A Study on Energy Efficiency of UTP Academic Buildings

By

Nik Siti Hasniati Binti Nik Leh

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

14/9/11

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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

A lot of energy is used annually by UTP office building to cater the UTP staff and ensure their comfort of working. The energy is mostly used to fulfill the requirement and basic needs of the staff such as lighting, thermal comfort, and office plug loads. Located in Malaysia, which has hot and humid climate causes the building to receive unnecessary solar radiation which causes heat gain. Due to that, improvements need to be made towards current condition of UTP building towards a more energy efficient and environment friendly. The objective of the project is to evaluate how far current UTP office buildings fulfill the building criteria that are prescribed by the requirements in Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building (MS 1525: 2007). Besides, it also aims to provide recommendations that could be implemented to reduce energy consumption through effective practices of efficient lighting and managing office plug loads. The study is carried out by incorporating building energy survey together with lighting system survey and office plug loads survey followed by data gathering and analysis. The results obtained shows building energy performance index of UTP is higher than the value set by MS 1525 guideline. UTP lighting system is found inefficient due to high level intensity and illuminance produced by the lights. For office plug loads, personal computer together with monitors results in the highest amount of energy consumption annually. New recommendations are suggested in which could further improve the energy efficiency of UTP office building. The recommendation for building envelope is to reduce the heat transfer coefficient (U-value) which will reduce the heating up of the office building. The recommendation for lighting system in the other hand is by using more daylighting which will allow the reduction of operating hours of the artificial lighting. For office plug loads, it is recommended that better power management is implemented and more efficient equipment should be used to replace the existing ones.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of study

Energy is one of the indispensable factors for continuous development and economic growth. The demand of energy is increasing in the developing countries due to automation, industrialization and urbanization. Rahman Mohamed and Lee (2006) investigated that the energy demand in Malaysia is increasing and the energy demand increased by almost 20% in 3 years (from 1999 to 2002). The energy demand is further expected to increase by approximately 60% within 8 years (from 2002 to 2010). Varman *et al.* (2005) predicted that residential electricity consumption will increase to 27,053 GWh in 2015.

Mahlia *et al.* (2001) conducted a survey on energy consumption and estimated that electricity consumption is increased from 326 GWh in 1970 to 9,471 GWh in 2000 and it will be 35,360 GWh in 2020 in the residential sector in Malaysia. It is reported by the Energy Information Administration (EIA) in independent analysis and statistics that Malaysia experiencing rapid increase of energy consumption for last five years.

Generally, the rapid increasing of global electricity energy demand is caused by rapid growth of industry and economic sector which also followed by the construction of huge buildings for offices, airports, and others. This is due to the fact that energy required for space heating and cooling in buildings has the highest share of all. As for large scale building, heating and cooling are among the essential aspects of maintaining human comfort and it lead to the usage of air conditioners in that buildings.

The worldwide increase demand for energy has put increasing pressure on identifying and implementing ways to save energy. The global contribution from buildings towards energy consumption, both residential and commercial, has steadily increased reaching figures between 20% and 40% in developed countries, and has exceeded the other major sectors: industrial and transportation. Growth in population, increasing demand for building services and comfort levels, together with the rise in time spent inside buildings, assure the upward trend in energy demand will continue in the future. For this reason, energy efficiency in buildings is today a prime objective for energy policy at regional, national and international levels. As Malaysia moves toward a developed country, energy requirements will remain very intensive. This means Malaysia has a strong need and great potential to apply energy efficient strategies in lowering energy consumption in buildings.

Malaysia government started various energy efficiency measures during the oil crisis in the 1970s such as using more efficient lamps and air-conditioning plants in public building (Suruhanjaya Tenaga, 2005).However EE was not pursued actively after the oil crisis. Promotion of EE was "renewed" in the 1990s by the Electrical and Gas Supply Department (now the Energy Commission) and the Ministry of Energy.

EE Regulations was drafted in mid 1990 but not implemented due to some legal issues. An Energy Efficiency unit was set up in late 1990s in the electricity and Gas Supply Department for promoting EE. Minimum energy performance standards were implemented for certain electrical products which require to be approved by the Department such as lamp chokes and fans. Awareness campaigns were conducted among school children, teachers and the general public as well as the industry and commercial sectors. Brochures and guidebooks on how to use energy wisely were published and distributed to the public. Energy Efficiency is important means towards the development of sustainable energy and reducing the impacts of the energy sector on the environment.

1.2 Problem statement

Building energy consumption is one of the most important issues faced by the building professionals, researchers and energy policy makers worldwide. There is a growing concern about building energy consumption in Malaysia which accounts for 14 % of the national total energy consumption.

Despite the variety of names - Low Energy Office (LEO), Zero Energy Building, Sustainable and Green building - energy efficient buildings have the same primary objective: to reduce energy use and maximize utilization. Constructing energy efficient buildings in the future helps Malaysia safeguard its depleting energy resources. Saving energy uses in buildings requires cooperation. Everyone from architects, engineers, interior designers, and researchers play important roles to mold ideas into the creation of energy efficient buildings. All parties involved should realize and understand the concept of efficient energy management before a construction starts.

The buildings in UTP are unique that they're having significantly large area of glass as walls. Since the buildings are located in a tropical country, they consistently receive high solar heat gain. Heat gain from building envelope together with inefficient devices and fixtures used resulted in high cooling demand and therefore increases the energy consumption.

From the problem above, the pressure is to study the efficient usage of energy in new academic buildings of UTP and to evaluate how far existing building in UTP fulfill the building criteria that is prescribed by the requirements in Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building MS 1525: 2007. This research will also look at the energy efficiency management based on the guideline by producing the use of effective and continuous energy and to evaluate the quality of energy usage by creating energy efficient environment that gives a better impact for the National Energy Sector in the future.

1.3 Objective of the study

The main objectives of the project are as stated below:

i. To calculate energy performance of the building envelopes in terms of the overall thermal transfer value (OTTV) and to evaluate how far current UTP office buildings fulfill the building criteria prescribed by the requirements in Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building (MS 1525: 2007) based on OTTV and U value.

ii. Provide recommendations that could be implemented to reduce energy consumption through effective practices of efficient lighting and managing office plug loads.

1.4 Project scope of work

There are extensive areas of studies for the energy consumption of room's air conditioners by the residential buildings in Malaysia. In this study, it is focused on the calculation of OTTV and U-value as building energy performance index. Building simulation techniques using TRNSYS was conducted to determine building heat gain characteristics and cooling load requirement. The second part of the study is looking on the current practices of lighting system and typical plug loads of the office. The aim of the study is to find energy saving opportunities through Energy Efficient practices compliance with Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building (MS 1525: 2007) guidelines.

The research and study area is limited to Building 21 Level 3 to represent the real situation for all UTP academic buildings due to missing and unavailability of data. The time frame selected for simulation and data gathering is in the month of June 2011.

CHAPTER 2

LITERATURE REVIEW

2.1 Building Envelope

A building envelope generally refers to the building components that enclose conditioned spaces and through which heat energy is transferred to or from the outdoor environment (Turner and Elder, 2001). This heat transfer is called heat loss when the indoor temperature being maintained is greater than the outdoor temperature, usually during the rainy season. The heat transfer that occurs when the indoor temperature being maintained is less than the outdoor temperature is called heat gain. Heat gains or heat losses translate into increased energy use to condition the interior space. More energy is needed to keep a constant temperature in the building because the heat energy is being transferred through the various components of the building envelope. Most of this energy (fifty percent) is transferred through the windows, as shown in Figure 2.1; 21% of the energy is transferred through infiltration, or air leakage in the building envelope. The remaining heat energy is transferred through the roof (16%); walls (10%); and floor or foundation (3%).

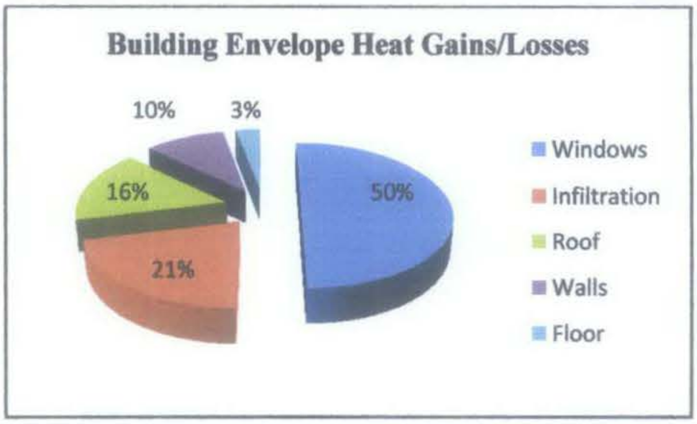


Figure 2.1: Energy transferred through Building Envelope

There are two ways to lower the heat transfer rate through the building envelope. The first is to raise the thermal resistance, or R-value, in the building envelope components, possibly by increasing the length (or depth) of insulation or choosing insulation with a lower thermal conductivity k. The second is to lower the temperature difference between the indoor and outdoor environment, a more difficult challenge to overcome if occupant comfort is considered. Lowering the heat transfer rate of the building envelope will allow the mechanical systems to use less energy when heating and cooling the building, thus making the building more energy efficient. New and existing technologies are available to make a building more energy efficient.

