Energy and Cost Saving Potential of Lighting System In Academic Building

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Abstract— Energy consumption and the potential for energy savings had become more intensive in public buildings in order to improve energy performance. This case study was identified the current occupancy, lighting use patterns and lighting performance in G3 Block B teaching building where most of the teaching rooms were located in University Tun Hussein Onn Malaysia (UTHM). In order to determine the energy saving potential and strategies for lighting system in the building, a series of data collection were conducted to the effects of occupancy and lighting use patterns to display the lighting energy consumption and lighting energy waste of the case study building. The findings of this study displayed lighting use patterns varied among all the investigated lecture rooms at which 31% of lighting load was wasted and 13% of lighting load misused by the building users were recorded. Moreover, the result of lighting performance of the lecture room obtained was met the recommended average illuminance level (300-500 lux) of lighting for working interiors as classroom in MS 1525:2007. In addition, the perception, awareness and practices of energy conservation behaviour on lighting of the building user were also studied through structured questionnaire. With regard to the findings of questionnaire in this study, the responses indicated that most of the respondents agreed they were at good perception, awareness and practices on their energy conservation behaviour on lighting. Based on the various data obtained in this project, the energy and cost saving potential strategies were suggested for instances the structural energy conservation measures and non-structural energy conservation measures to improve the usage and efficiency of the lighting system in the teaching building towards energy conservation.

Keywords-**energy consumption, teaching building, lighting use pattern**

I. INTRODUCTION (*HEADING 1*)

Energy consumption and the potential for energy savings become more intensive in residential, industrial, commercial and public buildings to improve energy performance nowadays. Energy consumption is growing as construction booms, particularly in countries such as China and India (Rusdy, 2011). According to this research (Dalshod, 2015), one of national energy policy's objectives in Malaysia is to promote efficient utilization of energy and the elimination of wasteful and nonproductive patterns of energy consumption. In any organization, electricity usage should be analysed to identify unwanted and unnecessary usage, which would create the opportunities to find waste and initiate solutions to reduce it. Investing and implementing energy saving practices, energy management and conservation will greatly contribute toward reduction in electricity cost but more importantly use the electrical energy in the most diligent way and reduce wastage in energy use. Figure 1 shows the operation and building maintenance in public university.

Lighting is one of the largest users of electrical energy in a typical commercial building (Bill, 2001) that accounts for 5–15% of the total electric energy consumption (Geun, 2012). Lighting is a key issue in minimizing overall energy consumption of building and energy consumption of a lighting installation is strongly dependent on lighting controls usually related to daylight and occupancy detection (Ryckaert, 2010). In both new and old buildings today, there are countless opportunities and various energy-efficient lighting technologies that are introduced to improve lighting efficiency and to minimise the cost of energy used.

As cited by research (Tuan, 2013), occupancy presence and behaviour in buildings has shown to have large impacts on energy consumption of lighting and space appliances such as heating, cooling and ventilation demand, and building controls. The irresponsible behaviour can add one-third to a building's designed energy performance, while conservation behaviour can save a third.

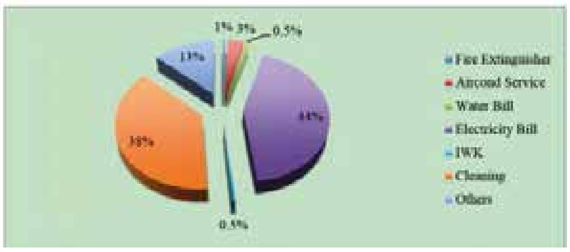

Fig. 1. Operation and building maintenance in public university.

Many researchers have studied and reported the significance of adopt energy-use behaviour. Principally, the research (Low Sheau, 2012) stated non-structural energy conservation approach by improving user's behaviour can be incorporated to reduce energy demand and achieve energy sustainability. For instance, consumer behaviour is one of the most important issues with respect to household energy consumption (Jianyong, 2009).

According to (CoCEaASCoJ, 2007), all occupants in the building are contribute and responsible for the increases in overall energy consumption. Thus reduction in energy consumption should be a common responsibility to every occupant subsequently. A study also stated that human behaviour plays an integral role in energy conservation activities by which a potential of energy and cost saving can be achieved by approximately 10 percent if building users can be persuaded to more energy conserving (Bream, 1986).

