A STUDY OF ENERGY EFFICIENCY BUILDING LIGHTING SYSTEM DESIGN

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ABSTRACT

A considerable portion of the energy consumed in the electrical system in the world today is converted to artificial lighting. Light is essential to harmony between the activities of people in the contemporary world. With the increase in the energy consumption by different segments in relation to the difficulty of generation, it is possible to see the importance of efficient ways of lighting. This research discusses the performance of different lighting system in the Masjid Tanah Community College (MCTT) and saving the energy consumption in the laboratory lighting application. DIAlux software is used to study and evaluate the efficiency lighting scheme through the three (3) different type lighting system. DIALux 4.10 Lighting Wizard software is used to design and evaluate artificial lighting scheme with similar illumination abilities for the same office space through the use of different types of lamps and the simulation results are highlighted. Its cost effectiveness is also studied. The impact of use of natural lighting and artificial lighting on heating, ventilating and air conditioning (HVAC) system is examined and highlighted. The major findings in this research are the energy-efficient lighting design could still be achieved without sacrificing the visual comfort and quality of lighting and replacement of older fixtures with new luminaries can improve.

ABSTRAK

Sebahagian besar tenaga yang digunakan dalam sistem elektrik di dunia hari ini ditukar kepada cahaya lampu. Cahaya adalah penting untuk keharmonian dalam aktiviti dalam dunia kontemporari. Dengan peningkatan dalam penggunaan tenaga pada generasi sekarang dengan pelbagai segmen ia adalah kemungkinan untuk melihat kepentingan cara yang kecekapan. Kajian ini membincangkan prestasi sistem pencahayaan yang berbeza di Kolej Komuniti Masjid Tanah (KKMT) dan penjimatan penggunaan tenaga dalam system pencahayaan makmal. Perisian DIAlux digunakan untuk mengkaji dan menilai kecekapan pencahayaan melalui tiga (3) jenis sistem lampu yang berlainan. Perisian DIALux 4.10 *Lighting Wizard* digunakan untuk merekabentuk dan menilai pencahayaan lampu dengan kebolehan pencahayaan dan ruang pejabat yang sama melalui penggunaan pelbagai jenis lampu dan akhirnya keputusan simulasi diketengahkan. Keberkesanan kos juga dikaji. Kesan penggunaan cahaya semula jadi dan cahaya lampu pada sistem *heating, ventilating and air conditioning* (HVAC) diperiksa dan dianalisis. Penemuan utama dalam kajian ini ialah reka bentuk kecekapan tenaga cahaya lampu boleh dicapai tanpa mengabaikan keselesaan visual dan kualiti pencahayaan. Berikutan dengan itu penggantian pemasangan yang lama dengan sistem lampu baru dapat dilakukan.

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CHAPTER 1

INTRODUCTION

A considerable portion of the energy consumed in the electrical system in the world today is converted to artificial lighting. Light is essential to harmony between the activities of people in the contemporary world. With the increase in the energy consumption by different segments in relation to the difficulty of generation, it is possible to see the importance of efficient ways of lighting.

1.1   Research background

In educational buildings a significant component of the energy used is spent in illuminating the interior of the building. As the energy costs rise, increasing effort has gone into minimizing the energy consumption of lighting installations. This effort could follow three basic directions: new more efficient equipment (lamps, control gear, etc.), utilization of improved lighting design practices (localized task lighting systems), improvements in lighting control systems to avoid energy waste for unoccupied and daylight hours. Lighting plays an important role in the classroom. Having the dynamics of daylight in a classroom improves concentration and keeps young minds alert. This aids a healthy attitude to learning.

This paper discusses the performance of different types of lighting installations used for Masjid Tanah Community College (MTCC). Initially, the researchers described the important of understanding energy efficiency on campus. Later, the result can be used as a reference for a new lighting system to improve energy consumption on the campus. These solutions harness people's visual, emotional and

biological responses to light to enhance learning environments. It was described as a preliminary point to conserve energy consumption.

1.1.1   The important of understanding the high energy efficiency on campus

The use of energy in buildings has increased in recent years because of the growing demand in energy used for heating, ventilating and air conditioning (HVAC) and lighting in buildings. Owing to the consistently growing demand, much effort has now been put towards reducing the demand for energy through energy efficiency in design. Energy efficiency is energy intensity, which, in simple terms, refers to the use of less energy to provide the same level of energy service or to do more work with the same unit of energy (EIA; 1 IEA; 2 Fickett *et. al*, 1990). This objective can be achieved primarily by using a more efficient technology or process rather than by changes in individual behaviour (Diesendorf, 2007).

1.1.2   High energy efficiency as a holistic tool to improve energy consumption on campus

The baseline energy and emissions scenarios for the higher education sector are presently unclear, which needs further investigation to create a reliable foundation for target setting. Without these baseline scenarios, it is also very hard to assess the environmental effectiveness of the existing policies and initiatives (Altan, 2010).

According to Altan (2010), there are some problems in establishing the assessment of energy efficiency for a heterogeneous sector as the higher educational institutions. Some barriers that he had identified are, lack of methodology for intervention studies, non-clarity of issues arising from the complex nature of energy demand and use, and complicatedness in establishing boundary conditions for the assessment of energy efficiency performance in heterogeneous sector. Different studies show that there are many situations in which cost-effective energy efficient procedure are not implemented. Furthermore there are a number of reasons that have been identified because lack of information, budget constraints and organizational behavior. In fact, some organizations are not providing information and training for

energy efficiency to their employees and not constantly advocating the importance of energy efficiency in the organization (Paulo and Gomes, 2009).