2.2 Introduction to Overall Thermal Transfer Value (OTTV)

Fundamentally, the building envelope has to block out heat gain into buildings via conduction and solar radiation. Simulation studies indicate that heat may be conducted both in and out of the building depending on the time of the day. This is especially so, for a typical office buildings that are air- conditioned during daytime only in which heat would be conducted into the buildings during daytime and heat would be conducted out of the buildings during night time especially during early morning hours when external temperatures are low. This phenomenon occurs in buildings that have high internal load at night. Internal loads are caused by lightings and equipments that are kept running during night time and these would generate heat within the building. It is therefore important that energy management is well conducted to ensure that night time internal loads is kept to minimum , to ensure that maximum benefit would be derived from the insulation of building envelope.

2.2.1 Concept of OTTV

The solar heat gain through the building envelope constitutes a substantial share of cooling load in an air-conditioned building. To minimise solar heat gain into a building, therefore, a design criterion known as Overall Thermal Transfer Value (OTTV) has been adopted. The OTTV requirement is simple, and applies only to air – conditioned buildings. The OTTV aims at achieving the design of building envelope to cut down external heat gain and hence reduce the cooling load of the air – conditioning system.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) was the first body to propose the OTTV method. In Asia, Singapore was the first country to develop an OTTV standard; her standard was based on the ASHRAE Standards 90-75 and 90-80A, but with some refinements to suit local climate and construction practices.

According to MS 1525: 2007, Malaysian Standard for Code of Practice on Energy Efficiency and Use of Renewable Energy for Non- Residential Buildings; the OTTV of the building envelope for a building having a total air conditioned area exceeding 4000 m^2 and above should not exceed 50 W/m^2.

2.2.2 OTTV Calculation

OTTV is an index for comparing the thermal performance of buildings. It is a measure of the average heat gain into a building through the building envelope and consists of three major components: conduction through opaque walls, conduction through window glass, and solar radiation through window glass. The usual practice is to have two sets of OTTV; one for the exterior walls and the other for the roof.

According to Surapong (2006), the use of OTTV as a measure of average heat gain across the building envelope of an air-conditioned commercial building has been accepted since it was introduced into Thailand and other ASEAN countries. Compared with thermal insulation standards in cold climates, OTTV is more suitable for application to buildings in hot climates because it accounts for the solar heat gain at the building envelope.

The surfaces of an opaque wall, solar and thermal radiation together with convection heat transfer causes a net conduction heat flow into the wall material. Hui (1997) stated that as walls at different orientations receive different amounts of solar radiation, the general procedure is to calculate the OTTV of individual walls with the same orientation and the given by weighted average of these values.

Surapong (2006) developed countries experience OTTV equation with building energy code and energy efficiency in the existing buildings of Thailand, Malaysia, Singapore, Indonesia and Philiphines. The OTTV standard equation for Malaysia is:
The OTTV of the whole exterior wall is given by the weighted average of the OTTVs of individual walls at different orientations, as shown below.

$$OTTV = \frac{A_{oi} \times OTTV_i + A_{o1} \times OTTV_1 + A_{o2} \times OTTV_2 + ..A_{on} \times OTTV_n}{A_{oi} + A_{o1} + A_{o2} + ..A_{on}} \qquad (2.1)$$

Where, A_{oi} is the gross exterior wall area for orientation i and $OTTV_i$ is the OTTV value from orientation from equation (2.2)

$$OTTV = 19.1\alpha \times (1 - WWR) \times U_W + 194 \times WWR \times CF \times SC \qquad (2.2)$$

Where, α (solar absorption coefficient) is the degree to which a substance (wall) will absorb energy.The value of α can be obtained from Table 2.1.

Table 2.1: Typical values of different parameters to calculate OTTV in Malaysia.
(Source: R. Saidur, M. Hasanuzzaman, M.M. Hasan and H.H. Masjuki, 2009.Overall Thermal Transfer Value of Residential Buildings in Malaysia. Journal of Applied Sciences, 9: 2130-2136)

Type of walls	Value of α	Typical value of U (W/m^2 K)
Normal glass window with coating	0.74	
Normal glass window without coating	0.89	
Tinted glass window with coating	0.64	
Tinted glass window without coating	0.75	
Single glazed windows with coatings		4.20
Single glazed windows without coatings		5.70
Double glazed windows with coatings		2.20
Double glazed windows without coatings		3.80
Wooden walls		3.05
Brick concrete walls		2.15
Well – insulated floors		0.2
Poorly – insulated floors		1.0

Lam et al. (2005) stated that Wall to Wall Ratio (WWR) is the percentage of results from dividing the total glass area of the building by the total wall area.

Total gross area of wall, $A_i = 2 \times H \times L + 2 \times H \times D$ (2.3)

Where H is the height of the wall, L is the length of the wall and D is the width of the wall. Window to wall ratio, $WWR = A_f/A_i$ (2.4)

Where A_f is the total gross area of the window and Ai is the total gross area of the wall

U_W is the U value of the opaque part of the wall while CF is the solar correction factor for the orientation of the fenestration under consideration as given by Table 2.2.

Table 2.2: Solar Correction Factor for the orientation
(Source: Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building MS 1525: 2007, First Revision)

Orientation	**Correction Factor**
North	0.83
North East	1.01
East	1.15
South East	1.02
South	0.85
South West	1.02
West	1.14

SC (Shading Coefficient) is the ratio of solar heat gain through a particular glass type compared to the solar heat gain through a 3 mm clear float glass. It measures the ability of window to reduce solar heat gain.The shading coefficient of glass shall be based on the manufacturer's recommended value assessed at an incident angle of 45 to the normal. The effective shading coefficient of external shading devices can be obtained from Table 2.3 and Table 2.4.

Table 2.3: Effective Shading Coefficient of Horizontal Projections
(Source: Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building MS 1525: 2007, First Revision)

Ratio	Orientation			
	North, South	East, West	North East, North West	South East, South West
0.3 – 0.4	0.8	0.8	0.8	0.8
0.5 – 0.7	0.7	0.7	0.7	0.65
0.8 – 1.2	0.7	0.6	0.6	0.58
1.32 – 2.0	0.66	0.5	0.54	0.5

Table 2.4: Effective Shading Coefficient of Vertical Projections
(Source: Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building MS 1525: 2007, First Revision)

Ratio	Orientation			
	North, South	East, West	North East, North West	South East, South West
0.3 – 0.4	0.8	0.9	0.85	0.85
0.5 – 0.7	0.7	0.9	0.75	0.75
0.8 – 1.2	0.7	0.8	0.65	0.65
1.32 – 2.0	0.66	0.75	0.60	0.60

It is also reported by Surapong (2006) that the Energy Conservation Promotion Act (ECP Act) of 1992 in Thailand requires that the management of every large commercial buildings conduct energy audit and set up plans to improve energy efficiency. Consultants routinely compile information on building shape and construction, and other details such as lighting power density, equipment power density and schedule of use of each space. Measurements are taken so that the performance of the air-conditioning system can be evaluated. Calculated value of OTTV of each façade and of the building is given in each energy audit report. A question inevitably ensues during the conduct of the energy audit is how energy use in a building is related to the energy performance parameters (such as OTTV and the performance of the air-conditioning system) and energy usage parameters (such as lighting power density) of the building.

2.3 Introduction to U value

Buildings with high levels of internal heat gain such as office blocks will generally require mechanical systems to maintain comfort conditions, but there are significant opportunities to reduce the energy consumption with careful design. In the design of energy efficient building dominated by internal heat gains, particular attention should be given to construction properties which will highly influenced the heat gain of the building. A material or group of materials forming a construction element of a building has properties that are determined partly by the thermal properties of the material themselves, and partly by the surface characteristics and geometry of the construction.

The properties of construction elements that are most relevant to thermal performance are overall heat transfer coefficient (U-value) and the thermal resistant of the material (R-value). The overall heat transfer coefficient is an approximate measure that simplifies the calculation of heat transfer through walls, floors, and roofs. It combines the heat transfer coefficient for convective and radiative heat transfer from both surfaces with the conductive heat transfer to provide a single overall heat transfer coefficient for the surface. It is somewhat approximate since the surface heat transfer coefficients for both convective and radiant heat transfer are dependants on surface temperatures.

2.3.1 U value Calculation

Overall heat transfer coefficient is the inverse of overall thermal resistance.

$$U_o = \frac{1}{R_o} \qquad (2.6)$$

Where U_0 is overall heat transfer coefficient in W/m^2K, while R_0 is the overall thermal resistance measure in hm^2K/kJ.

R_0 is the summation of inside, surface and outside thermal resistance of the material

$$R_0 = R_{inside} + R_{surface} + R_{outside} \quad \text{or} \qquad (2.7)$$

$$R_0 = \frac{1}{h} + \frac{l}{k} + \frac{1}{h} \qquad (2.8)$$

Where h is the convective heat transfer coefficient (kJ/hm^2K) , k is the thermal conductivity (kJ/hmK) and L is the thickness measured in metre (m).

