INVESTIGATION ON ENERGY EFFICIENCY OF LIGHTING SYSTEM IN A UNIVERSITY LIBRARY

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ABSTRACT

The electrical lighting system is one of the most significant contributors to energy consumption and operational cost for a library building. The extended operation of the lighting system in the library building consumes a high amount of energy, which requires the adoption of energy efficiency implementation to reduce energy consumption and to overcome energy waste. The objective of this paper is to present the outcomes of investigation on the energy efficiency of the lighting system in a university library building. The lighting system operated in a library building in one of the universities in Malaysia was chosen as the subject of the case study. A semi-structured face to face interview was carried out to interview four respondents who currently in-charge in the lighting system operation of university library building under the study. Looking at the results of the study, the lighting system of the university library is not energy efficient which leads to high energy consumption. To overcome energy waste, the results revealed that a proper guideline for the adoption of energy efficiency and cost-effectiveness of the lighting system is essential to be developed by the university authority for the university library.

Keywords: Energy, efficiency, lighting system, the university library

INTRODUCTION

The built environment today will have a significant impact on the environment. According Chew, Syaiful Rizal, Azri & Mohd Hafizzudin (2016), buildings consume a lot of energy during its operation, which leads to a terrific impact on cost and the environment. With the growing concern of society about the adverse effects of the construction industry into the environment, the concept of 'green building' has been introduced to reduce environmental problems. It is believed that the practices of optimising the efficiency of natural resources will create a better environment and more energy efficient building (Assad, Hosny, Elhakeem, & Haggar, 2015; Azizi, Wilkinson, & Fassman, 2014). A research carried out by Trifunovic et al. (2009), as cited in Aman, Jasmon, Mokhlis & Bakar (2013), estimated that about 30% of energy consumption could be reduced by implementing energy efficiency technologies. This is because natural resources conservation depends on optimal energy management in the building sector. As mentioned by Isover Saint Gobin (2008), (as cited in Chew et al., 2016), energy efficiency is a vital element in fighting global climate

change. Besides that, Olanrewaju and Abdul-Aziz (2014) also mentioned that the green principle is a combination of energy optimisation, durability, waste

minimisation, social impacts, pleasant indoor environment, pollution control, life cycle cost, user-friendliness, user comfort and satisfaction.

Also, the concept of energy efficiency is not about eliminating the uses of electrical appliances, but it is more on how to consume less energy (Chew et al., 2016). Electricity is one of the critical aspects in ensuring the building to perform as the required function, such as to facilitate the occupants in the building in operating the air-conditioning plant, lighting, fan and other electrical appliances (Kamaruzzaman & Zulkifli, 2014). Since energy consumption increases with the population growth, it requires an increase in the level of comfort and services in the building. Lighting consumes a large amount of energy in buildings, which represents 42% of total energy in building (Mahlia, Abdul Razak and Nursahida, 2011; Aman et al., 2013). These have produced a considerable waste of energy used, which efficacy of energy is crucial to reduce the energy cost (Xuan and Hongyan, 2011).

Based on a study by Ma, Lu and Weng (2015), energy consumption per capita in the university buildings and energy consumption per unit area are much higher than the energy consumption per unit area of the residential buildings. For example, in the United States, the average annual energy consumption per unit area in the university campus is the largest in the world, which up to 490kWh/m^2. This has made the university building a vital task to implement energy efficiency as energy consumption is enormous. University library building is one of the main contributors to the enormous energy consumption on the university campus. This is because the library is a large area building, with poor natural lighting and works in long operation hours. The library building needs more artificial lighting during the day and also relies on mechanical ventilation to maintain indoor air quality such as air conditioning (Xuan & Hongyan, 2011). In China, it has realised that the energy consumption needs to be reduced in the library buildings as the energy cost is over the book purchasing cost (Xuan & Hongyan, 2011).

In recent years, there are a lot of studies on the building energy consumption especially in residential building, office buildings and large space building, however, few numbers of researches involved the energy consumption in the university library building (Song, Zhang & Meng, 2015). The objective of the paper is to present the outcomes of investigation on the energy efficiency of the lighting system in the university library building. The lighting system operated in a library building in one of the universities in Malaysia was chosen as the subject of the case study. The university library building reported in this paper

is wholly anonymized to resolve any ethical issues of confidentiality and disclosure. This paper follows the other paper that has been presented elsewhere by the authors (Siti Zulaiha, 2015a, Siti Zulaiha & Mohd Fairullazi, 2015b).