University is the place where the occupants consume a substantial amount of energy. Nowadays the higher probability of energy wastage is mainly caused by the user's negative energy use behaviour in a building (Low, 2012). Increased electrical energy usage in University Tun Hussein Onn Malaysia every year that ends up with huge cost of electricity bill was due to the rapid growth of the university's activity (Noranai, 2011). The teaching rooms were involved in this study since they consume the greatest item of energy, comfort and well-being of students which are the main objectives pursued in educational environment.

It is normal to observe that building users do not diligently turn lights off when they vacated spaces, with the lighting system in an empty classroom. Consciousness and intention of building users are not strong and causing unnecessary wastage of energy consumption to a building. Thus, this produces the opportunity to analyse the energy usage of teaching room and identify the potential energy reduction and cost savings. Moreover, there is great need to promote intention of user's behaviour change to ensure they switched off the electric loads when the users were out of the room. Users usually turn on the wall switch lights, which need manual controlled, as they enter the room, but not usual turned off as they vacate. Users may not hesitate and unwilling to turn off lights in a small room if they think someone else may still be in the space or enter again shortly. If those students do not turn off the lights when they leave for the day the organization winds up consuming power for example 100 unnecessary lights for 3 hours each day. Then, the 36 watt fluorescent light left on for an additional 3 hours each day burns up RM3.94 of electricity per day or RM118.26 per month at 36.5 cents/kWh.

Based on the pilot study that has been conducted in this study, the researcher can observed there are 36% - 46% of the total hour usage of lighting system are needlessly in the unoccupied lecture rooms. Thus, it was crucial to analyse the energy usage of lighting system in teaching building for identification of potential energy reduction and cost savings. Apart from that, the intention of user's behaviour towards energy conservation can be done by raising the energy awareness and improve energy-use behaviour among the students by their behavioural improvement (Weng Wai, 2010).

II. AIM

The scope of this study was the case study of a teaching building by analysis of the effects of occupancy, lighting use patterns and lighting performance of the teaching building by determine the occupancy condition and status, lighting operation data and internal illuminance in the room for study. Also, this study involved the distribution of structured questionnaire about the user's behaviour on energy conservation when using the lighting. These can explore their perception, awareness and practices about the need to conserve energy. Furthermore, recommendations for energy saving potential and strategies that encouraged energy conservation were suggested at the end of this project. Objectives of this study were as follows:

1) To determine the energy saving potential and strategies for lighting system in the building.
2) To identify the effects of occupancy, lighting use patterns and lighting performance on lighting energy consumption.
3) To study the user's perception, awareness and practices of energy conservation behaviour in lighting in teaching building.

III. METHODOLOGY

There were appropriate methodology processes in the direction of achieving the objectives of this study. In order to achieve this study, several procedures to conduct the study have been selected as shown in the overview of methodology process in Figure 2.

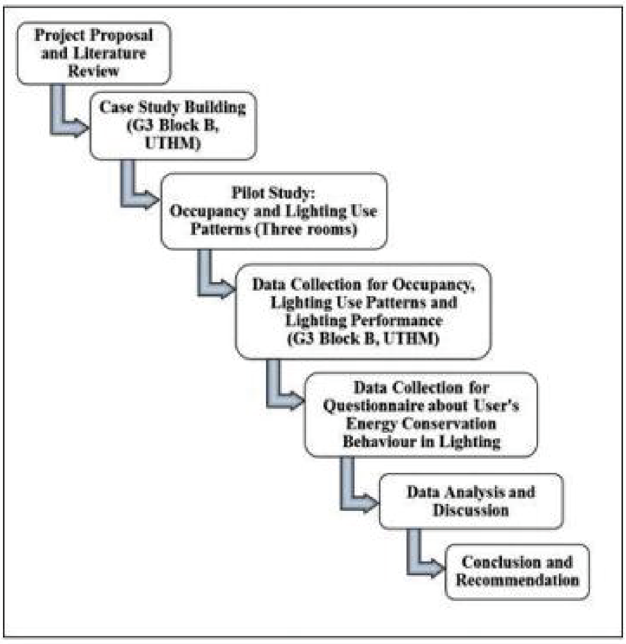

Fig. 2. The overview of methodology process

A. Case Study Building

This project was based on a case study of the occupancy, lighting use patterns and lighting performance of lighting system in G3 building Block B, UTHM. G3 building located at the centre of the university and constructed various type of teaching rooms and lecture halls with teaching facility. Thus, this teaching building was selected to be studied due to its high usage of teaching rooms by the users. The selection of case study building was determined by the following factors:

- This teaching building consists of the most amount of teaching rooms in the campus.
- The existing lighting control system of this building is manually controlled by the users.
- This building is free access by the users in the building operating hours resulting the users of the rooms are intermittent and unpredictable.