2.4 Building Heat Gain Simulation using TRNSYS

TRNSYS is a complete and extensible software environment for the transient simulation of systems, including multi-zone buildings. It is used by engineers and researchers around the world to validate new energy concepts, from simple domestic hot water systems to the design and simulation of buildings and their equipment, including control strategies, occupant behavior, and alternative energy systems

2.4.1 Heat Gain Calculation using TRNSYS

Heat gain through radiation and convection were calculated using

$$q_{si} = q_{comb,si} + S_{si} + \text{Wall gain} \qquad (2.9)$$

$$q_{s,o} = q_{comb,s,o} + S_{s,o} \qquad (2.10)$$

$q_{comb,s,i/o}$ = combined convective and long wave radiation of inside/outside surface.

$$q_{comb,si} = \frac{1}{R_{equiv,i} \times A_{s,i}} (T_{s,i} - T_{star}) \qquad (2.11)$$

$$q_{comb,s,o} = q_{c,s,o} + q_{r,s,o} \qquad (2.12)$$

Where,

$$q_{c,s,o} = h_{conv,s,o}(T_{a,s} - T_{s,o}) \qquad (2.13)$$

$$q_{r,s,o} = \sigma\varepsilon_{s,o}(T^4_{s,o} - T^4_{fsky}) \qquad (2.14)$$

Latent heat gain from ventilation/infiltration air is calculate using

$$Q_{lt} = V_a\rho_o(\omega_o - \omega_r)\, h_{fg,32} \qquad (2.15)$$

The amount of heat gain per occupant is based on ISO 7730 table. Degree level of activity was inputted to get the portion of sensible and latent heat from table.

2.4.2 Calculation of Latent Heat

Latent Heat is the heat given up or absorbed by a substance as it changes state. It is called latent because it is not associated with a change in temperature. Latent heat is a form of cooling load that should be decreased in order to save energy to cool a building. The latent heat flow can be expressed in SI-units (metric) as

$$Q_{latent} = h_{we} \rho \, q \, \Delta\omega \quad \text{.......} \quad (2.16)$$

where;

Q_{latent} = latent heat flow (kW)

h_{we} = latent heat of vaporization of water (kJ/kg)

ρ = air density at standard conditions (kg/m^3)

q = air flow (m^3/s)

$\Delta\omega$ = humidity ratio difference ($kg_{water}/kg_{dry\ air}$)

2.4.3 Calculation of Sensible Heat Gain

This is the Solar Gain due to differences between inside and outside temperatures. In tropical countries this can be quite significant. This gain only applies to materials of negligible thermal capacity i.e. glass.

$$Q_g = A_g \, . \, U_g \, (t_o - t_r) \qquad (2.17)$$

Where;

Q_g = Sensible heat gain through glass (W)

A_g = Surface area of glass (m^2)

U_g = 'U' value for glass ($W/m^2 K$)

t_o = Outside air temperature (K).

tr = Room air temperature (K)

2.5 Designs for Energy Efficient Building in Tropics

In the study made by C.K Tang in November 2008, Energy Engineer for IEN Consultants, he came up with 7+1 design strategies for energy efficient building in tropics. The strategies are as follows:

i. Increase efficiency of cooling system
ii. Reduce electrical lighting loads
iii. Reduce internal plug loads
iv. Reduce fan energy consumption
v. Reduce dehumidification of air
vi. Control Solar Gain
vii. Insulate the building
viii. Energy Management

The conclusion of this study is that even though energy management was listed last, but it is still the most important strategy because everything can go wrong in a very energy efficient building if the energy management team is not doing very well to maintain the good condition.

Figure 2.2 shows breakdown of building energy efficiency factors which lead by chiller energy, lighting, small power, fan energy, dehumidify fresh air, solar gain, exit conduction gain and energy management. The red color graph represent worst case scenario happen in the commercial building in Malaysia. The blue graphs represent the best practice building which is Ministry of Energy, Water and Communication building located at Putrajaya.

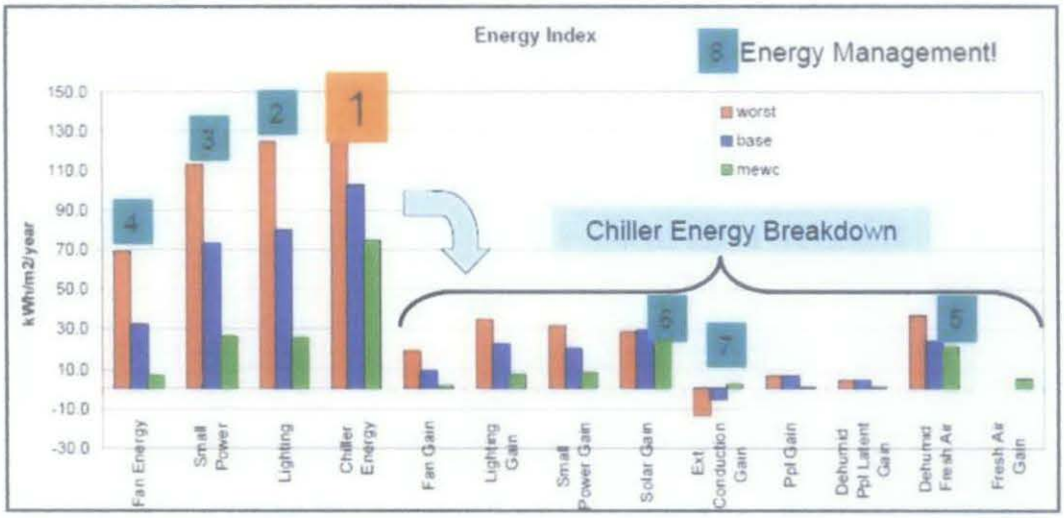


Figure 2.2: Breakdown of Energy Efficiency Factors

2.6 General Principles of Efficient Lighting Practices

The typical design in office building lighting load is 15-25 W/m^2.This lighting load can be calculated by sum up the total watt of lighting in selected area and divided by the area in meter square. The proposed lighting load by MS: 1525 is 15 W/m^2.There is also bad lighting load design in some places which consumed as much as 25-45 W/m^2.

Table 2.5 below shows the recommended level of illuminance proposed by Department of Standards Malaysia in the Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings, MS: 1525:2007. Lighting must provide a suitable visual environment within a particular space i.e. sufficient and suitable lighting performance of a range of tasks and provision of a desired appearance.

Table 2.5: Recommended average illuminance level
(Source: Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building MS 1525: 2007, First Revision)

Task	Illuminance (Lux)	Example of Applications
Lighting for infrequently used area	20	Minimum service illuminance
	100	Interior walkway and car-park
	100	Hotel bedroom
	100	Lift interior
	100	Corridor, passageways, stairs
	150	Escalator, travellator
	100	Entrance and exit
	100	Staff changing room, locker and cleaner room , cloak room, lavatories, stores
	100	Entrance hall, lobbies , waiting room
	300	Inquiry desk
	200	Infrequent reading and writing
Lighting for working interiors	300-400	General offices, shops and stores reading and writing
	300-400	Drawing office

Installed power and energy consumption should be minimized by the use of more efficient lamp/ballast systems and luminaries. According to MS: 1525:2007, the fluorescent ballast loss shall not exceed 6.0 W. Luminaries shall be selected for efficient distributions of light without producing discomfort glare. Lighting load shall not exceed the corresponding maximum value as specified in Table 2.6.

Table 2.6: Unit lighting power (including ballast loss) allowance
(Source: Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building MS 1525: 2007, First Revision)

Type of Usage	Maximum lighting power W/m^2
Restaurants	15
Offices	15
Classrooms/Lecture Theatres	15
Auditorium/Concert Halls	15
Hotel/Motel Guest Rooms	15
Lobbies/Atriums/Concourse	20
Supermarkets/ Department Stores/Shops	25
Stores/Warehouses/Stairs/Corridor/Lavatories	10
Car Parks	5

All lighting systems except those required for emergency or exit lighting should be provided with manual, automatic or programmable controls. For lighting loads exceeding 100 kW automatic controls should be provided. Sensors also should be installed in the building because by using these sensors, lighting will automatically turn off after a few minutes the sensors detect there is no person in the area. Besides, lighting switch should be installed next to exit doors to make it easier for the people leaving the room to switch off the light. Finally it would also possible to install day lighting sensors which will automatically turn off the artificial light when there is enough light in the area detected by sensors.

Estimated annual energy consumption for lighting can be calculated by multiplying wattage and annual operating hours with number of lamps. Further calculation to calculate annual energy cost per year can be done by multiplying the annual energy consumption with utility cost.

2.7 Energy Efficient Office Plug Loads

A plug load is the energy consumed by any electronic device that's plugged into a socket. Office equipment is the fastest growing electrical load in the business sector. With the widespread use of desktop computers, printers and other devices, an office can have hundreds of units and the energy costs can add up. Energy use from office equipment has surpassed lighting in many buildings. In a recent study by APS, office equipment and other miscellaneous uses accounted for over 40 percent of electricity consumption in large office buildings with most of that by office equipment. Since office equipment accounts for an increasingly large share of the electricity bill, it is important to consider energy use characteristics for new equipment. By purchasing the most efficient products, the electric bill will be reduced, adding to the bottom line. Energy-efficient offices help to protect the environment as well.