LITERATURE REVIEW

Energy Consumption

The rapid growth of energy use has already raised the concern of the world in terms of the supply, limited energy resources, and some environmental impacts. According to the Department of Energy and Climate Change (DECC) (as cited in Gul & Patidar, 2015), commercial buildings, and primarily office and university buildings, are classified amongst the buildings that consume the highest energy during their operations. It has been reported that the energy consumption of buildings including the residential and commercial buildings in the developed country has been increasing gradually from 20% to 40% (Perez-Lombard, Ortiz & Pout, 2008). The development in Malaysia's economic and population have resulted in significantly higher electricity consumption (Mohd Shahidan, Hafizah &Intan Maizura, 2013). According to the data from Malaysian Energy Info Hub (MEIH), the base landing of electricity at 134 billion kWh has been doubled since 2012 (Figure 1). It is foreseen that electricity demand will increase by more than 3% by the year 2020.

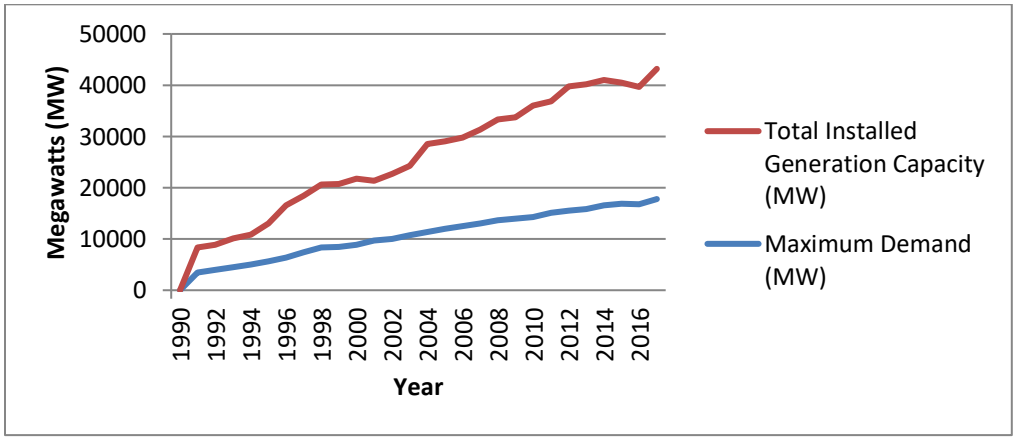

Fig 1. Installed capacity and maximum demand for electricity in Peninsular Malaysia by TNB
(Source: Malaysian Energy Info Hub)

Energy Efficiency in Buildings

Energy efficiency is believed to be one of the ways to control and manage energy consumption. In buildings, energy efficiency can be described as the minimum amount of energy is utilised for heating, cooling, appliances and lighting that is necessary to maintain comfort conditions for the occupants.

Energy efficiency is vital in reducing the operating costs and controls the energy efficiently, which considerable cost savings can be attained with these energy efficiency improvements (Muhamad, Zain, Wahab, Aziz & Kadir, 2010). This shows that energy efficiency also can enhance economic growth

as well as reducing energy demand. This is because efficiently managed energy usage can assist the organisations in spending less money on the energy cost and the operating cost.

According to Al Ferreira (2001), as cited by Mazlina Ibrahim (2009), the energy management is the process of analysing how efficiently energy is used and how reasonable the cost per unit is in the deregulated marketplace. Also, Van Gorp (2004) reported that energy management has conventionally focused on technologies that can help to increase the energy efficiency of a building. Long-term energy savings also can be accomplished by improving the building design as well as conserving energy during the operation phase of the buildings (Gul & Patidar, 2015). Malaysia has included energy efficiency as a significant element in the government policy, as in the Tenth Malaysia Plan (2011-2015) as well as in Eleventh Malaysia Plan (2016-2020) (Chew et al., 2016). In 1989, the Ministry of Energy, Communications, and Multimedia Malaysia (MECM) created a guideline for energy efficiency implementation, which is called the Malaysian Guidelines for Energy Efficiency in Buildings. Although the sustainability in the development and energy efficiency aspect has become the primary agenda in the Tenth Malaysia Plan, the guideline does not make compulsory for construction players to adopt the measures (Kamaruzzaman & Zulkifli, 2014; Mohd Fairullazi, 2014).