1.2   Problem statement

i.   Installation Design for good energy usage begins by ensuring that lighting is not spread unnecessarily (Wan Norshafizan ..etc, 2010).

ii. Much lighting in commercial building has in the past been provided by regular arrays of ceiling mounted luminaries which giving uniform illuminance over the specific area.

iii. Energy efficiency is important for some main reasons such as reducing the operating costs and manages the electricity efficiency. High quality lighting design includes the coordinated selection of lighting, fixtures, fixtures placement.

1.3   Objective

The major objective of this research paper identify the energy usage discusses the performance of different types of lighting installations used in MTCC. In order to complete this research few objectives are set, which are:

To identify the ideal number of luminaire needed in certain room.

i.   To determine the minimum required lamps in a specific place without reducing the quality of lighting.

ii. To identify the performance of different types of lighting installations used in the Masjid Tanah Community College and saving in energy consumption in the education building lighting application.

1.4   Project scope

The investigation is done in certain classroom and lab for experimental to calculate the energy used in daytime by referring to the classroom and laboratory due to class timetable.

1.5   Thesis outline

This thesis consists of five (5) chapters. Chapter one (1) will describes the introduction, problem statement, objectives, project scope and research significant.
In chapter two (2), the Literature Review will describe about the energy efficiency and the lighting system. Chapter three (3) will explain about the methodology used to carry out this research and the development process. Chapter four (4) is where the result of testing will be explain and discussed, to conform to the objectives. Final chapter which is chapter five (5) will summarize the whole project development process. Suggestion and recommendation for further improvement and potential development of this application would be done based on the advantages and weaknesses of the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Energy efficiency

Energy efficiency in buildings can be achieved in many ways, but fundamentally, one should not ignore the basics of the passive building designs. Passive building design is one of the main factors determining the building's energy performance, besides building services design and appliances and occupant behaviors (Al-Mofleh, Taib, Mujeebu, & Salah, 2009), the latter factors are difficult to control and maintain.

The efficiency of electricity use in each residential college was evaluated by adapting a method from (Saidur, Hasanuzzaman, & Rahim, 2010) who estimated energy intensity, EI in kWhlm2 by using following equation:

$$EI= AEC\ /TFA \qquad\qquad (2.1)$$

Where, AEC is annual energy consumption (kWh) and TF A is total floor area (m2). Principally, (Kamaruzzaman & Edwards, 2006) stated that the energy use per unit floor area can be described as 'Normalized Performance Indicators' (NPI), which is also known as the energy use index or Building Energy Performance (BEP) (Griffith, Long, Torcellini, & Judkoff, 2008).

Consequently, the ten BEP will be used in this study to indicate the performance of electric use at the residential colleges, while Energy Efficiency Index (EEl) will be used to elaborate kWh/m2/year (Chou, 2004). Referring to Iwaro & Mwasha (2010), energy use in residential buildings is usually 10- 20 times lower compared to office buildings. Thus, the electricity usage in residential buildings in Malaysia amounts to approximately 10 to 25 kWh/m2/year if the electricity use in

office buildings in Malaysia is in the range of 200 to 250 kWh/m2/year (Jamaludin, Inangda and Mohdariffin, 2011).

2.1.1   Glare

If the light too bright, glare will result and may affect visibility. Disability glare usually happens when broad-band light illuminates on workstation, like light from window.

Reposition the workstation to prevent such light sources falling within the field of vision. For example, align your workstation at right angle to windows and similar light sources.

Figure 2.1 : Disability glare from a light fitting

Figure 2.2 : Disability glare form windows

Discomfort glare does not cause direct visual interference, but it can be annoying or uncomfortable. It can be caused by direct or reflected light. This can be avoided by:

i.   Reposition the light source and, or workstation appropriately.

ii. Avoid the use of well-polished surfaces and

iii. Reduce the contrast between your work area and its surrounding.

Figure 2.3 : Veiling reflection: the reflection of light is masking information on the screen.

2.1.1.1   UGR Method

The "Unified Glare Rating" method (UGR) is a method developed by the International Lighting Commission CIE (Commission International de l'Eclairage) to standardized glare assessment worldwide.

In contrast to previous methods, where glare was rated using the luminance of a single luminaire, the UGR method calculates the glare of the entire lighting installation at a defined observer position. DIN EN 12464-1 provides the UGR reference value for a standard room. Modern lighting design software makes it possible to calculate the precise UGR value for a defined observer position in a room. The lower the UGR value, the lower the glare. Where luminance is < 1,000 cd/m² (luminous intensity per unit area), the elevation angle – 65°, 75° or 85° – is also indicated. This is the critical angle above which the luminaire has an all round luminance of 1,000 cd/m².

The UGR method relates to glare from ceiling fixtures that are placed in a regular pattern. European standard EN 12461, Lighting of Indoor Work Places, contains a table in which the maximum allowed UGR value is prescribed per type of room and per type of activity. The UGR method produces a scale figure: below 13 no glare 13 – 16 suited for accurate eye tasks 16 –19 suited for average eye tasks 19 –22 suited for moderate eye tasks 22 –28 suited for simple eye tasks above 28 not suited for work lighting .(*technical guides emergency lighting guide*, n.d.)

