to impact the energy consumption of air conditioning system [4]. However, the country received in average 6 hours of sunshine per day with low air velocity. With rapid economic boost and technological growth happening in the country, most buildings in the city depend on air conditioning system to maintain good ventilation indoors. Further devastation in energy efficiency is through the use of indoor lighting, which represents around 20-30 percent of the annual electrical load, particularly in large building.

The biggest challenges to achieve electricity efficiency has been associated with usage behavior of the occupants[5–8]. In residential buildings, the occupant’s behavior may be easily tolerated as it involved small group of people in the family per unit residence. The maintenance of good practice can be monitored closely and any disobedience can be confronted directly in this settings. In industries, there are guidelines and rules should be complied with, thus the wastage of electricity can always be recognized, addressed, and counter-measured. However, bigger challenges are presented in commercial buildings, in which the occupants are casual with unexpected behavior. As the occupant behavior in a particular building cannot be measured in order to quantify the energy usage, direct assessment to control the behavior manually by building good habits may be the only possible way to achieve energy efficiency in commercial building.

The present study aims to demonstrate how good practice can help to increase energy efficiency in educational complex. A set of procedure was developed in combination with methodical daylight system are expected to improve energy efficiency of the building.

2. Methodology

This study involved one of the buildings in Malaysian Institute of Industrial Technology, Universiti Kuala Lumpur (UniKL MITEC) as a subject. The building is able to accommodate more than 200 people at a time, but the average number of daily occupants are 124 people. The building is a 4-storey complex with 6 lecturer rooms, and 6 laboratories. All rooms and laboratories have access to natural light through various horizontal sliders. Laboratories are furnished with vertical blinds, whereas the lecturer rooms keep the privacy using translucent static film. Apart from the lecturer rooms – which were not accounted in this study – uniform indoor lighting is fitted across the building with 608 units of 36-watt and 64 units of 18-watt bare channel fluorescent lights, in total. Specific staffs are assigned for operation and maintenance of each laboratories, in which the

laboratories are in used in corresponding to the current semester schedule.

A floor plan layout with 23 grid points of the whole building was sketched using AutoCAD 3D (Autodesk, USA) as shown in Figure 2. The grid points were the points of interest to measure illuminance with consideration of natural lighting parameters such as windows position and cardinal directions. Illuminance at each points was measured using a HD450 data logging heavy duty light meter (Extech Instruments, USA). The recorded illuminance was used to calculate the energy consumption based on the following equations;

$$\text{Cost of electricity consumption} = \text{electricity consumption} \times \text{price of electricity} \quad (\text{Equation 1})$$

$$\text{Bil saving} = \text{energy saving} \times \text{electricity tariff} \quad (\text{Equation 2})$$

$$\text{Electricity consumption} = \frac{N \times W \times OH}{100} \quad (\text{Equation 3})$$

where N is the number of equipment, W is power rating in Watt and OH is the operating hours.

Initial electricity consumption was calculated using the illuminance recorded for the first 15 consecutive working days at four period intervals; 9.00 am, 11.00 am, 3.00 pm, and 5.00 pm. This measurement was taken with and without indoor lighting. Based on the recorded measurement, a lighting schedule was developed and disseminated to all involved occupants in the building, especially the staffs in charged for practice and monitoring. Department of Occupational Safety and Health (DOSH) regulates the average luminance of educational buildings to be 500 lux [9]. In the proposed lighting schedule, the luminance at each grid points were bounded to be in between 400 to 500 lux. Another 15 working days were taken to build habits and make certain that the schedule was respected.

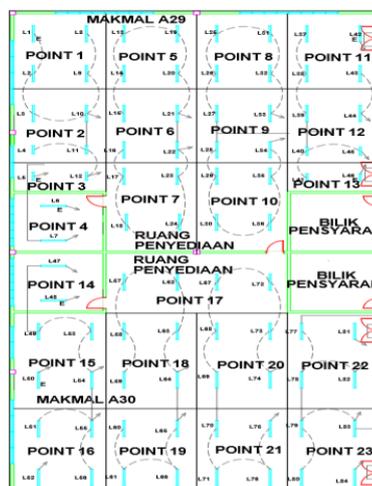


Figure 2: Example of a floor plan with 23 grid points for illuminance measurement. Note that each floor in the building has the same layout plan.

As the occupants were ensured to be abided by the proposed lighting schedule, the same measurement of illuminance was conducted daily for the next consecutive 15 working days. Then, this procedure was repeated twice in the following 30 working days to eliminate disparities in the measurement. Electricity consumption cost for each 15 working days of measurement was calculated and compared to the initial consumption cost.