The Malaysia Green Building Index (GBI) is the first comprehensive environmental rating system for buildings in Malaysia that acts to evaluate the environmental design and the building performance, which is useful for the developers to design, build and operate a sustainable building (Kamaruzzaman & Zulkifli, 2014). The GBI system was launched by the Minister of Works on May 21, 2009, to facilitate and encourage the property developers and the construction stakeholders to design and develop sustainable buildings in Malaysia (Kamaruzzaman & Zulkifli, 2014; Mohd Fairullazi, 2014). In Malaysia, the maintenance of the building is a critical component in the GBI to achieve a sustainable development goal (Olanrewaju & Abdul-Aziz, 2014). The university building requires a complex operational need since it includes the classrooms, offices, libraries etc. The university building is procured to provide a suitable, conducive and adequate environment to support and stimulate the academic activities (Olanrewaju & Abdul-Aziz, 2014).

In the early 1990s, the management of library buildings has taken initiatives to be sustainable buildings for academic libraries. The phrase 'green library' refers to a library building that is certified as an environmentally friendly building (Aulisio, 2013). The greening concept is about tackling the world's climate change, which the main reason behind climate change is human activities (Olanrewaju & Abdul-Aziz, 2014). According to Shane (2012), the

green library building is desirable as it can improve the occupants' health and saves energy consumption and cost. Jankowska and Marcum (2010) also agreed with sustainability and environmental education through the implementation of green library practice in the case that it can help to create a sustainable future for libraries.

Lighting System

The lighting system is a crucial part of the buildings to make sure the occupants feel comfort, work in more productivity and a safe environment during the night. Recently, there has been continuous development in the type of lighting and its efficiency. Thus, it becomes possible to use lighting during the day to enhance the daylight and giving dramatic visual effect (Kamaruzzaman & Zulkifli, 2014). Although artificial lighting is preferable to be used in library buildings rather than natural illumination, however, it has been identified that the artificial lighting is inefficient because it consumes more energy when it is operated for long hours (U.S. Department of Energy, 2002; Castanheira et al., 2015). Generally, the lighting system's characteristics comprise of the lumen, lux, and efficacy. According to Aman et al. (2013) lumens are a measurement of the amount of light or a total number of lines of lighting flux emitted from a lighting source. Whereas, lux level also known as illuminance level is used as the SI unit for the illuminance. It measures the direct illumination on one square meter of surface area (Chin, Ahmad, Yik & Kuan, 2013). Efficacy, as defined by Aman et al. (2013), is a measurement of how many lumens are given out (non-electrical quantity) for given electrical input power (Watt).

Since many current lighting technologies are highly inefficient, improved technologies for lighting hold great potential for energy savings and for reducing the associated greenhouse gas emissions (Muhamad, Zain, Wahab, Aziz & Kadir, 2010; Aman et al., 2013). Various types of lamp are commonly being used as a lighting system such as (1) Incandescent Lamps (IL), (2) Fluorescent Lamps (FL), (3) Compact Fluorescent Lamp (CFL) and (4) Light Emitting Diode (LED). The summary of the advantages and disadvantages of these types of lamps are presented in Figure 2. Based on the comparisons of types of the lamp in Figure 2, it can be seen that the types of the lamp also contributed to the energy efficiency of the lighting system in the university library building. For example, the usage of LED is more energy efficient

compared to the usage of IL. However, the application of LED is limited in the university library building as the initial cost for the LED is higher than the IL.