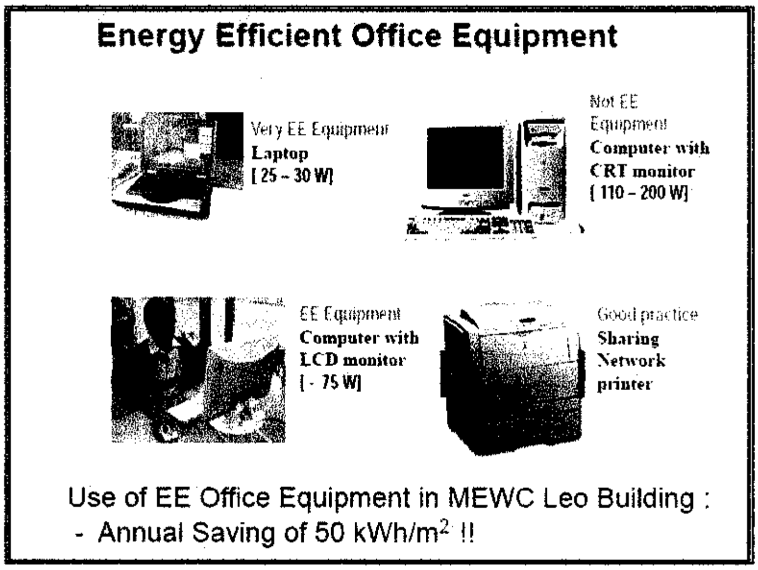


Figure 2.3: Energy Efficient Office Equipments

According to EIA (Energy Information Administration) in 2008, plug loads are one of the largest and fastest growing end-users of the residential and commercial sectors. In 2006, USA Energy Conservation Operations in cooperation with RLW Analytics and LBNL-conducted the first comprehensive residential plug load field monitoring in the United States. It is found that plug load energy use is between 1069 and 1207 kWh per year. This is at least 15% of electricity used in a California household. In 2008, commercial field monitoring study that is conducted by the same organizations revealed that office plug loads are dominated by computers, monitors, and imaging equipment. Research conducted early 2008 visited 48 offices in Northern and Southern California, inventoried nearly 7000 plug loads devices and monitored 470 of them in 24 offices for two weeks.

Commercial plug load field study on 2010 by the same organization is aimed to determine the extent to which commercial building occupants can reduce peak demand and energy consumption of their plug load devices through changes to hardware, software and also occupant behavior. Changes of hardware can be made by using highly efficient office equipment such as smart plug strips while in term of software by using power management. For occupant behavior , user are recommended to use manual power down of equipment, enable and properly program power management setting and also procurement of highly efficient equipment.

Computers, printers, fax machines and copiers consume energy even while they are not in use. The following table 2.7 provides a summary of typical electrical power requirements and annual energy use for common office equipment.

Table 2.7: Office Equipment Energy Usage

Equipment	Typical Power Requirements (Watts)
Computer	55
Monitor (17 inch)	35
Laser Printer	60
Fax Machine	35
Copier (Small)	115
Copier (Large)	310

By multiplying these values by the number of devices in the office an estimated of how much money is spent on electricity to power these devices can be calculated. Estimated annual energy consumption for each plug loads can be expressed in kilowatt-hour per year as

$$\text{kWh per year (kWh/year)} = \text{Number of unit (Wattage} \times \text{Hours Used/Day} \div 1000)$$

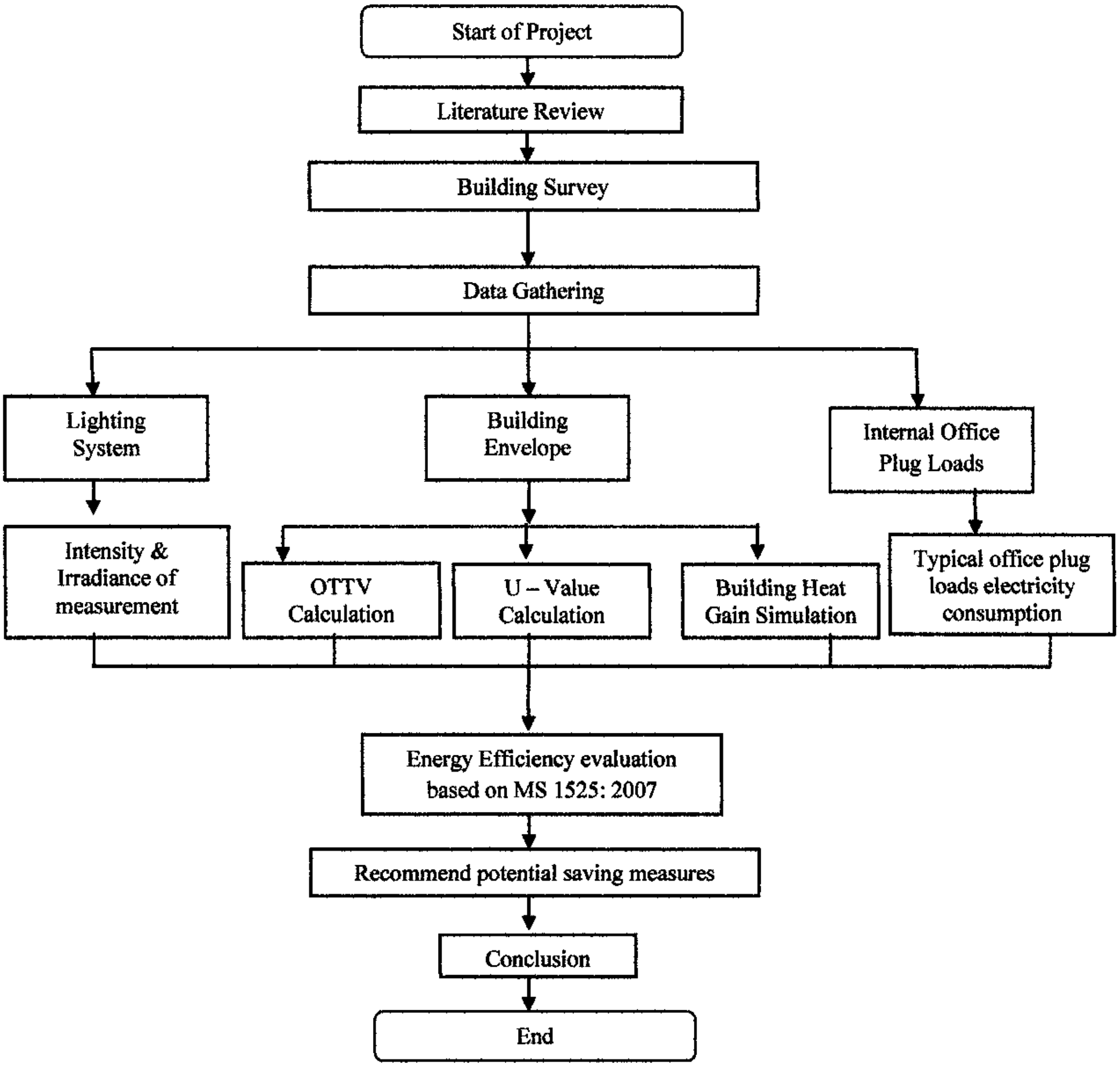
The annual cost to run an appliance can be calculated by multiplying the kWh per year by local utility's rate per kWh consumed.

The Energy Star Office Equipment Program promotes and labels energy-efficient computers, monitors, printers, fax machines, scanners, copiers and multi-function devices. This energy-efficient equipment automatically powers down when not used for a period of time and can be recognized by looking for the familiar Energy Star label.

With Energy Star equipment, energy use can be reduced by 50 percent or more. This also helps reduce the load on air conditioning equipment and it helps to protect the environment. Computers, printers and copiers have similar characteristic which they draw significant amounts of power, much of which is wasted when the device is not being used. Devices that have power management capabilities enable them to be power down after a predetermined period of inactivity. For computers, laptop is recommended as a typical laptop computer draws only 15 to 25 watts during use compared to the 150 watts used by a conventional desktop computer and monitor and its sleep mode typically uses just a fraction of a watt.

CHAPTER 3
METHODOLOGY

3.1 Project Flow



The methodology is started by conducting research and literature review. The understanding of the concept of Overall Thermal Transfer Value and U value is required in order to evaluate the efficiency of targeted building envelope. The investigating of the lighting system and internal office plug loads is performed by conducting building survey and through cooperation with building personnel. This method is planned to be conducted to give an insight and self-experience towards energy consumption of the building. In addition, more information regarding building characteristics was acquired from the building survey.

The data collection and gathering is made after few surveys and research. The calculation of OTTV and U value is determined and analyzed. The result is then evaluated to determine how far current office buildings fulfil the building criteria prescribed by the requirements in Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building (MS 1525: 2007). A part from calculation of thermal performance, building heat gain simulation is also conducted using TRNSYS software to analyze heat gain characteristics of the building.

The second part of the study is looking on the current practices of lighting system and typical plug loads of the office. The study involved calculating typical office plug loads electricity consumption and evaluating current lighting system efficiency. The aim of the study is to find energy saving opportunities that can be implemented in order to increase the efficiency of existing system and thus reduce energy consumption. The method for conducting research is obtained via internet as there are a lot of engineering websites that contains information regarding this topic. Online journals are also a good source of reference. Lastly, there are also a lot of information on studies regarding energy efficiency and ways to conduct energy performance evaluation of buildings in books and journals. Duration of this study will take around 8-10 months.

3.2 Building Envelope Survey

This survey involves gathering the building characteristics and construction details. The location of study is focused only at Level 3 Building 21which is the office of the lecturers. Material used for each envelope elements, thickness and thermal conductivity were described in Table 3.1.

Table 3.1: Building Construction Details

Building Construction	Material	Thickness (m)	Thermal Conductivity (kJ/hmK)
Floor	Common Concrete	0.100	7.56
	Tile	0.005	3.6
	Cement Mortar	0.005	5.04
Roof	Aluminum	0.001	846
	Rockwool	0.025	0.162
	Aluminum foil	0.001	846
	Common Concrete	0.010	7.56
Inside Wall	Steel	0.005	54
	Steel	0.011	54
External Wall	Optiwhite Glass	0.012	0.98
Partition Wall	Plasterboard	0.025	0.576
	Plasterboard	0.025	0.576

Overall Thermal Transfer Value (OTTV) is calculated based on parameter obtained from building survey and construction details. The OTTV is then compared to the baseline stated in MS 1525: 2007 to measure the flow of heat through building material, U-value that serves as overall thermal transfer coefficient is calculated based on building construction details provided in the Table 3.1 above.