Table 2.1 : Glare rating according to UGR

glare rating according to UGR											
ρ-ceiling		70	70	50	50	30	70	70	50	50	30
ρ-walls		50	30	50	30	30	50	30	50	30	30
ρ-workplane		20	20	20	20	20	20	20	20	20	20
room dimensions X	Y	viewed crosswise					viewed endwise				
2H	2H	15,3	16,7	15,6	16,9	17,1	15,3	16,7	15,6	16,9	17,1
	3H	15,6	16,6	15,8	16,8	17,0	15,6	16,6	15,8	16,8	17,0
	4H	16,1	17,1	16,4	17,3	17,5	16,1	17,1	16,4	17,3	17,5
	6H	16,5	17,4	16,8	17,7	17,9	16,5	17,4	16,8	17,7	17,9
	8H	16,7	17,6	17,0	17,9	18,1	16,7	17,6	17,0	17,9	18,1
	12H	16,8	17,8	17,1	18,0	18,3	16,8	17,8	17,1	18,0	18,3
4H	2H	15,2	16,1	15,4	16,3	16,5	15,2	16,1	15,4	16,3	16,5
	3H	16,5	17,4	16,8	17,7	17,9	16,5	17,4	16,8	17,7	17,9
	4H	17,2	18,1	17,5	18,4	18,7	17,2	18,1	17,5	18,4	18,7
	6H	17,5	18,2	17,8	18,6	18,9	17,5	18,2	17,8	18,6	18,9
	8H	17,7	18,4	18,1	18,8	19,1	17,7	18,4	18,1	18,8	19,1
	12H	18,0	18,7	18,5	19,1	19,5	18,0	18,7	18,5	19,1	19,5
8H	4H	17,3	18,0	17,7	18,3	18,7	17,3	18,0	17,7	18,3	18,7
	6H	18,2	18,9	18,6	19,3	19,7	18,2	18,9	18,6	19,3	19,7
	8H	18,6	19,2	19,0	19,6	20,1	18,6	19,2	19,0	19,6	20,1
	12H	18,7	19,2	19,2	19,7	20,2	18,7	19,2	19,2	19,7	20,2
12H	4H	17,5	18,2	17,9	18,6	19,0	17,5	18,2	17,9	18,6	19,0
	6H	18,4	19,0	18,8	19,4	19,9	18,4	19,0	18,8	19,4	19,9
	8H	18,6	19,1	19,1	19,6	20,1	18,6	19,1	19,1	19,6	20,1
variation of observer position											
S =	1,0H		+0,2/	–0,2				+0,2/	–0,2		
	1,5H		+0,4/	–0,6				+0,4/	–0,6		
	2,0H		+0,8/	–1,0				+0,8/	–1,0		
standard-table				BK04					BK04		
correction for luminaire				–8,1					–8,1		
correct glare indices for a total flux of 1200lm											

2.1.1   Uniformity

Uniform light and brightness levels across a space can be desirable but may also be boring; in such cases, sparkle elements, color and/or other methods can be employed to create visual interest without causing fatigue.

Flicker or strobing of luminaires can cause annoyance as well as headaches and fatigue. This may be caused by fluorescent ballasts near the end of life or placement of

luminaires in relation to ceiling fans. If ceiling fans are required in a space, position the luminaires so that they are suspended below the level of the fans.

Requirements for appropriate uniformity by followed IESNA uniformity criteria for specific areas unless superseded by other UFC criteria. Considerations for appropriate uniformity in office areas, uniformity should not exceed 5:1 in immediate work surrounds, and not including accent lighting. Exterior uniformity should not exceed 10:1 along areas of use including roadways, walkways, and parking areas.

2.1.2 Colour Rendering Index (CRI)

Color rendering relates to the way objects appear under a given light source. The measure is called the "color rendering index", or CRI. A low CRI indicates than objects may appear unnatural under the source, while a light with a high CRI rating will allow an object's colors to appear more natural. For lights with a "warm" color temperature the reference point is an incandescent light. For lights with a cool color temperature the reference is sunlight. The table below lists typical color rendering index ratings for a variety of lights, including compact fluorescent light (CFL) bulbs.

Table 2.2 : Colour Rendering Index

CRI		
22	high pressure sodium lighting	street lighting
62	common 4 foot fluorescent tube	office
80-85	compact fluorescent lighting (warm white)	residential
85	premium 4 foot fluorescent tube	retail
80-90	solid state LED lighting	residential
95	incandescent light bulb	residential

Lights with CRIs of 80 or higher are generally considered to have a high CRI. CRI values should only be compared when the light sources being compared have similar color temperature ratings.

2.2 Lighting System

Lighting affects almost every aspect of our lives good lighting is invisible. You only notice the lighting of a room if it's too bright or too dim, not if it's just right. Lighting has a direct impact on the quality of our lives -good lighting enhances the mood and desirability of spaces and contributes greatly to a sense of well-being.

From the student perspective, the visual environment should be conducive to studied. Studies show that a well-designed working environment can aid recruitment and the retention of student as well as improving their morale. Another role that lighting can play is to make the environment of the class easy for lecturing and experimental studies. It needs to be visually prominent and provide lighting with maximum efficiency for all users. The immediate environment should be harmonious with variety of luminaires to give the eyes a chance to rest.

The most common aspects of lighting that cause visual discomfort are insufficient light, too much variation in illuminance between and across working surfaces, glare, veiling reflections, shadows and flicker. All these aspects are considered in the proposed design.

Natural illumination in the office buildings requires correctly designed passive architecture to provide sufficient day lighting at some distance into the building but can also cause glare, overheating, high heating and cooling energy costs (Soori & Alzubaidi, 2011). Thus, artificial illumination is required to supplement daylight on a temporary or permanent basis. The basic parameters used in lighting design are luminous intensity, luminance, luminous flux and illuminance. Table 2.1 shows different types of lamps used in lighting applications with their luminous efficiency and lamp service life. (Soori & Alzubaidi, 2011). In this research we only concentrate 3 different type of lighting which is T8, T5 and LED.