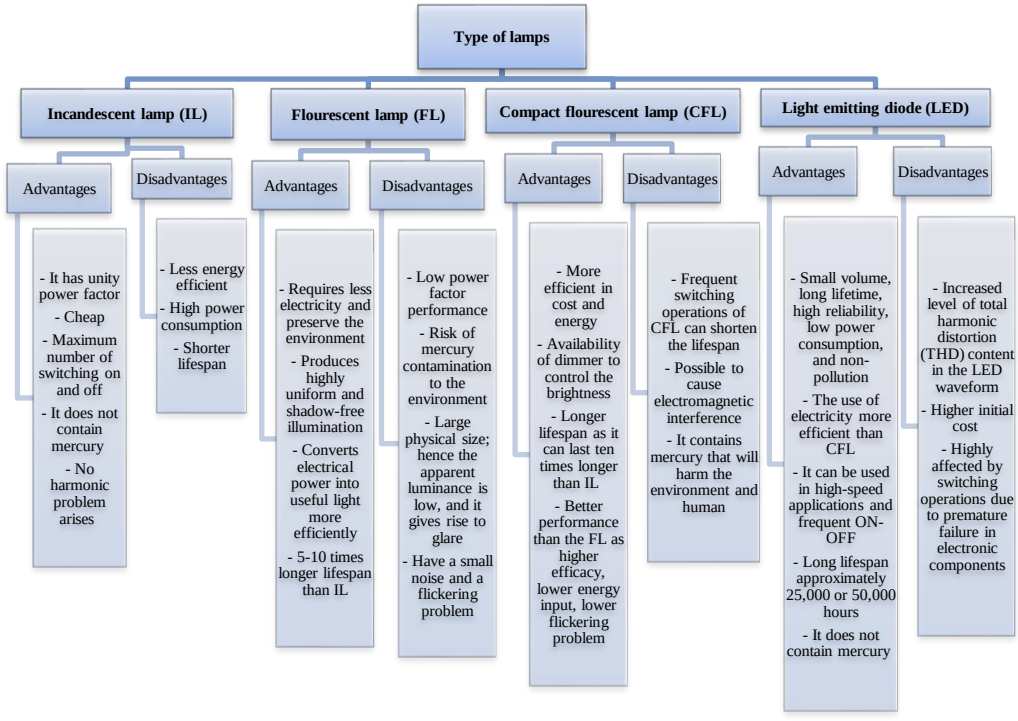

Fig. 2 : Advantages and disadvantages of different types of lamps
(Source: Aman et al., 2013; Chin et al., 2012; Horng et al., 2014; Mahlia et al., 2011; Narendra & Devendra, 2008; Nikolaos et al., 2012; Tatsiana et al., 2012)

Muhamad et al. (2010) stated that lighting had contributed 19% of electricity consumption. This is agreed by Nikolaos et al. (2012**)** and also a study by Mahlia et al. (2011) when they mentioned that it is up to one-third of the total buildings' electric energy consumption is accounted from lighting. Based on previous researches (Muhamad et al., 2010; Mahlia et al., 2011; Nikolaos et al., 2012), it was found that one way to reduce electricity consumption is by adopting energy efficient lighting. This can be done by selecting lamps that are suitable for the purpose and have high efficacy. Hartungi (2009) also pointed out that the potential energy saving can be achieved if the building is designed to be energy efficiency technologies. Therefore, according to the Sustainable Energy Authority of Ireland (2010), they have outlined some criteria that need to be considered to achieve energy efficient lighting. The criteria are as follows:

i) Daylight availability
ii) Selection of lighting source

iii) Colour appearance of the light source
iv) Lifespan of the lamp
v) Luminaires efficiency

vi) Light distribution
vii) Luminaires position
viii) Controls of light source

Challenges of Implementing Energy Efficiency Lighting System

However, there are some barriers to implementing the energy efficient lighting system. Capital costs become the most vital barriers to investment in energy-efficient technologies because of the requirements of high investment in the lighting system of a library building (Lena, Luis & Elvira, 2009; Marquez, McGregor & Syme, 2012). Besides that, Marquez et al. (2012) also highlighted that the government and higher authority in an organisation plays a vital role in the making decision process for investing capitals and the implementation of regulations. Thus, in this study, the researcher has carried out a series of face to face interview to collect the opinions of the respondents who have knowledge and experience in the lighting system of university library building regarding the energy efficiency of the lighting system in the university library building.

RESEARCH METHODOLOGY

A research strategy is a step-by-step process in designing research flow, which can be divided into three main techniques namely qualitative, quantitative and mixed methods research (Naoum, 2013). In this research, qualitative research has been adopted rather than quantitative research because the issues of the study can be examined in detail and in depth using qualitative research. The qualitative method used is based on human experience and knowledge, which sometimes more compelling than quantitative data. In this study, the method used fits with the exploratory nature of the research objectives, which is to investigate the energy efficiency of the lighting system in a university library building by observing and analysing opinion from respondents who have knowledge, skills and experience in the energy efficiency of the university library building. This qualitative research comprises of case study approach and a semi-structured interview.