B. Occupancy and Lighting Use Data

This study presented the analysis on the data of lighting usage and occupancy for a two-week monitoring period between March and October in 2016. The purposes were to determine and understand the energy usage pattern of the lighting system based on the occupancy data and amount of lighting operation data in the rooms for study.

Data for twelve rooms were originally collected for the monitoring period, start at 8.00a.m to 6.00p.m every day in the weekdays. The rooms for study included BP1, BP2 and BK-B1 until BK-B8. The total lighting load or amount of lighting operated in the room and the status of occupancy were observed and recorded in every 30 minutes into a data collection form. Due to the limitation of measurement equipment in the faculty and university, direct observation and manual data collection were chosen to conduct the data collection in this study.

An occupancy pattern is the information of condition for people enter or leaves the building from the start and end of daily occupancy in the building. Besides, lighting use patterns is the measure of status of lighting used during the building operation hours in the lighting zone (Geun, 2012). According to the previous study (Bill, 2001), the condition of occupancy and lighting use patterns were observed to analyse and determine the basic energy savings potential. Lighting and occupancy use in any space will usually categorize into one of the following four conditions as shown in Table 1.

TABLE I. TYPES OF DATA REQUIRED FOR ACCUPANCY CONDITION

Condition	Description
1	Occupied with the lights on
2	Occupied with the lights off
3	Unoccupied with the lights on
4	Unoccupied with the lights off

Meanwhile, Table 2 showed the status of occupancy. It was categorize into another three occupancy status, namely ‘CLASS’, ‘EMPTY’ and ‘MISUSE’. The collection of status of occupancy data eases up the analysis of total hour usage and energy use of lighting system. Status of ‘CLASS’ was meant to the room was occupied and used for attending a class or teaching and learning activities. ‘EMPTY’ is meant to the room is unoccupied by any building user.

TABLE II. TYPES OF DATA REQUIRED FOR STATUS OF ACCUPANCY

Status	Description
CLASS	Room is occupied for class with lights on or off.
EMPTY	Room is unoccupied with lights on or off.
MISUSE	Room is occupied with unnecessary lights on or off.

As mentioned, there was a specific condition that was emphasized in this study, which was the ‘MISUSE’ status. The building users sometimes misused the lighting for the activities that switch on the excessive and unnecessary number of lighting in the room. For example, one or two users in the room were switched on the entire lighting for the activities like resting or discussion which excessive lighting operation can be avoided. These statuses of condition were observed for the aid of determining the influence and awareness of the user behaviour towards energy conservation.

C. Lighting Perfomance

The basic requirement for adequate lighting are that the work must be easy to see and the light comfortable to the eyes. To investigate the lighting performance, the illuminance level of daylighting and artificial lighting installed in the room were measured and analysed. The lighting performance was then determined whether meeting the comfortable illuminance levels and MS 1525:2007 recommended average illuminance of lighting for working interiors (M. Standard, 2007).

Lux meter was used to measure internal illuminance in this study. Firstly, the internal area or dimension of the room for study was measured and recorded. The floor area was used to determine the necessary number of points needed to obtain an accurate measured average illuminance. To measure the illuminance level of the rooms, the methods to conduct the illuminance measurement explained in the (CIBSE, 2012) were applied in this project. The data of average illuminance level obtained in this study were recorded and analysed to determine the energy saving potential and strategies for the lighting system in the building.

D. Questionnaire about Building User’s Energy Conservation Behaviour on Lighting

Building user perception and motives towards electrical energy usage is essential for energy conservation behaviour. To suggest well-aimed energy saving recommendation, it is essential to understand the existing demands and user patterns on energy by the effect of building occupancy and building use. Structured questionnaire were distributed among the users of the teaching building. The aim of the questionnaire was to identify user's underlying perception, awareness and user practices in energy conservation behaviour in the building as shown as in Table 3.