Table 2.3 : Lamp efficiency and service life

Type of Lamp	Lumens per watt	Average lamp life in Hours
T5	8-25	1000-2000
T8	60-600	10000-24000
LED	28-79	25000-100000

The energy used by lighting system depends on both the power rating of lamps used and the time. Energy efficiency can be achieved by using the most effective and efficient lighting equipment and control that can keep the energy requirement minimum whilst achieving the lighting design objectives

2.2.1   Illuminance

Illuminance levels are specified for specific visual tasks area. Illuminance is the luminous flux density at a surface measured in lumens per square meter (lm/m2) or Lux (lx). Light quality is an important factor in the design as it affects how well people can see to do visual tasks and how visually comfortable they feel. Also, it is important to energy efficiency because spaces with higher quality lighting need less illumination and less light fittings

2.2.2   Heat dissipation

At rated power, T5 and T8 fluorescent lamps generate about 73%–77% of their total power as heat, while three types of high-brightness LEDs dissipate about 87%–90% of input power as heat. Heat dissipation is an important factor particularly for air-conditioned buildings when overall energy efficiency is considered. (Qin, Lin, & Hui, 2009)

Table 2.4 : Comparison of luminous efficacy and heat dissipation of LEDs and fluorescent lamps

At full power	18W T8 fluorescent lamp (OSRAM)	14W T5 fluorescent lamp (Philips)	LED (Philips)
Rated Efficacy Lumen/watt	61.1	96	40
Measured Efficacy Lumen/watt	60.3	96.7	30 at 3W (heat sink temperature of 80^0C)
Heat Dissipation Factor	0.77	0.73	0.89

2.2.3 Ballast

All electric discharge lamps, each fluorescent lamp requires a ballast to ignite the discharge and to properly control the discharge current. For optimal operation and long lamp life, it is important that the ballast provides adequate open circuit voltage, quick glow-to-arc transition, and low current crest in normal operation (John F. Waymouth, 1971). The choice of the ballast can be either electromagnetic or electronic. Both electromagnetic and electronic ballasts have their own advantages and disadvantages. The conventional electromagnetic ballast (which is sometimes simply called magnetic ballast) is operated at 50- or 60-Hz mains power frequency. It consists of a magnetic choke, a starter, and a power factor correction capacitor. The structure of the ballast system is simple, robust, and reliable. It can be used even under hostile working environments and has a very long service life. That is why electromagnetic ballasts have been around for over 60 years. However, the "conventional" magnetic ballast has its own shortcomings, i.e., poor power regulation ability and high power loss caused by the iron and copper losses in the magnetic choke.
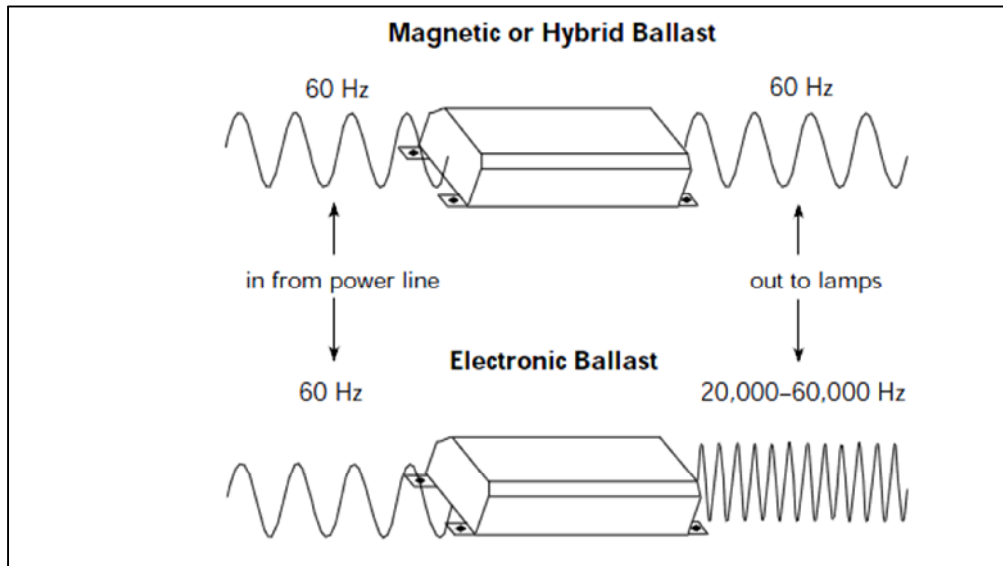
Figure 2. 4: Operating Frequencies (in Hertz of Ballasts)
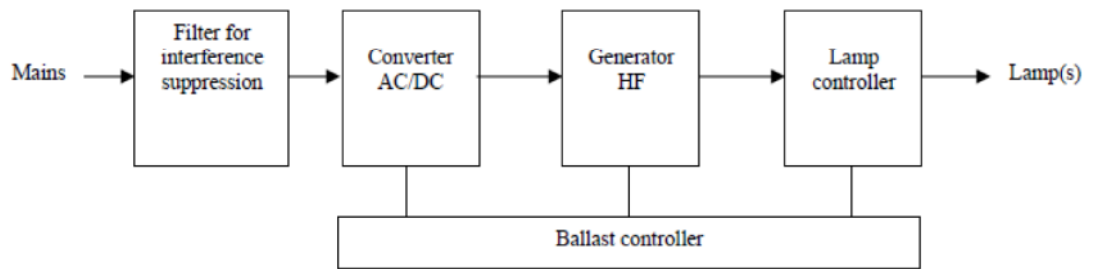
Figure 2. 5 : Block diagram indicating main functions of electronic ballast