The approach and equations for calculating roof OTTV are similar to those for the walls. Calculation for the roof is often much simpler because roof does not usually contain large amount of glazing (except skylights over an atrium). Heat gain through the roof is generally small compared with external walls. For simplicity, therefore, only wall OTTV has been analysed in this study.

The building is facing southwest with large window glazing area and on 32 m above sea level. Floor lay-out of the second floor of Building 21 can be seen in Figure 3.1. Activity schedule of building occupants is based on UTP working days and working hours which have 5 working hours for each day (0800-1700 hours) and some of Malaysian's national holidays.UTP academic Building 21 as presented in Figure 3.1 uses a centralized HVAC system to keep 20°C - 24°C of indoor temperature and 60% of indoor relative humidity as required by ASHRAE.

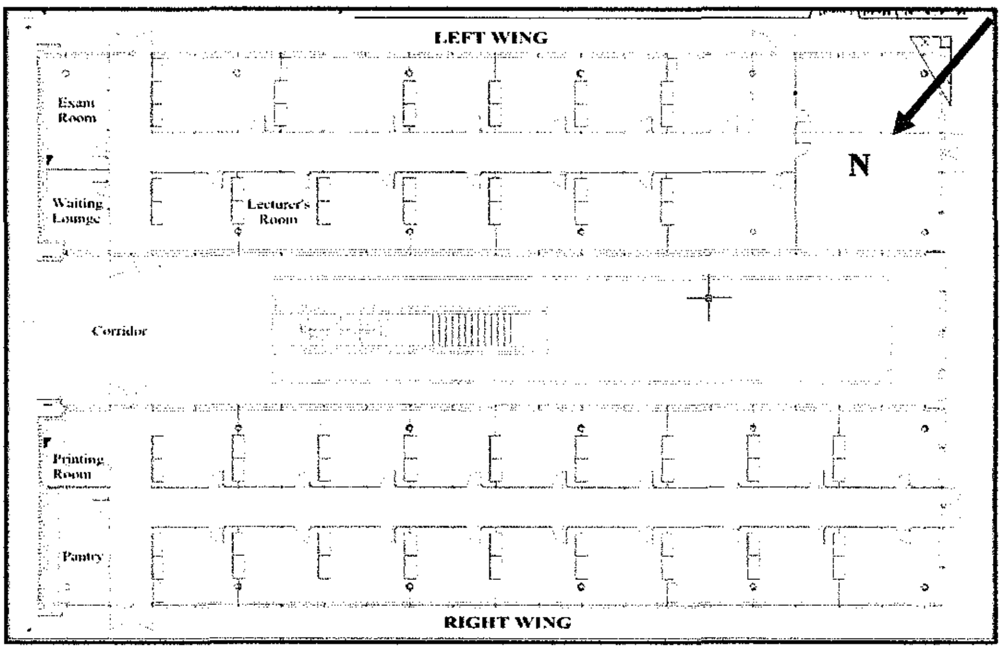


Figure 3.1: Layout of the Level 3 of Building 21

Calculated gross wall area for each orientation is summarized in the Table 3.2.

Table 3.2: Calculated gross wall area for each orientation

Orientation	Area (m^2)
South West	20.25
South East	104.14
North East	20.25
North West	104.14

The HVAC system operation for Academic Block 21 is summarized in Table 3.3.

Table 3.3: HVAC system operation for Academic Block 21

Level	AHU AB		AHU CD	
	ON	OFF	ON	OFF
3	0733	1900	0733	1900
2	0737	2230	0737	2359
1	0741	2230	0741	2230
0	0745	1900	0745	1900

For building simulation using TRNSYS, various data being input into the software is measured during building energy survey. The average temperature is 24^0C while the average of relative humidity is 60%. In practical, the operative temperature should be kept below the design temperature. The reason was that operative temperature is approximately the mean value of indoor air temperature and mean radian temperature. The mean radian temperature is usually higher than indoor air temperature.

Ventilation rate of 7.5 L^{-1} sec per person as required by ASHRAE standard is supplied by AHU. Infiltration rate were based on door openings and air leakage which was assumed to be 3% in this fully sealed office. Temperature of ambient air, relative humidity of ambient air and wind velocity, wind direction and global solar radiation were provided by TRNSYS software. All parameters are assumed to be applicable to UTP building conditions based on choice of Ipoh as source of weather data.

TRNSYS was used to carry out the simulation, since TRNSYS is a transient system simulation program which can be used to solve complex energy system using heat balance method. In order to establish confidence in the simulation results of TRNSYS, the predictions of this software were validated in the following way. The room temperatures and relative humidity of Level 3 Building 21 were measured for a week and then compared with the predictions of TRNSYS. Based on this comparison, the input parameters of the simulation tool were calibrated so that the maximum deviation of the prediction from the actual measurement was less than 5%.

3.3 Evaluation of Lighting System

Energy used per square meter is calculated in order to evaluate whether the lighting load not exceeding maximum values recommended by MS 1525: 2007.This is achieved by dividing the floor area by the total wattage of the lighting system. The second step is to measure the lighting lux levels. A lux is the lumens per square meter and a lumen is the measurement for light.

The readings of the light intensity and illuminance are taken from 5 or 6 different locations in the room being measured (at desk height in the office and at the floor level for general passage ways such as corridors) using digital light meter. Since the amount of light a room receives from its windows will vary at different times of the day and year, Lux reading was taken when day lighting is at a minimum, that is, early in the morning or late in the afternoon depending on the location of windows, or, on an overcast day.

Lux readings can vary by as much as 30-40 Lux within a distance of only a few centimeters, a couple of measurements in the same general position is taken and the lowest figure is considered. Movement is minimized during measurement as the sensors are very sensitive in order to obtain accurate reading. Standing between light sources and sensor is also avoided as it will lower Lux readings.

Number, type of lamp and the estimates of total wattage is obtained from the building lighting survey. Total floor area for each of the selected interiors is listed in the Table 3.4.

Table 3.4: Total floor area for each of the selected interiors

Type of interiors	Floor area (m^2)
Pantry	6.26
Printing room	5.06
Waiting lounge	7.08
Exam room	8.62
Lecturer's room	9.11
Corridor	187

The efficiency of lighting system can be calculated by dividing the total Watts used by the lighting system by the total floor area. Based on the result obtained, evaluation is done to investigate whether the current lighting system complies with Malaysian Standard according to MS 1525: 2007. Recommendations and options for saving measures are made in order to increase energy efficiency of lighting system.

3.4 Evaluation of Internal Office Plug Loads

To estimates how much energy it takes each year to power the plug loads in the office buildings, various required data is obtained such as quantity of the equipment, typical power requirements and estimated number of hours use per month. From that data, power consumption per month is calculated. Recommendations to reduce energy consumption for each of the plug loads are assessed. Then, annual energy and cost savings realized by implementing those recommendations is further calculated.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Overall OTTV value

As walls at different orientations receive different amounts of solar radiation, the general procedure is to calculate the OTTVs of individual walls with the same orientation and construction. The OTTV of the whole exterior wall is then given by the weighted average of these values. Based on the assumption made for solar shading coefficient; $\alpha = 0.75$ calculated OTTV for each orientation are as Table 4.1 followed. The calculations for each of the orientation can be found in the Appendix 1 attached.

Table 4.1: Calculated OTTV for each orientation

Orientation	Area (m^2)	OTTV (W/m^2)
South West	20.25	123.48
South East	104.14	113.20
North East	20.25	107.18
North West	104.14	102.06

From this result it shows that south west orientation yield very high OTTV as compared to other orientation. This is due to 90% of solar radiation is absorbed in this orientation. The value of Overall Thermal Transfer Value or OTTV of left wing Building 21 is **108.88 W / m²** (Refer Appendix 1) and this is higher than the value set by the guideline in MS 1525:2007 which is **50 W / m²**. A high OTTV means more heat gain (especially solar heat) and hence requires more cooling energy. This shows that building envelope efficient energy assessment of building 21 is inefficient. Since the OTTV value measured the heat transfer from outside to the indoor environment through the external envelope which is glass that made up the large area of the walls, it can be concluded that the building envelope that primary having glass as walls are the major contributor to building envelope cooling load and high energy consumption. Thus, building envelope is an important aspect that needs to be considered by any building designer to gain efficient energy usage before considering other aspects.

One way to reduce electricity consumption would be to limit heat gain into the buildings, and hence reduce the demand for air-conditioning. Key factors affecting heat gain through building envelopes into the buildings, and hence the OTTV calculations included building orientation, exterior wall area and its construction type, surface finish (wall absorption coefficient), window area, glass type (U-value and shading coefficient), external shading, roof area and its construction detail.

The major cooling load component is solar heat and the design variables that contribute the most to the building envelope OTTV are shading coefficient and window area. As UTP buildings are located in a tropical country and having significantly large area of glass as walls, solar heat gain through fenestration is considered as the largest provider to building envelope cooling load and the most important parameter for OTTV determinations.