TABLE III. QUESTIONNAIRE STRUCTURE

Part	Description
Part A	Occupancy and room activities
Part B	User perception and awareness about energy conservation behaviour in lighting
Part C	User practices of energy conservation behaviour in lighting
Part D	Demographic

IV. RESULTS AND DISCUSSIONS

A. Building Description

Table 4 shows the details of the teaching building characteristics and lighting equipment that are used in the teaching building. This information was used to analyse the current usage of energy for lighting to identify the unnecessary lighting used and wastage. Throughout the direct observation to the building, the lighting system in this building was mainly utilizing the fluorescent lighting and CFL downlight. In this study, the lighting system of lecture rooms were focused due to it were represented the most wastage of electricity on unnecessary lighting consumption. The lecture room's lighting system were designed to be controlled by manual switches thus it causing some irresponsible building users used excessive lighting that can be reduced or avoided and they did not switched off the lights after they vacated.

TABLE IV. THE LIGHTING EQUIPMENT THAT ARE USED IN THE TEACHING BUILDING

Lighting System of G3 Block B Building, UTHM		
Men and Women Toilet	6 units	
Lighting type	Quantity	Power rating, Watts (W)
CFL Downlight	24	18
Handicap Toilet	6 units	
Lighting type	Quantity	Power rating , Watts (W)
CFL Downlight	6	8
Lecture Room	12 units	
Lighting type	Quantity	Power rating , Watts (W)
CFL Downlight	36	18
T8 Fluorescent Lamp	432	36
Corridor Lighting		
Lighting type	Quantity	Power rating , Watts (W)
CFL Downlight	31	18
Staircase Lighting		
Lighting type	Quantity	Power rating , Watts (W)
T8 Fluorescent Lamp	28	18

The ground floor and first floor lecture rooms were also installed with two additional downlights at the front of the rooms. Due to the lack of maintenance, the downlights mostly were unable to light up. Thus, the amount of downlights operated in the room was not recorded in this study. Moreover, the staircase lighting with fluorescent lighting was also showed unnecessary usage in the daytime due to the ineffective three-way manual light switch. The corridor lighting in each floor were controlled by the photocell sensor which exterior lighting would be automatically turned off when sufficient daylight is available in the daytime. There are only few corridor downlights were designed to be manual controlled by the building user such as the area near to toilets. Meanwhile, the lighting systems of toilets were also displayed unwanted wastage of lighting, which the lights were switched on all the time even the toilet was empty.

B. Occupancy and Lighting Use Data

According to Figure 3, lighting use patterns varied among all the investigated lecture rooms. Among the lecture rooms, the occupants recorded 42.53% to 69.97% of lighting use for the teaching and learning purpose. The energy saving potential from unnecessary lighting in empty room was recorded from 15.18% to 42.53%. This indicated the lecturer rooms was light on in an unoccupied space due to the building users not turn off the light when they vacated the room. In the meantime, there were also 9.01% to 14.93% of lighting energy misuse in the investigated lecture rooms.

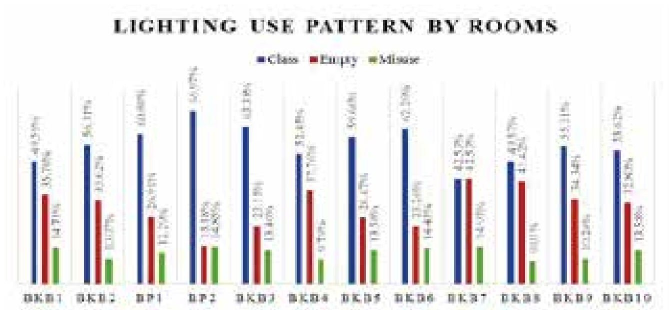

Fig. 3. Lighting use pattern according to lecture rooms.

Figure 4, summarize the total lighting load or amount of electricity operated that were obtained in all 12-lecture rooms that studied during the monitoring period. There were recorded 56% or 35.451kWh of energy cost spent to light up the class for building users to attend lectures and other activities. 31% or 19.385kWh of lighting load was unnecessary which the energy cost can be saved and the building users misused 13% or 7.91kWh of lighting load.