The ballast takes advantage of a characteristic of fluorescent lamp whereby greater efficacy is obtained at high operating frequency above 10 kHz. The overall lighting system efficacy can be increased by 20 to 30 percent due to three main factors:

    i.   Improved lamp efficacy at high frequency operation.

    ii. Reduced circuit power losses.

    iii. Lamp operates closer to optimum performance in most enclosed luminaires.
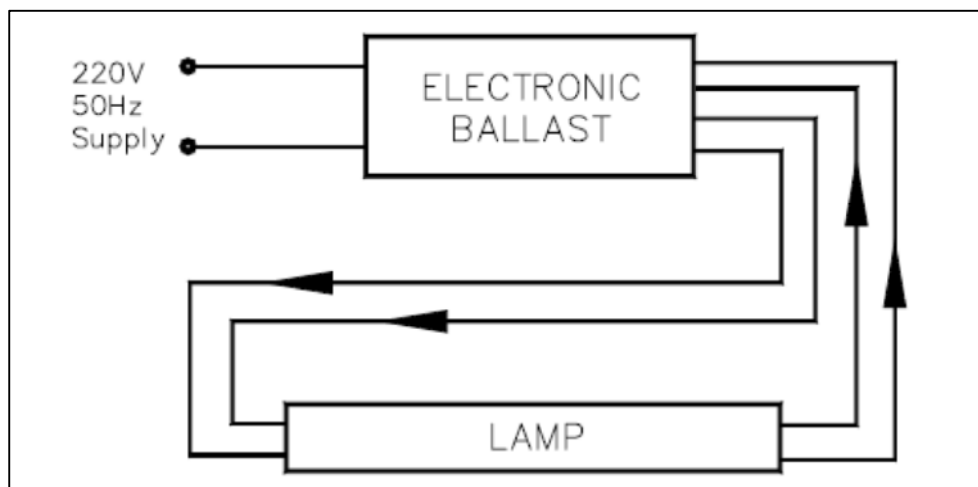
Figure 2.6: Lamp circuit using electronic ballast

Efficacy due to high frequency operation is increased by about 10% thereby enabling the lamp to be operated at a lower input power than at 50Hz mains power frequency. For instance, a 36W 1200mm T8 lamp normally consumes a circuit power of 47W with conventional ballast, can now be run at 36W for the same light output.

The net effect is that same useful light output is maintained at lower power input in a typical luminaire.
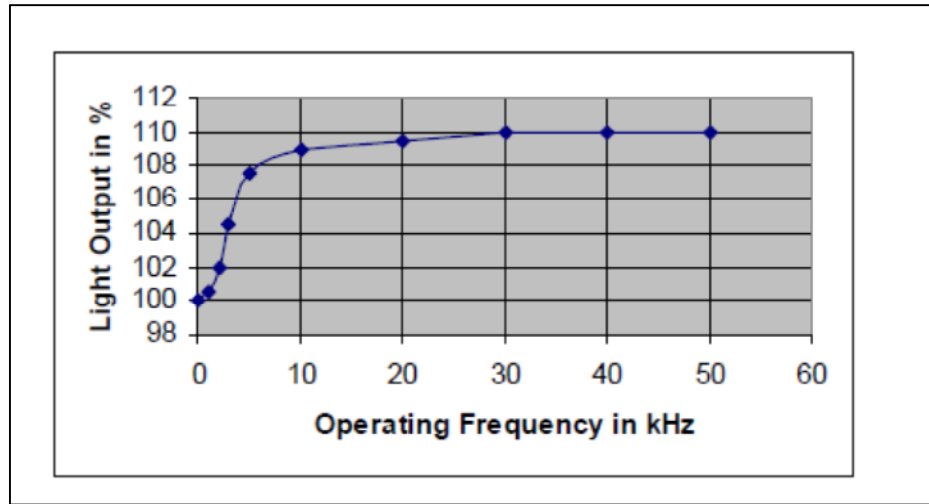
Figure 2.7 : Luminous flux of fluorescent lamp as a function of supply frequency at constant Power

Ballast losses are reduced compared to electromagnetic ballast, as the solid state circuit contains no conventional copper windings. In the case of a twin 1200mm 36W lighting circuit the losses can be reduced from 24W to a mere 6W when using electronic ballast. The overall achievement in a suitable luminaire, therefore, is an energy reduction in the region of 20% to 30%. These energy saving features enable lighting levels to be maintained with a dramatic cut in electricity costs. With less heat generated, the cooling load on air conditioning equipment will also be reduced. Other benefits electronic ballast offered include:

i.   Rapid or instant starting of lamp without flickering.
ii. Single ballast can be designed to drive one, two, three or even four lamps.
iii. Increased lamp life due to lower lamp operating current.
iv. Quiet operation without audible noise.
v.   Dimmable version is also available.
vi. No visible flicker during operation.
vii. No stroboscopic effect and HF operation.
viii. Most modern design has lower total harmonic distortion (THD) than conventional ballast with or without power factor correction capacitor.
ix. High total power factor due to low THD and cos .

    x.   Cooler ambient temperature inside luminaires for optimum operation of lamp, control gear, capacitor and batteries for emergency lighting.

    xi.   Low operating temperature and reduce carbonization and blackening to luminaire and decoration in the vicinity.

    xii.   Less effect on variation of luminous flux due to mains supplies voltage fluctuations.

    xiii.   Much lighter in weight.

Unlike other T8 lamps, the new T5 lamps are especially designed for operation with electronic ballasts for greater efficiency. Table 1 below summarizes the suitability of ballast types for various fluorescent lamp groups.