Because of their transparency, fenestrations transmit solar radiation into the building. Heat transfer through transparent surfaces is distinctly different from heat transfer through opaque surfaces. When solar radiation is incident on an opaque building wall, a part of it is absorbed while the remaining part is reflected back. Only a fraction of the radiation absorbed by the opaque surface is transferred to the interiors of the building. However, in case of transparent surfaces, a major portion of the solar radiation is transmitted directly to the interiors of the building, while the remaining small fraction is absorbed and/or reflected back. Thus the fenestration or glazed surfaces contribute a major part of cooling load of a building. The energy transfer due to fenestration depends on the characteristics of the surface and its orientation, weather and solar radiation conditions. A careful design of fenestration can reduce the building energy consumption considerably. So, the objective here is to decreased solar factor and shading coefficient of the glass. It is noted that shading coefficient can be reduced by applying a coating on window glass.

4.2 U-value Calculation

The calculations of U-value are made for the wall, roof, and floor. To examine the values accuracy, the calculated value will be compared with the U- value analyzed by TRNSYS. In TRNSYS, convective heat transfer coefficient for inside and outside wall surface are 11kJ/hm^{2}K and 64kJ/hm^{2}K respectively. To calculate U-value manually, assumptions has been made where all four surfaces involved will experience combined convective and irradiation heat transfer coefficient with value of 27kJ/hm^{2}K and 90 kJ/hm^{2}K respectively. The comparison between these u values is shown in table 4.2.

Table 4.2: Comparison of U-value

Surface	Manual Calculation	TRNSYS Calculation
Floor	4.3630 W/m^{2}K	4.421 W/m^{2}K
Roof	1.3694 W/m^{2}K	1.356 W/m^{2}K
Internal Wall	5.7628 W/m^{2}K	5.846 W/m^{2}K
External Wall	5.3000 W/m^{2}K	5.405 W/m^{2}K

Based from the comparison between manual and TRNSYS calculation, it shows that there are some difference between manual and TRNSYS calculation. In manual calculation, assumption was made for combine convective and irradiative heat transfer coefficient inside and outside surface to be 27 kJ/hm^{2}K and 90 kJ/hm^{2}K respectively while for TRNSYS, the software has defined the value of heat transfer coefficient for inside and outside wall surface based on weather data which are 11 kJ/hm^{2}K and 64 kJ/hm^{2}K respectively.

From the calculated U-value, internal and external wall seems to have the highest thermal conductivity (both internal and external) followed by floor. U-value of the roofs is 1.3694 W/m^{2}K, much lower than internal wall, external wall and floor. Conduction heat gain through the roof is, thus, very much smaller than that through the walls and roofs. The U- values of internal and external wall indicate that the external walls of the building which are built using two types (steel and single glazed windows) are in need for proper assessment to select a suitable insulation scheme to improve their performance and to reduce energy consumption to cool the building. In general, adding insulation and installing internal or external shading to the walls will improve the ability of the wall to insulate heat thus reducing the energy consumption.

It is crucial to select the proper glazing to balance the need for view and daylight, while minimizing heat gain into the building. Hence, the designer has to choose a glazing with high visible transmittance (more natural light into the building) and low solar transmittance (less solar heat into the building). Based on this data, the best solution is to use double glazed windows. This is because, double glazed windows has lower U-value which is 2.8 W/m^2K compared to single glazed windows which typically has U-value of 5.6 W/m^2K. By having a lower U -value, there will be less heat transferred in or out of the building thus would result in reduction of energy required to keep the office in comfortable thermal condition.

Besides, improving shading coefficient of the glass wall is more effective than using internal blinds that currently practiced. The objective here is to block the direct sunlight from heating the wall surface. It is known to designers and architects that the shading coefficient value plays a significant role in the selection of glass, especially at high-temperature areas. Usually at those areas, low shading coefficient is needed to lower the solar heat gain through the glass. It works with the direct sunlight, and with the absence of sunlight shading coefficient loses its significance in design.

4.3 Building Heat Gain simulation using TRNSYS

The design cooling load or heat gain is the amount of heat energy to be removed from a conditioned space by the HVAC equipment to maintain the conditioned space at indoor design temperature. There are two types of cooling loads which are latent cooling load and sensible cooling load. The sensible cooling load refers to the dry bulb temperature of the building and the latent cooling load refers to the wet bulb temperature of the building.

Figure 4.1: Latent Heat characteristic of Level 3 Building 21

Latent heat is a form of cooling load that should be decreased in order to save energy to cool a building. There are various factors that contribute to the latent cooling load. The moisture that increased the latent cooling load is introduced through building occupants, equipment and appliances as well as air infiltration through cracks in the building, doors, and windows. The result for latent cooling load characteristics shows that latent heat keeps increasing from 5-6 am. This is due to the amount of fresh air that is been brought into the building during an hour purging duration that will lead to increment of Relative Humidity as well as latent heat.

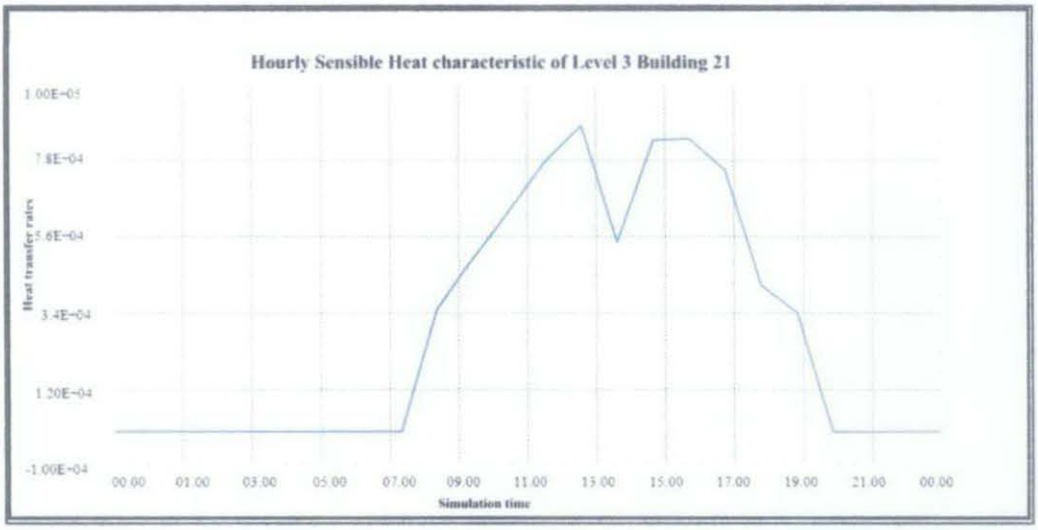


Figure 4.2: Sensible Heat characteristic of Level 3 Building 21

From sensible heat graph (figure 4.2), we obtain high value of heat transfer rate because the climate in Malaysia is hot and wet (tropical climate). There are various factors that influence the sensible cooling load. The factors mainly come from building construction material of each envelope elements such as glass windows, walls, roofs, lights and also sunlight striking window or skylights.

The area under the curve is the total heat gain of the room based on its specified occupied time. Heat transfer rate in the graph represents the cooling load measured in kJ/hr. Based on the graph, the area under the curve is larger from time 0630 hours until 1300 hours. Then, it drops slightly between 1300 hours until 1400 hours because the occupants leave the building for lunch. The absence of heat gain from occupant, artificial lighting and computer also makes the graph to decrease slightly. Then, at 1400 hours – 1700 hours, the heat gain increases back. The requirement for cooling loads depends on the heat gain transferred to the room due to external heat gain (conduction, convection and radiation through the walls and roof) and internal heat gain (floor, occupant and equipment used in the room). It can be conclude that in the afternoon, the building exposed to high amount of radiation, conduction and convection and more heat gain is transferred to the building. At this time, the room temperature is above 20^0C - 24^0C where it required cooling to remove heat gain from the building and provide comfort to the workers.

4.3.1 Building Envelope Optimization

Based on the graph of latent heat and sensible heat, it is observed that cooling load required to cool the building during occupancy hour is very high. This is due to high heat transfer coefficient of material for each envelope elements especially the external wall that uses glass as it building construction. High heat transfer coefficient leads to the increase of heat gain and thus required high cooling load to comfort the building. Also, through glasses, there are two ways of gaining the heat, which are from radiation and convection. The load can be reduced if we replace the usage of single glazing glasses to double glazing or utilizing external and internal shading device for existing building with low heat transfer coefficient. Shading help to reduce solar heat gain up to 80 percent.

Energy efficient walls, roofs and glass will impact the heat gain inside the building. In recent times, major glass manufacturers have produced huge improvements in glass technology and now can provide a wide range of energy sensitive glazing solutions. Many of those solutions can be retro fitted without making any change to the window frame structure. Others such as double glazing are a more complex solution.

There are a number of options available, such as adding external insulation for wall in order to minimize the heat penetrates through the material. In building construction high insulation is used to allow the internal environment temperature to maintain constant independently of external temperature changes. This not only makes the inside a more 'pleasant' place to live, it helps reduce heating and cooling costs by making it easier to keep at the same temperature; The objective here to improve the R-value of the material thus decrease the heat transfer coefficient or the U-value. The R-value of a substance is its direct measure of its resistance to transferring energy or heat. Basically the higher the figure the better it is at resisting energy transfer, so the easier it is to maintain a difference in temperatures across it for a longer time. The U-value or the overall heat transfer coefficient is the inverse of the R-Value. As the R-Value goes up the U-Value goes down and as the R-Value goes down the U-Value goes up. So the U-Value is a measure of how well a material transmits heat.