For this study, a literature review was conducted to review the common types of the lighting system and energy efficiency in building with specific reference to the university library building. The literature review was carried out during the initial stage of the research to have a general overview of what other researchers have studied, thought and discussed on the research topic. Primary data is the first-hand data obtained through fieldwork approach, which are the case study and semi-structured interview.

Fieldwork Approach

A case study is a study in detail of a particular research problem rather than an extensive statistical survey or comprehensive comparative inquiry (Naoum, 2013). It is used to narrow down a vast field of research into one or a few easily researchable examples. The case study approach was selected for this research to provide an in-depth analysis of the energy efficiency of the lighting system in the university library. In addition, literature review has identified several past researchers that have chosen case study as a method to study the energy efficiency of lighting system in the buildings, i.e. Mahlia et al. (2011), Chin et al. (2012), Gul and Patidr (2015) and Xuan and Hogyan (2011). In this study, the researcher has chosen library building in one of the public universities in Malaysia as the subject of a case study to investigate the energy efficiency of the lighting system used in the building operation. It is crucial for the library building to be energy efficient since the operation hours of the university library is more than 8 hours per day.

Besides that, a semi-structured interview also was adopted to ascertain the respondents' opinions, knowledge and experiences of the lighting conditions used in the case study selected (Naoum, 2013). A semi-structured interview consists of 'open-ended' and 'closed-ended' questions, which has been prepared for the interview so that the respondents could explain and describe their experiences or opinions relating to the subject of this study. This method is used to gain in-depth knowledge, opinions and ideas from the respondents who have knowledge and skills regarding the energy efficiency of the lighting system used in the university library building.

In this research, the semi-structured interview questions were divided into two sections, which are section A and section B. Section A presents the background details of the respondents, while section B provides the electrical energy consumption information of the lighting system in the university library. The questions imposed to obtain the general knowledge of the respondents on the lighting system used in the building and required them to give opinion relating to energy efficiency implementation in the university library building. A two-round of the pilot questionnaire was carried out by face to face discussion with the research supervisor due to time constraint. This pilot study aims to identify mistakes and problems that the potential respondents might face to understand the questionnaire and to improve the quality of the questionnaire.

For this research, the selected sampling is adopted since the research required the expertise and experienced respondents to give opinions on the selected subject. The population of this study consists of the expertise on the electrical energy in the building, the library building operator and the person-in-charge for the maintenance of the lighting system in the university library.

After the sampling selection was made, the potential respondents were approached to set an appointment for the interview session. The respondents have briefly explained the purpose of the study and the questions that are going to be asked in the interview session. This includes negotiating their terms of engagement, the interview subject, how the information would be used and their confidentiality.

Data Analysis

Data analysis was based on examining, classifying and tabulating the evidence gained from the interview sessions. All the information obtained during the findings stage was analysed, and interpretation works were conducted. In this stage, the recording of information, analysing of data and interpretation of facts is crucial (Naoum, 2013). The interview session was audiotaped with the respondents' permission. During the recording of the information stage, all data collected were transferred into writing manner which interview recorded were transcribed and translated into tables and in written form before the analysing of facts took place.

The transcription of the data is produced manually using Microsoft Word 2010, by listening to the recorded audio tapes together with the observational notes. The transcribed interview is then studied to identify the main themes, which are related to the energy efficiency of the lighting system in a university library. The contents of the interviews were analysed to determine the themes that emerge from the responses given by the respondents. The face to face interview data transcription was compiled and indexed according to the following themes:

i) Electrical energy consumption in the university library
ii) Types of lighting system used in the university library
iii) Criteria of energy efficiency for lighting system in the university library
iv) Setbacks that can hinder the implementation of energy efficiency procedures in the university library
v) Suggestions to implement the energy efficiency of the lighting system in the university library

For the data analysis, the four respondents are characterized as R1 to R4.