Table 2.5 : Suitability of ballast types for various fluorescent lamp groups

Lamp group	Conventional ballast	Low loss ballast	Electronic ballast	Dimmable ballast (magnetic)	Dimmable ballast (electronic)
T12 (38mm)			X		X
T8 kryron-filled (25mm)				X	
T5	X	X		X	

CHAPTER 3

METHODOLOGY

The research methodology is directly connected to the problem statement and the goal of research because the research goal and problem may vary different methods of research can be utilized. This chapter will explain about the methodology used to carry out this research. A diagram is produced to illustrate the steps to research methodology. The method used in this research set out to determine the energy efficiency and savings possible using several types lighting system in building in Masjid Tanah Community College (MTCC).

In order to accomplish this research, there are five (5) phase to be complete. The research has been done using Energy Audit Process (WECAM, 2009).

```
┌─────────────────────────────────────────┐
│     Determine the lighting requirement.  │
└─────────────────────────────────────────┘
                   │
                   ▼
┌─────────────────────────────────────────┐
│          Select adequate lamp fit        │
└─────────────────────────────────────────┘
                   │
                   ▼
┌─────────────────────────────────────────┐
│ Estimate the required number of the light fixtures │
└─────────────────────────────────────────┘
                   │
                   ▼
┌─────────────────────────────────────────┐
│             Simulation DIAlux            │
└─────────────────────────────────────────┘
                   │
                   ▼
┌─────────────────────────────────────────┐
│             Operation costs-             │
│             • life cycle cost            │
│             • result payback             │
└─────────────────────────────────────────┘
```
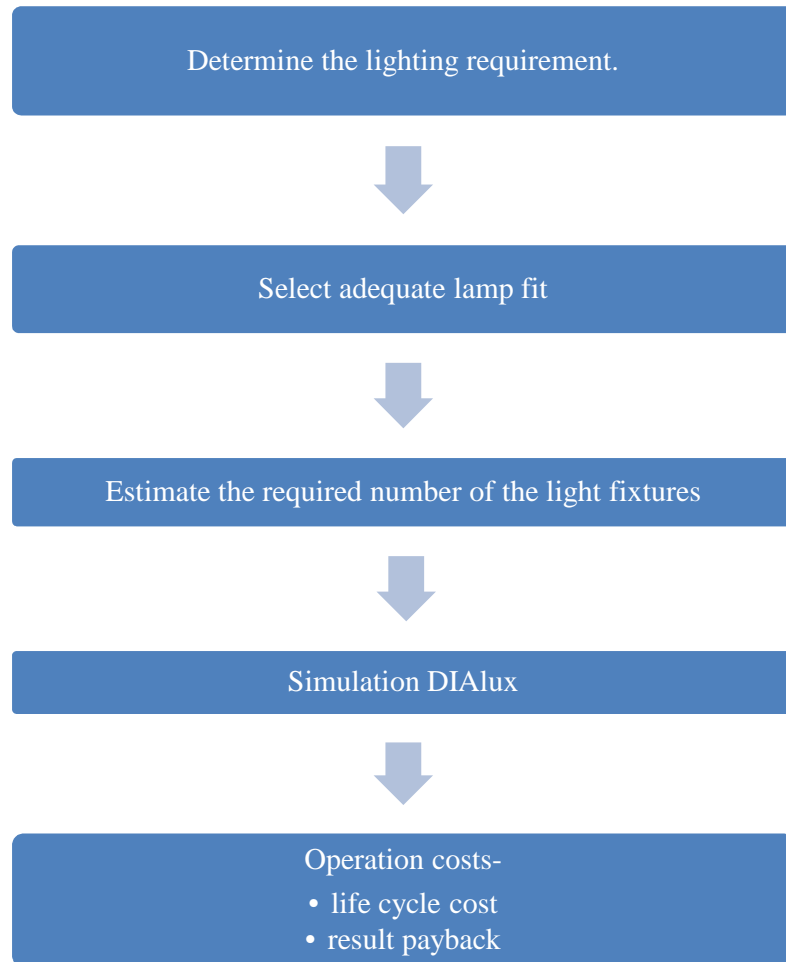
Figure 3.1: Energy Audit Process (Source: WECAM, 2009)
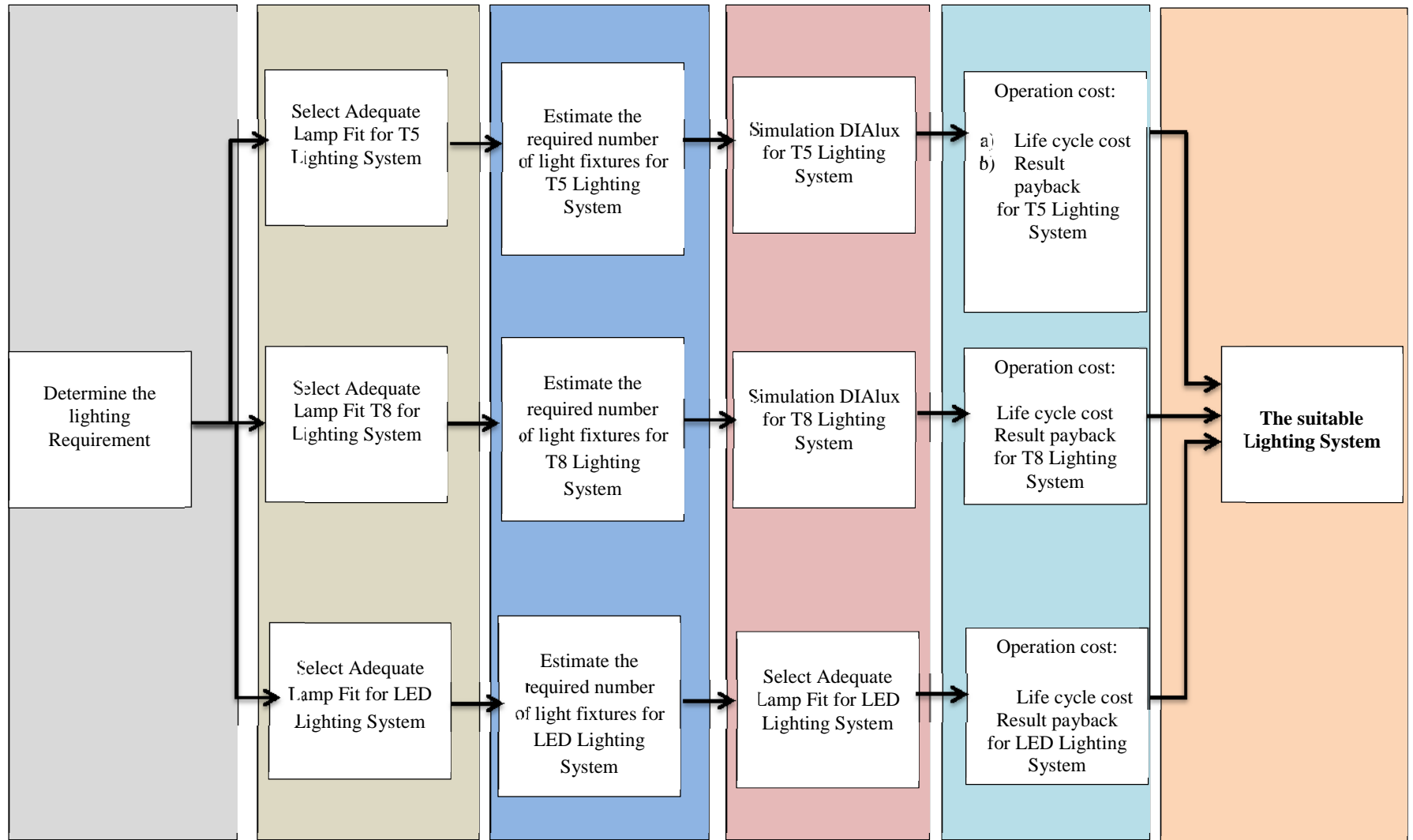
Figure 3.2 : Framework Lighting System