4.3.4.1 Heat Gain Characteristics using Double Glazing Glasses

The external wall of the building was changed from single window glazing to double window glazing and the result showed that there were only small difference in heat gain before and after double window glazing was applied. Calculated sensible and latent cooling load in this simulation was 89.35 kW and 29.84 kW respectively.

U-value of external wall before and after the single glazing of the glass is changed to double glazing is 5.405 W/m^2K and 3.0 W/m^2K respectively. Lower U-value, thus lower Solar Heat Gain coefficient reduces the heat gain inside the building, which results in reduction of cooling load.

4.3.4.2 Heat Gain Characteristics using external shading device for wall

External shading device for the external walls with shading factor equal to 1 was applied in the simulation and the result showed that calculated total sensible and latent cooling load was 82.8 kW and 29.75 kW respectively.

U-value of external wall before and after shading device is applied is 5.405 W/m^2K and 4.2 W/m^2K respectively. With this implementation, it is observed that significant reduction of building cooling load due to the lower U – value of the wall as it leads to lower heat gain inside the building.

The value of the heat gain given by TRNSYS is slightly different with manual calculation using formula. Latent heat gain and sensible heat gain derived from TRNSYS considered the total are being cooled, the size and position of windows and whether they have shading, the number of occupants, heat generated by equipment and heat generated by lighting. While in normal calculation, assumption is made due to its complexity and the scope of this study only covered the generated heat gain using software.

4.4 Lighting Systems Evaluation

4.4.1 Current Lighting Condition

With lighting accounting for 15 % to 25 % of the energy consumption in the building, any energy efficiency measures in this area will provide very good opportunities for savings. In this study, there are two primary reasons why more energy is consumed by lighting in building than necessary. The first reason is from the common perception that it is more economical to leave fluorescent lighting on than to turn on and off as needed. The second is that in the past lighting systems were designed to use older less efficient lamps and fittings, and due to the low costs of energy, over lighting was common practice. This section deals with these issues, identifies how energy saving can be made and estimate potential saving costs with the implementation of energy saving measures for lighting.

Based on the lighting survey that had been conducted, the type of lamp used for the building in this study area is the T8 linear fluorescent tube with magnetic ballast. These lamps have a diameter of 26 mm and come in 600mm/18W, 1200mm/36W, and 1500mm/58W. Very new systems may have 16mm T5 tubes that come in 550mm/14W,1150mm/28W,and1450mm/35W.The data gathered for the current lighting condition for level 3 Building 21 is summarized in Table 4.3.

Table 4.3: Current Lighting Condition in Building 21

Type of interiors	Lamp type	Number of lamp	Average watt per lamp (Watt)	Illuminance (Lux)
Pantry	Fluorescent	4	43	316
Printing Room	Fluorescent	2	43	297
Waiting Lounge	Fluorescent	2	43	269
Exam Room	Fluorescent	4	43	434
Lecturer's room	Fluorescent	4	43	463
Corridor	Compact Fluorescent	76	35	187

Based on the gathered data, UTP lighting system is inefficient due to the high level of intensity produced by the lights. The lighting system installed for UTP office building exceeds the recommended average illuminance level proposed by Department of Standards Malaysia in the Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings, MS: 1525:2007. By having a higher level of illuminance means that it provides brighter lighting for the specified area. However, when energy consumption is taken into account, more illuminance means higher energy consumption and more operating costs. Due to that, it is suggested that the illuminance of the office meets the recommended designed illuminance but not to exceed it in order to save energy and reduce operating costs.

According to the table, we can see that the recommended illuminance (lux) for pantry, printing room, corridor and waiting lounge should have around 100 lux. However, based on Table 4.3, the illuminance for each of these parts exceeds the recommended lux by 87 to 216 in value. The same thing happens to the lecturers and the exams room. The recommended illuminations for these rooms are 300 to 400 lux however the lux for office rooms in UTP academic building exceeds the value by 34 to 63 lux.

The illuminance of the lights is also determined by the number of lamps installed in an area. For example, pantry, exam room and lecturer's room has four fluorescent lamps installed in each area which produce a higher amount of lux which are in range from 300 to 500 lux. In contrast with printing room and waiting lounge which only have two fluorescent lamp installed in each area, the amount of produced lux is much less ranging from 200 to 300 lux. However, the same principal does not work with the corridor area. This is because the corridor has a much larger area compared to other rooms, thus it requires more lamps in order to illuminate the whole corridor area. The surface area is one of the factors that need to be consider to ensure that the whole lighting system become more efficient. The efficiency of the lighting system is explained in the following part of this report.

Other than the gathered technical data, the conducted survey has also point out a few other reason which leads to the inefficiency of UTP lighting system. One of the reasons is by having less awareness of the importance or needs to save and conserve energy. It is observed that the lighting system in UTP offices does not use or apply the free source of lighting which is day lighting. UTP academic building has the highest capability of utilizing day light since most of the building walls are made of glass, thus reducing the needs for artificial lighting. The lighting system of UTP can be more efficient if this day lighting method is implemented.

The survey has also shown that the lighting system in UTP offices does not use or apply the free source of lighting which is day lighting. UTP academic building has the highest capability of utilizing day light since most of the building walls are made of glass, thus reducing the needs for artificial lighting. The lighting system of UTP can be more efficient if this day lighting method is implemented.

It is very crucial to have an efficient lighting system because it can reduce the overall operating cost. The efficiency of lighting system can be calculated by dividing the total Watts used by the total floor area. Calculated lighting load in watt per square meter for each interior in Level 3 Building 21 is summarized in Table 4.4.

Table 4.4: Lighting load for each interior in Level 3 Building 21

Type of interiors	**Floor area (m^2)**	**Lighting power (W/m^2)**
Pantry	6.26	27.47
Printing room	5.06	16.99
Waiting lounge	7.08	12.15
Exam room	8.62	19.95
Lecturer's room	9.11	18.88
Corridor	187	14.22

Based on the results, lighting load in the pantry, lecturer's room, exam room, pantry and corridor are exceeding the recommended lighting load by MS 1525: 2007. According to MS 1525: 2007, maximum lighting power for office room is 15 W/m^2 while for corridor is 10 W/m^2. However, calculated lighting power for pantry, lecturer's room, exam room, and pantry are ranging from 16.99 W/m^2 and 27.47 W/m^2 respectively and for corridor 14.22 W/m^2. Good lighting practice is observed only in waiting lounge, where the lighting power measured does not exceed the maximum value.

Energy use of lighting system is further calculated by multiplying the input wattage with numbers of operation hour in a year. Table 4.5 present estimated energy uses and how much money is spent on electricity to power lighting system. This table also includes estimated saving cost if operational time can be reduced.

Table 4.5: Estimated energy consumption and savings potential

Type of lamps	Typical Wattage including ballast (Watt)	Number of lamps	Operating hours (Hours/day)	Annual Energy Consumption (kWh)	Annual Cost (RM)
Fluorescent	43	160	12	21 464	RM 7083.65
			8	14 310	RM 4722.43
			4	7 155.2	RM 2361.22
Compact Fluorescent	35	76	12	8 299.2	RM 2738.74
			8	5 532.8	RM 1825.82
			4	2 766.4	RM 912.91

Based on table 4.5, UTP will have to pay a total of RM9822.39 just for the operating cost of the lighting system if the light operating hours are 12 hours per day. 72% of the cost is contributed by the 160 fluorescent lamps that are used to light up the rooms in the office. Another 18% of the cost is caused by 76 compact fluorescent which are functioned to illuminates the corridor.

However, the table also shows that by reducing the operating hours of the lighting system in UTP office building, a great reduction in annual cost can observed. For fluorescent lamp, by reducing the operating hours from the maximum 12 hours to just 4 hours per day can significantly reduce the annual operating cost by RM4722.43. For compact fluorescent lamp in the other hand, the annual operating cost can be reduced by RM1825.83 for the same reduction of operating hours. In total, UTP is capable of saving RM6548.26 per year.

Due to the reduction of the lighting system operating hours, one of the most economical and efficient method to ensure sufficient lighting for the office throughout the day is by implementing daylighting. The lighting system can be switched on early in the morning when the sun light is not sufficient to brighten up the office rooms and automatically switched off when the sun is bright enough. This can be made possible by installing a light sensing device. However, during rainy season, the amount of day light might not be sufficient to support the requirement of the office. Due to that, the operating hours of the lighting system during this time of year should be extended perhaps to 8 hours per day.

4.4.2. Improving lighting system

Reduction of lighting energy can decrease cooling system consumption since internal heat gains is reduced. Using a more efficient and energy saving light ballast would give a lot of advantage. Since energy efficient light ballast uses less energy, we can save up to 27% energy on average on all fluorescent lighting system. Lighting accounts for a significant portion of electrical energy consumed in a building. Energy is saved in the lighting system by reducing illumination levels, improving lighting system efficiency curtailing operating hours and by taking advantage of day lighting.

In order to incorporate a more energy efficient lighting system, the currently being used lighting which is fluorescent (referring to both applications) could be replaced with Light-Emitting-Diode (LED) type of lamp which has been proven to be more efficient and uses less energy. LED Starlight Inc. has conducted studies which indicate that LED has six time longer life span and around 60% less energy consumption compared to the fluorescent type of lamps. By changing the lamp type, UTP will be able to save quite a fortune in a long run.

Another way of improving the lighting system in UTP is by implementing motion sensor technology to the each of the office buildings. This motion sensor technology works by switch off the light in partition that does not have any movement and switch them back on when they detect movements. In application towards UTP office building, this could imply to the printing room and pantry which are only being occupied when UTP staffs are doing photocopy work in the room having snack. It is a waste of energy if the lights in the room are kept on throughout the day while maybe on average only 2-3 hours per day that the room might be in used.