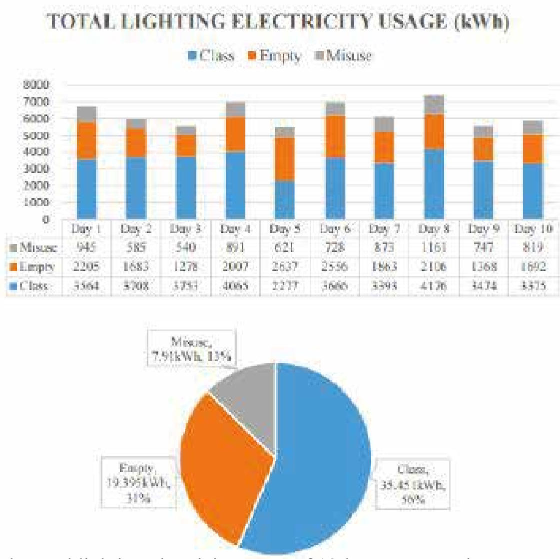

Fig. 4. The total lighting electricity usage of 12 lecture rooms in two-week monitoring period.

According to Figure 5, there were 61% condition of occupancy that building users occupied the lecture room with the lights on. Then, there were only 3% conditions of building users occupied with the lights off. The data shown for condition 2 indicates that building user rarely occupied spaces with the lights off, indicating that for the lecture room may be a small potential benefit of installing manual controls. Moreover, there were 25% in condition 3 which indicated the wasted lighting energy of the lecture rooms were unoccupied with the lights on. These reflected that the occupants to utilize the lighting system not effectively and not efficiently used the existing manual lighting control devices. At last, the most satisfied situations were only recorded as 11%, which the lights were off when the room was unoccupied throughout the monitoring period.

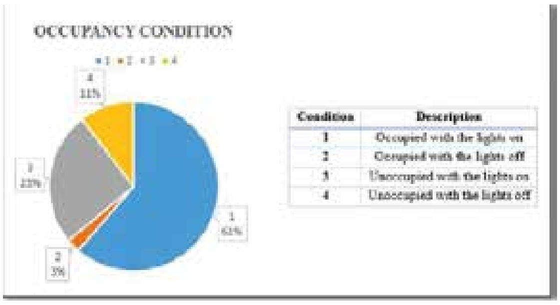

Fig. 5. The occupancy condition in the lecture rooms during monitoring period.

C. Lighting Performance

Based on the illuminance measurement of daylighting in the lecture room as shown in Figure 6, the result showed that the space were not lighted up evenly by the natural lighting from the windows.

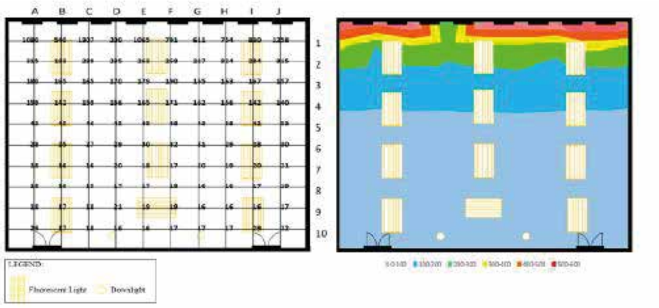

Fig. 6. The illuminance (lux) and illuminance contour of daylighting into the lecture room.

These were due to the building façade and space allocations in the lecture room were not designed to utilize daylighting fully into the internal space. Thus, artificial lighting became essential for internal lighting system. Meanwhile, the result obtained for artificial lighting was met the 300-500 lux, recommended average illuminance level of lighting for working interiors as class room in MS 1525:2007 as shown in Figure 7. These meant that the lighting system in the lecture room was designed and utilized effectively to provide an adequate illuminance levels for the building user to occupy the room and interior works. Thus, the replacement of the existing lighting system into more energy efficient lamp fittings would possibly become the energy saving potential to reduce the cost of operation for lighting system in the building.

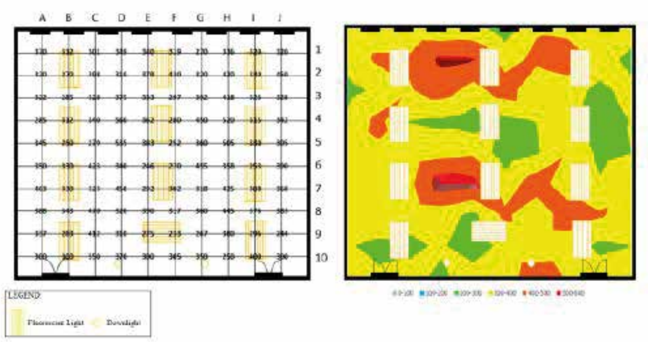

Fig. 7. The illuminance (lux) and illuminance contour of artificial lighting in the lecture room.