3.1   Determine the lighting requirement

From the flow chart at figure 3.1 the first thing to determine is the lighting illuminance requirement by knowing the lux level. For each area, there is a recommended lux level as in Table 3.1.

Table 3.1: Recommended Lux (lx) values

Area/location	Lux (lx)
Open plan office mainly screen based work	300
Open plan office mainly paper based work	500
Deep plan core area (more than 6m from window)	500
Cellular office-mainly screen based work	300
Cellular office-mainly paper based work	500
Graphics workstations	300
Dealing rooms	300- 500
Executive offices	300- 500

In this research, researcher determine that the room is an open plan office mainly paper based work. Therefore the room needs at least 500 lux based on Raynham (2009) table.

3.2   Select adequate lamp fit

There are 3 different cases will be done in research, which is by using 3 different method of lighting system:

3.2.1   Case 1: Using T8 Lighting System

In this case T8 is the initial lighting system in laboratory at Masjid Tanah Community College (MTCC).

Figure 3.3: T8 Fluorescent lamp Lighting System

Below are the details about the lamp:

Luminaire	: TMS022 2xTL-D36W HFS +GMS022 R
Total Lamp Flux	: 5250 lm
Light Output Ratio	: 0.71
System Flux	: 4757 lm
System Power	: 72 W
LxBxH	: 1.23x0.10x0.06 m
Ballast	: HF Standard

3.2.2   Case 2: Using T5 Lighting System

In case 2, new lighting systems T5 were introduced. It is because to get comparison luminance between T8 and T5 in same group which is a Compact Fluorescent Lamp (CFL).

Figure 3.4: T5 Fluorescent lamp Lighting System

Below are the details about the lamp:

      Luminaire   : TMX204 2xTL5-28W HFP +GMX555 MB

      Total Lamp Flux   : 5250 lm

      Light Output Ratio   : 0.70

      System Flux   : 3675 lm

      System Power   : 62 W

      LxBxH   : 1.17x0.06x0.09 m

      Ballast   : HF Performer

3.2.3   Case 3: Using LED Lighting System

Figure 3.5: LED Lighting System

Below are the details about the lamp:

      Luminaire   : BMS022 2xLT-GA25W/865

      Total Lamp Flux   : 3400 lm

      Light Output Ratio   : 1.00

      System Flux   : 3800 lm

      System Power   : 50 W

      LxBxH   : 1.52x0.10x0.07 m

      Ballast   : NO

3.3   Luminaries

For calculating lighting system basic design is the lumen method. General lighting requirement must be determined for that surface such as number of foot candles (lumen per square foot), room area, light loss due to room proportions, colour of walls, coefficient of utilization and maintenance factor. The researcher shall utilize the 'lumen' manual calculations to compare these to luminaires (T5, T8 and LED) to illustrate the differences before utilizing the real time measurements and the computer program. The calculation can be seen in figure 4.9.1.

$$luminaire, N = \frac{A \times E}{F \times n \times MF \times UF} \tag{3.1}$$

Where:

A = Floor area to illuminate (m^2)

N = Number of luminaire required   (unit)

E = Required flux

F = Initial lamp lumen

n = Lamp per luminary

MF = Maintenance factor

UF = Utilization Factor

Figure 4.9.1 Lumen calculation (Interior Lighting Guide, 1997)

3.3.1   Room Index (RI)

The room index (RI) is the ratio between the surface of the working plane and the half surface of adjacent the walls. This indicates whether is narrow and high, low and wide. These influences the amount of light that is reflected to the working plane form the walls.