RESULTS AND DISCUSSION

Based on the case study carried out, the university library building has a spacious area of more than 25,000 square meters, which provides a large and favourable environment with carrel rooms, research rooms, discussion rooms, computer labs, etc. It is a well-equipped institution that aims to serve the community with a dynamic learning environment for its teaching, learning and research purposes. Generally, the library operation hour is from 8.00 am to 10.45 pm, which shows that its operation exceeded the regular working hours (i.e. 8 hours). Thus, it has been reported that long operation hours has resulted in the building to have the highest electrical energy consumption. In addition, to ensure the university library building in good condition, an Integrated Facilities Management Services (IFMS) company has been employed by the university; called Company A. Company A has been out-sourced to carry out the function of operation and maintenance of the university buildings including the library building. This IFMS services covers the mechanical and electrical aspect of the building, civil and structural, custodial service and also in other related services to ensure the quality of service delivered to the users.

Besides that, a series of four semi-structured interviews were conducted to obtain detailed opinions from the experienced respondents in the building operation and lighting system. The respondents are selected based on their position and experience in the electrical system of the building. In Section B, the interview was conducted to gain information on the lighting system used in the university library building and its relation to energy efficiency.

The four respondents stated that the library building used the Fluorescent lamp (FL) for its lighting system. All the four respondents have positive responses on the high electrical energy consumption for the current lighting system, and they have agreed that it is due to the types of lighting system used, operation hours and the number of lamps used in the building. Based on the finding in Figure 3, it is in agreement with the study by Mahlia et al. (2011) that the most common type of lighting system used recently in the building is the fluorescent lamp. The fluorescent lamps are used because it is cheaper than any other energy efficiency lighting. However, according to the findings in this study, there is a large number, which is about a hundred fluorescent bulbs have been replaced per day due to the short lifespan of the fluorescent lamps. Besides that, the average amount of energy consumption in the library building is about one million kWh per month. Nevertheless, a study by Mohd Fairullazi (2014) has mentioned that a green building with an energy efficiency consideration was designed for operating less than 200 kWh per square meter per year. This shows that the library building has spent a high cost of energy consumption to operate the lighting system in the building.

The respondents also were asked about the criteria of energy efficiency of the lighting system as indicated in Table 1. In reviewing the literature, scholars have mentioned that there are several criteria need to be taken into consideration for implementing the energy efficiency in the lighting system (Kamaruzzaman & Zulkifli, 2014; Liu, Shek, Lee & Li, 2013 & Sustainable Energy Authority of Ireland, 2010). Contrary to expectation, as in Table 1, there are four top

criteria in the ranked list of eight criteria outlined in this research with the highest rank were chosen by the respondents to be considered in the guideline for implementing energy efficient lighting. The four criteria are the selection of light source, the colour appearance of the light source, light distribution, and controls of the light source are factors to be considered to install an energy efficient lighting system in the library building. Even though only half of the criteria listed were selected by the respondents, this study shows that the majority of the respondents shared the same opinion on the criteria to implement the energy efficiency of the lighting system in the university library building. Besides that, the result in Table 1 indicates that the respondents have knowledge and awareness on the importance of energy efficient lighting system in the university library building and the appropriateness of the criteria of energy efficiency selected for the lighting system in the university building.

However, in this study, all of the respondents have answered that there is no procedure for the energy efficiency of lighting system implementation in the university library building. This is the main reason why the implementation of energy efficient lighting system in the university library building in very limited. Thus, they have outlined several suggestions to implement the energy efficiency of the lighting system in the university library under the study. They have suggested that the university authority needs to provide a guideline for the energy efficient lighting installation. This finding corroborates the outcome of the study by Trianni and Cagno (2012) and Marquez et al. (2012), which they have stated that the higher authority plays a vital role in making a decision and providing guidelines for the adoption of energy efficiency in a building and cost-effectiveness. This is also with an agreement with Olanrewaju and Abdul-Aziz (2014) that there is a lack of logical, holistic and consistent reference point among the universities for maintenance management frameworks.

Energy efficiency is a significant input in assisting the building owners and clients to achieve the best value for money decision making by helping them to attain potential cost saving in the building operation (Mohd Fairullazi & Khairuddin, 2013; Mohd Fairullazi & Khairuddin, 2016). Therefore, an appropriate system needs to be developed to provide suitable procedures on how the user can achieve cost-effectiveness and energy efficiency of the

lighting system in the library building under the study. Plus, the respondents also suggested that there is a need to install a control device in the particular area of the library such as the reading and book section which the lighting can be turned off when the device detected no occupant. The majority of the respondents also agreed that the current lighting system in the university library under the study should be replaced with more cost-effectiveness lighting such as LED. The respondents concurred that replacement cost for changing the current lighting system with the energy efficient lighting system is high;

however, they believe that this will provide optimum future cost as compared to other lighting systems. These present findings seem to be in line with other studies that discussed the lack of investment capital and limited knowledge on the energy efficiency of the lighting system (Marquez et al., 2012; Nam-kyu & Eunsil, 2013; Olanrewaju & Abdul-Aziz, 2014).