3. Results and Discussion

In the first 15 working days, the average luminance recorded at all period intervals are as shown in Figure 3. Red ring marks the acceptable range of luminance

resolved (400-500 lux) from the lighting for workplace guideline from DOSH [9]. At 9.00 am, the luminance in the laboratories fell much below the minimum acceptable level of 200 lux. The building is situated in between two similar buildings of the same height, thus morning sunlight passing through the windows is limited at this hour. All occupants chose to have all indoor lightings on to improve the luminance level in the room. However, at most grid points, indoor lighting may not be necessary as the luminance leaped over the acceptable range, but not exceeding the maximum level of 700 lux.

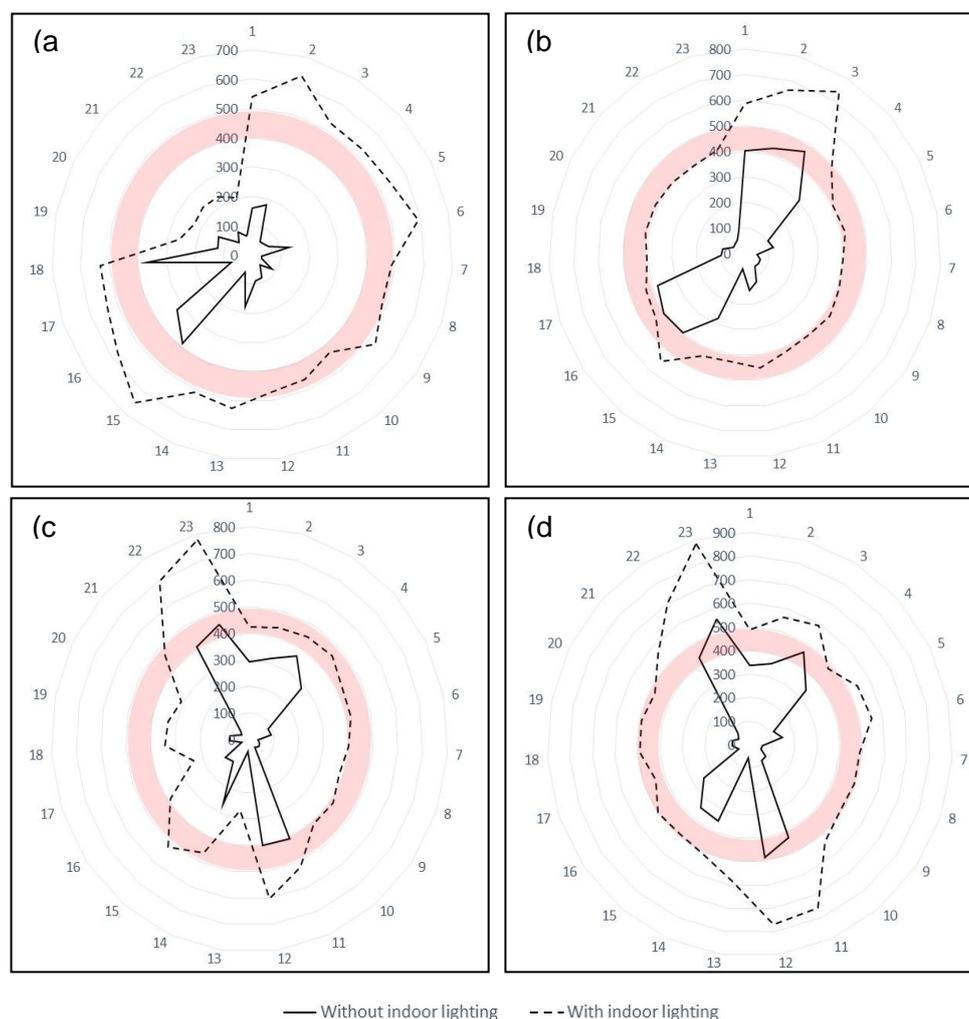


Figure 3: Average luminance with and without indoor lighting for 15 days measured at (a) 9.00 am, (b) 11.00 am, (c) 3.00 pm, and (d) 5.00 pm.

Similar condition was observed at 11.00 am measurement in which the luminance recorded with indoor lighting mostly falls in the acceptable level range. This is related to the position of the sun (altitude 58° heading towards 84° E [10]) and less significant shadows from the neighboring buildings. However, some grid points recorded spiked luminance over the maximum acceptable level. Similar behavior was observed on the luminance

recorded at 3.00 pm and 5.00 pm. Climate, or the environmental factors presented in a particular building can contribute huge effects on the consumption of energy, but the roles of occupants are also important for efficiencies [7]. Dimmed rooms resulted in occupants' tendency to switch all lights on to improve the indoor luminance. The average cost of electricity consumption cost per day calculated is shown in Table 1.