The room index need to determine first before proceed with coefficient of utilization. Below is the equation to determine the RI (Wan Norshafizan et al., 2010)

$$room\ index,\ RI\ =\ \frac{L\ \times\ W}{H(L\ +\ W)} \qquad \text{(3.2)}$$

Where

L	= Room length	(meter)
W	= Room Width	(meter)
H	= Room High	(meter)
RI	= Room Index	

3.3.2 Utilization Factor (UF)

The utilization factor indicates how well a lighting installation uses the luminous flux of the lamps. This is indicated as the ratio between the luminous flux that reaches the working plane and the light source of the bare lamps, expressed as a percentage.
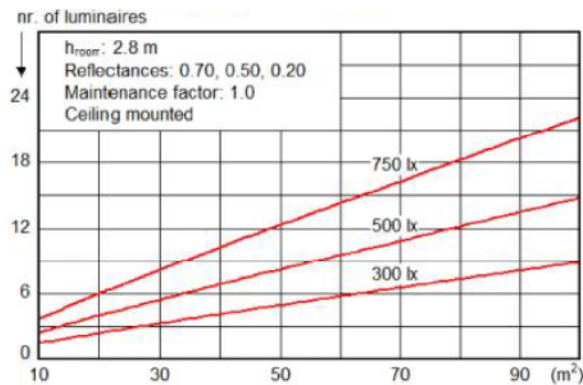
Table 3.2: Quantity Estimation Diagram

Table 3.2 can be referring from the each data sheet type of lighting system at the appendices. By taking the value of reflectance 0.70, 0.50 and 0.20 and the value of room index (k) we can find the value of Utilization factor.

Table 3.3 : Utilization Factor

Room index k	reflectances for ceiling , walls and working plane (CIE)										
	0.80	0.80	0.70	0.70	0.70	0.70	0.50	0.50	0.30	0.30	0.00
	0.50	0.50	0.50	0.50	0.50	0.30	0.30	0.10	0.30	0.10	0.00
	0.30	0.10	0.30	0.20	0.10	0.10	0.10	0.10	0.10	0.10	0.00
0.60	0.34	0.33	0.34	0.33	0.32	0.27	0.27	0.23	0.26	0.23	0.22
0.80	0.42	0.40	0.41	0.40	0.39	0.34	0.33	0.30	0.33	0.30	0.28
1.00	0.48	0.45	0.47	0.46	0.44	0.39	0.39	0.34	0.38	0.35	0.34
1.25	0.55	0.50	0.53	0.51	0.49	0.45	0.44	0.41	0.43	0.40	0.39
1.50	0.59	0.54	0.58	0.55	0.53	0.49	0.48	0.45	0.47	0.44	0.43
2.00	0.66	0.59	0.64	0.61	0.59	0.55	0.54	0.51	0.53	0.50	0.49
2.50	0.71	0.65	0.69	0.65	0.62	0.58	0.57	0.55	0.56	0.54	0.53
3.00	0.74	0.62	0.72	0.67	0.64	0.61	0.60	0.58	0.59	0.57	0.55
4.00	0.78	0.67	0.75	0.71	0.66	0.64	0.63	0.61	0.62	0.60	0.59
5.00	0.80	0.69	0.78	0.73	0.68	0.66	0.65	0.63	0.64	0.62	0.61

Utilization factor (UF) table also can be finding at every each data sheet lighting system at the appendices. Example value of reflectance 0.70, 0.50 and 0.20 and the RI is 1.25 for T8 lighting system so the value of UF is 0.51.

Table 3.3 : Utilization Factor

Room index k	reflectances for ceiling , walls and working plane (CIE)										
	0.80	0.80	0.70	0.70	0.70	0.70	0.50	0.50	0.30	0.30	0.00
	0.50	0.50	0.50	0.50	0.50	0.30	0.30	0.10	0.30	0.10	0.00
	0.30	0.10	0.30	0.20	0.10	0.10	0.10	0.10	0.10	0.10	0.00
0.60	0.34	0.33	0.34	0.33	0.32	0.27	0.27	0.23	0.26	0.23	0.22
0.80	0.42	0.40	0.41	0.40	0.39	0.34	0.33	0.30	0.33	0.30	0.28
1.00	0.48	0.45	0.47	0.46	0.44	0.39	0.39	0.34	0.38	0.35	0.34
1.25	0.55	0.50	0.53	0.51	0.49	0.45	0.44	0.41	0.43	0.40	0.39
1.50	0.59	0.54	0.58	0.55	0.53	0.49	0.48	0.45	0.47	0.44	0.43
2.00	0.66	0.59	0.64	0.61	0.59	0.55	0.54	0.51	0.53	0.50	0.49
2.50	0.71	0.65	0.69	0.65	0.62	0.58	0.57	0.55	0.56	0.54	0.53
3.00	0.74	0.62	0.72	0.67	0.64	0.61	0.60	0.58	0.59	0.57	0.55
4.00	0.78	0.67	0.75	0.71	0.66	0.64	0.63	0.61	0.62	0.60	0.59
5.00	0.80	0.69	0.78	0.73	0.68	0.66	0.65	0.63	0.64	0.62	0.61

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