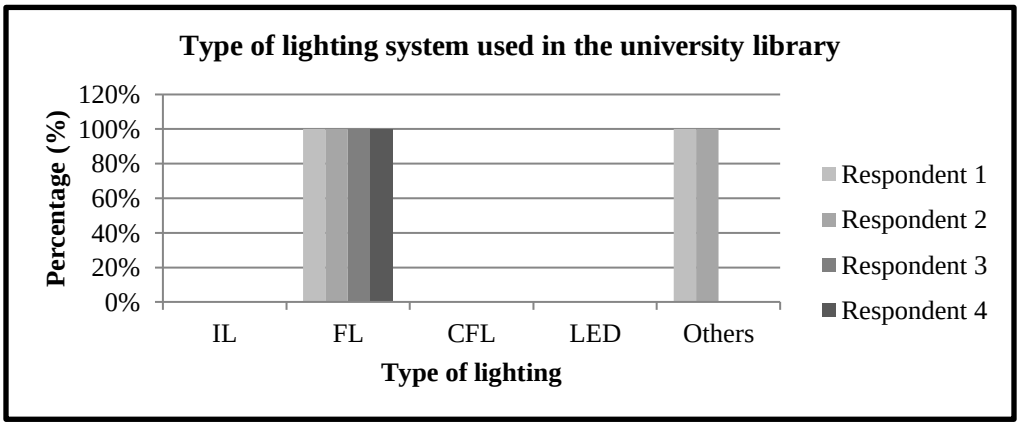

Fig. 3 : Lighting system used in the university library

Table 1 Criteria for an energy efficient lighting system

Criteria of energy efficient lighting system	Respondent's opinion	Total criteria selected
Daylight availability	R3	1
Selection of lighting source	R1, R2, R3, R4	4
Colour appearance of the light source	R1, R2, R3, R4	4
The lifespan of the lamp	R2, R3	2

Luminaires efficiency (luminaires' Light Output Ratios (LOR))	R3	1
Light distribution	R1, R2, R3, R4	4
Mounting height of light source (for illumination and maintenance)	R3	3
Controls of the light source (by time, occupancy and daylight availability)	R1, R2, R3, R4	4
Others	-	

CONCLUSION AND RECOMMENDATION

This paper has presented the outcomes of investigation on the energy efficiency of the lighting system in the university library building. There are two approaches adopted in this study, which are the case study and semi-structured interview. Based on the primary data collection, the type of lighting system used in the library building is the Fluorescent Lamp (FL). Besides that, the results of this interview with the experienced respondents who involves in the library building operation show that the university library does not adopt the criteria of energy efficiency lighting when choosing the lighting system. Due to this, the university library has consumed much electrical energy for its current operation. This also leads to the high operating cost of the library building. To overcome energy waste, the majority of the targeted respondents proposed that the university authority needs to develop a proper guideline that provides step-by-step procedures for energy efficiency of the lighting system for the university library under the study. This guideline would improve awareness among building users to optimise energy consumption concerning the lighting system and its operation. The study concludes that it is appropriate for the university library to be installed with a lighting control system, such as a sensor device, in some areas of the building for the light to be turned off when there is no occupant. Besides that, the current light fittings used in the university library should be replaced with more cost-effectiveness lights such as LED.

Nonetheless, this research has faced several difficulties to obtain data which most of the constraints are related to data, time and human resources. First, there is a limited number of study have been done on the energy consumption in the university library building with specific reference to the lighting system. Besides that, this research only involved a small number of respondents, which only four respondents have been interviewed due to the limited number of experienced respondents in the lighting system of the university building. The primary data collection using the semi-structured interview was time-consuming since the respondents are hard to approach due

to their tight schedules. Thus, it is beyond the control of the researcher if the targeted respondents were unable to spend the time to be interviewed.

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