Table 1: Average daily power consumption and cost in the first 15 working days

| | |
|--|--------|
| Average duration per day (h) | 9 |
| Average power consumption per day (kWh) | 207.36 |
| Total electricity consumption cost* per day (RM) | 75.69 |

*Tariff rate = RM 0.036 per kWh

Based on the recorded luminance in the first 15 working days, a lighting schedule was constructed and distributed to all occupants (see Table 2). The schedule was apportioned into four time phases; each specifies the lights to be switched on or off.

Table 2 Proposed lighting schedule to control luminance level within acceptable range.

| Time phase | Grid with off | points lights | Grid with lights on | points lights on |
|--------------------|---------------|---------------|---------------------|------------------|
| 8.00 am – 10.00 am | 2 | | 1 | |
| | 6 | | 3-5 | |
| | 13 | | 7-12 | |
| | 15 | | 14 | |
| 10.00 am – 1.00 pm | 1-4 | | 5-13 | |
| | 14-15 | | 16 | |
| | 17 | | 18-23 | |
| | | | | |
| 2.00 pm – 4.00 pm | 2-3 | | 1 | |
| | 11-12 | | 4-10 | |
| | 14 | | 13 | |
| | 22-23 | | 15-21 | |
| 4.00 pm – 6.00 pm | 2-3 | | 1-2 | |
| | 5 | | 4 | |
| | 11-14 | | 6-10 | |
| | 16 | | 15 | |
| | 21-23 | | 17-20 | |

This schedule considers to utilize natural light in order to optimize the electricity consumption. However, the location of the building of interest which situated in between two similar buildings limits natural light penetration indoors. The luminance level at each grid points is improved as shown in Figure 4.

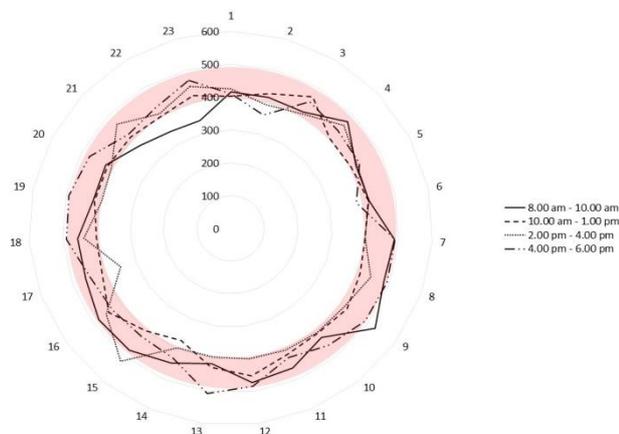


Figure 4: Average luminance following the lighting schedule measure at 9.00 am, 11.00 am, 3.00 pm, and 5.00 pm; recorded for 45 working days.

As the lighting schedule is confirmed not to intrude the luminance level required for educational building, the total cost of electricity consumption incurred is calculated as tabulated in Table 3. The total power consumption with lighting schedule is 152.93 kWh. Total electricity consumption cost per day is RM 55.82 with lighting schedule. This shows reduction of 26.25 percent in comparison to the initial power and cost recorded in the first 15 working days.

Table 3: Average daily power consumption and cost after lighting schedule implementation for 45 working days.

| Time phase | 8.00 am | 10.00 am | 2.00 pm | 4.00 pm |
|------------------------------------|----------|----------|---------|---------|
| | – | – | – | – |
| | 10.00 am | 1.00 pm | 4.00 pm | 6.00 pm |
| | am | pm | pm | pm |
| Duration (h) | 2 | 3 | 2 | 2 |
| Power (kWh) | 40.32 | 52.70 | 33.98 | 25.92 |
| Electricity consumption cost* (RM) | 14.72 | 19.24 | 12.40 | 9.46 |

*Tariff rate = RM 0.036 per kWh

4. Conclusion

Apart from environmental factors such as the climate, building location, and landscaping, the electricity consumption in a building is highly affected by occupants' behavior. The tendency of the occupants to over utilize the facilities provided in commercial buildings in particular led minimizes the energy efficiencies and may contribute to destruction of building's quality.

The chosen building in the present work has limited daylight penetration as it is located in between two similar buildings against direct sunlight. This condition bounds maximum utilization of natural light in order to improve electricity efficiency in the building. However, with some controls and monitoring of the occupants' behavior, the electricity consumption can be minimized without upsetting the occupants' comfort. A lighting schedule was proposed and implemented for 45 working days in this study which showed improvement to the electricity consumption and cost for more than 26 percent. It is expected that with the same analysis and construction of lighting schedule in other buildings within the campus can help to reduce cost and save more energy.

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