D. Questionnaire about Building User's Energy Conservation Behaviour on Lighting

In order to achieve the third objective in this study, the questionnaire was distributed through online survey to the random selection of 400 building users or students in the G3 Block B building, UTHM. A total of 323 were returned, representing a response rate of about 80.8%. In total, 290 cases were retained for analysis since 33 cases were not fully completed. Prior to conducting the main questionnaire, the research instrument was piloted by five lecturers. Thirty participants were recruited through convenience sampling, and each of these volunteers completed the questionnaire in the authors' presence, verbalizing all responses. The authors identified items that were consistently regarded as repetitive, misleading or confusing, and the item were revised accordingly. Prior to sending out the mail surveys, permission was granted by the supervisor.

The questions in part A were specifically designed to obtain information on the users of the building and the activities that they carried out within the building which were helpful in explaining the energy consumption profile of the building. Based on the result recorded, 94.1% of respondents were used the lecture room for teaching and learning purpose, 47.9% for attend meeting and discussion, 14.8% for rest and relaxation and 11.7% for their personal work. There was a highest percentage (63.1%) of respondents spent 1 hour to 2 hours in the lecture room every section for their activities and only 2.8% respondents who stay for only 10 minutes to 30 minutes. Thirty percent of respondents stated that the number of occupants entered the lecture room when the respondents used ware more than 40 people. In addition, 54.1% of respondents probably chose to sit at the middle of lecture room, 35.5% chose to sit at front and 10.3% chose to sit at back of lecture room. The result also indicated the front row of seats filled by occupants in the lecture room were only 56.2% meanwhile 72.5% responded that the seats in the back of lecture room were filled by occupants.

In part B, the questions were asked and used to identify the building user's perception and awareness of energy conservation behaviour on lighting. In general, the mean score of most of the questions were around 5.00 which meant the respondents were agreed about they were aware of energy conservation such as they knew what energy conservation was and how to reduce energy use (M=5.08, S.D=1.230); they aware the term of energy efficiency (M=5.07, S.D=1.199); they feel the need to frequently save energy for lighting (M=5.25, S.D= 1.194) and reducing energy use at university would be good for the environment (M=5.51, S.D=1.273). There were also some questions were slightly agreed by the respondents (M= 4.00-5.00) such as when the respondents were asked whether they aware and feel positive towards energy saving, but it is not part of their current workday culture.

In part D, the mean score of the building users on 12 practices of energy conservation behaviour on lighting was identified. The findings shown the respondents were scored more than 5.00 mean score in most of the questions which displayed they were agreed they had good practices to conserve energy on lighting system. For instances, they were motivated and try to influence others to save energy for lighting (Mean score=5.02); they always take action to save energy for lighting (Mean score=5.08); they routinely try to save energy in lighting both at home and at university (Mean score=5.26) and they turned off electric bulbs when not in use even at night (Mean score=5.49). From these responses we concluded that the respondents were motivated and took action to reduce energy use for lighting in the building. Meanwhile, there were 92.4% of the respondents interested in participating in energy saving activities in the future while 7.6% were not interested.

V. CONCLUSION

This paper reported field survey results on occupancy, lighting use patterns and illuminance distributions in the case study building to achieve the first and second objectives of this study which were the identification of the cost and energy saving potential of lighting system in the teaching building and the effects of occupancy, lighting use patterns and lighting performance on lighting energy consumption.

The findings in this study showed the lighting use patterns were significantly related to the occupancy patterns of the investigated lecture room and the building user's behaviour. There was a strong tendency of turning on lighting on occupants' first arrival in the morning and of keeping the lighting on. Thus, it was crucial to understand when and how the occupants use lighting. This study resulted that almost half (44%) of lighting use in the investigated lecture room were wasted (31%) and misused (13%) by the building user. The behavioural patterns for lighting that were revealed in field studies, and found that the occupants did not consider indoor daylight availability and keep the lighting systems on throughout the duration they occupied for any activities. They were also not aware to minimize the overhead lights based on the space that needed to light up for indoor activities and the moment that lighting was not necessary such as in an unoccupied space.

Conclusively, there were large energy saving potentials of lighting system in the investigated teaching building resulted from this study. Our data also indicated that the design of building and lighting systems and the building user's energy conservation behaviour in lighting are closely associated with lighting energy demands, for instances the building orientation, space allocation and internal illuminance measurement of natural daylighting and artificial lighting. Thus, changes in building user's behaviour can contribute positively to the University for reducing their energy usage and costs.

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