Apart from that, the design of UTP academic buildings is very suitable for day lighting to be utilized. Foster and Partners has design UTP academic building with a sophisticated modern look with mostly glass walls. These glass walls are great in allowing sunlight to shine into the building. By allowing the lights to illuminate the office, the needs for artificial lights during the day can be reduced. One of the ways to utilize this day lighting is by raising the curtains or shades during the day and switch off any artificial lights. Lighting sensors are required to be installed so that the lights will be switched on when the daylight is no longer sufficient for optimal lighting condition.

Besides that, UTP office building should also be installed with lighting timer which will allow the lights in the office to automatically turn on or off as scheduled to avoid from leaving the lights on overnight. Example of this application is by setting the timer to turn off the lights at 530 PM. Any remaining staffs that plan to extend their stay in the office pass 530 PM should give a call to the control room and inform them so that they could allow the lights to remain on for the particular partition of the office. This way, wasted energy will no longer be an issue and lots of energy can be saved.

4.5 Internal Office Plug Loads Analysis

4.5.1 Typical Office Plug Loads

There are many appliances and machines in the office that contributes to the total amount of power used which are considered as plug loads. Below are some of the common offices plug loads and its power requirement available at Level 3 of Building 21 is listed in Table 4.6.

Table 4.6: Typical Office Plug Loads in Office Building 21

Equipment	Quantity	Typical Power Requirements (Watts)
Computer	37	55
Monitor (17 inch)	37	35
Laser Printer	2	60
Fax Machine	2	35
Copier (Large)	2	310

From the results , it is observed that the copier machine requires highest power requirement to be operated which is at 310 watts per machine. However, as stated, computers and monitors are the most used in the office. There are 37 sets or units of personal computers and monitors which are use frequently throughout the day. Even though total power requirement for both personal computer and monitor is only 90 watt, but from overall point of view, with 37 units run at once, personal computers and monitors requires the highest power compared to other electrical appliances with a total of 3330 watts. Power management is not routinely or fully utilized since only small fraction of desktop computer automatically go to sleep. Many are on after hours consuming energy unnecessarily. Meanwhile, there is still a good practice observed with the use of sharing network printer , copier and fax machine.

The average desktop computer consumes 55 watts in active mode, 4 watts in sleep mode, and 2 watts while turned off. A computer that's turned off nights and weekends uses about 295.65 kWh per year on average with estimated 9 hours used per day, costing about RM 97.56 per year at RM0.33/ kWh for each desktop computer. However, a desktop computer left on continuously will consume more than 788 kWh annually at a cost of almost RM 260.17. A high-performance system with a powerful graphics card and multiple drives can cost significantly more.

From the calculated data, it shows in figure 4.7 that personal computers together with monitors results in the highest amount of energy consumption annually. Personal computers and monitors itself contributes to 88% of total annual energy consumption. Fax machine, laser printer, and copier machine are all at par in terms of annual energy used. Their range of energy consumption is around 200 to 300 kWh per year for each machine. By estimating using the same electric tariff throughout the year which is RM0.33 per kWh, the total annual operating costs for the whole plug loads is RM4145. This is estimation for one office building in UTP.

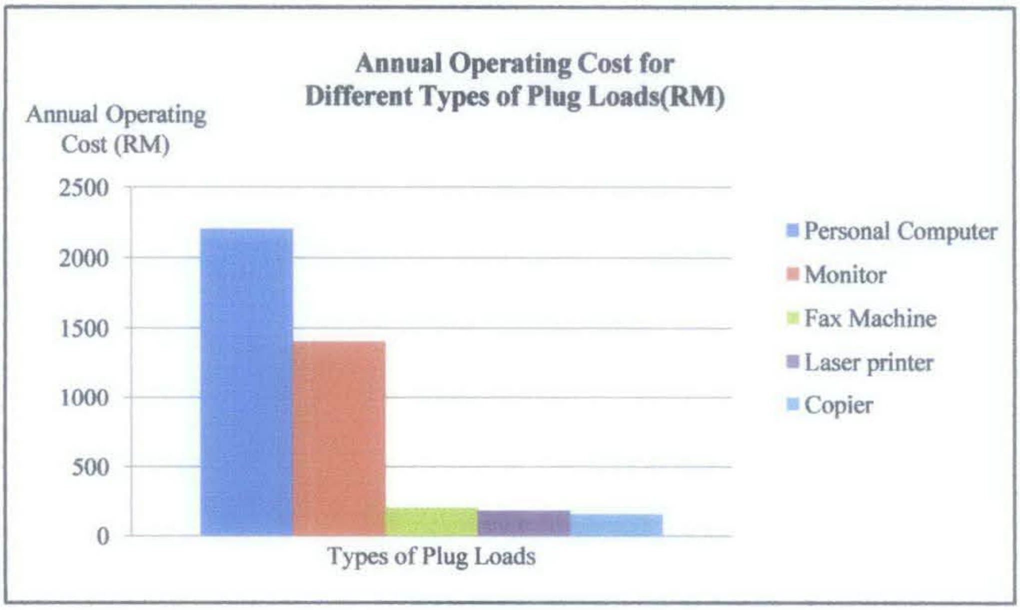


Figure 4.7: Annual Operating Cost for Different Types of Plug Loads

As per discussed earlier, both personal computer and monitor turns out to be the highest electric consumer in compare with the other electric appliances. Due to that, it is best if energy saving application could be applied to personal computers and monitors. By doing that, UTP will definitely be able to reduce the total power consumption for offices in academic building thus results in cheaper annual operating cost.

4.5.2 Savings Potential with Plug Loads

There are various energy efficiency measures and control strategies that can be adopted to reduce plug load energy consumption. Energy efficiency measures include shifting from desktop computers to micro-sized desktop computers with basic functionality and ultra- power use when possible and also replace inefficient equipment with comparable and high efficiency models. Inefficient equipment included high power consumption computer monitor with a comparable high efficiency models. Much of the energy use of computers and their peripherals could be eliminated by enabling power management settings and use of other control devices such as smart plug strips.

Besides energy efficiency measures, there are also control strategies and occupant behavior measures that will include the use of load sensor plug strips, remote control plug strips , and timers to minimize off- hours energy use. Although limited in the amount of potential savings, power strips are an easy way for employees to switch off all their often-forgotten energy users like computer speakers and radios quickly and easily at the end of the day. Power strips can yield additional savings if used with a computer because they eliminate off-mode power draw. Timer plug strips can also be used to turn off the printer and copier machine when not in use or during unoccupied period. Users are also encouraged to adjust brightness settings of computer monitors, enable power management setting for PCs, monitors and imaging equipment. Posters, energy monitoring displays and outlook reminders can be used to educate and increase awareness among the building occupants to turn off devices when not in use. To do this, IT staff, energy managers, and/or executive management should hold a meeting to explain the plan, then follow up with an e-mail or explaining to employees on how to enable power-management features on their machines—and exhorting them to do so. This method is essentially free and may result in greater awareness and less energy waste.

If power-management settings on individual computers turn out to be ineffective, there are low-cost or free network-based power-management software options available. This software differs from individual computer power settings because it's centrally controlled. This helps IT personnel ensure maximum energy savings and users are less likely to disable it.

Though offices usually have relatively few fax machines and copiers, these items can still represent a significant plug load. This is because these machines can consume a lot of power in both active and standby modes. The best approach with any machine in the office is to choose aggressive power settings but avoid making power setting too tight because it will consume more time for the machine to wake up from sleep mode. Choosing Energy Star models can also save significant amounts of energy up to 500 kWh per year per copier. These savings may be even greater for companies that are replacing old, inefficient models.

Controlling office plug loads is among the least expensive and most straightforward efficiency measures in any office. The decentralized nature and relative low replacement costs for many technologies means that companies can initiate programs at whatever pace they find comfortable and economically realistic. Before installing efficient lighting and HVAC upgrades and long before purchasing carbon offsets companies can enjoy the economic, social, and competitive advantages of simply turning off office appliances when not in use and shopping for the most efficient models when it comes time to replace old equipment. To that end, effectively controlling office plug loads is among the easiest and most inexpensive ways a company can reduce its carbon footprint, cut costs, and enhance its overall economic picture.

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1 Conclusions

The first part of this study was performed by calculating the Overall Thermal Transfer Value (OTTV) and overall thermal transfer coefficient (U-value) of the UTP Building 21. From the analysis, it is found that Overall Thermal Transfer Value or OTTV value is **108.88 W / m²** and this is higher than the value set in MS 1525:2007 guidelines. There are few factors that influence efficient energy usage in the building including the building constructions and U-value. The simulation method by using TRNSYS was performed to simulate the building heat gain. Results show that cooling load required to cool the building during occupancy hour is very high. This is due to high heat transfer coefficient of material for each envelope elements especially the external wall that uses glass as it building construction. High heat transfer coefficient leads to the increase of heat gain and thus required high cooling load to comfort the building.

The second part of this study was performed by investigating the current practices of lighting system and typical plug loads of the office. Results reveals that UTP lighting system did not meet the recommended average illuminance level proposed by MS: 1525:2007 guidelines and is inefficient due to high level of intensity produced by the lights.The utilization of day lighting is still low even though outdoor lighting is available and it is also observed that lighting systems for corridor lighting seems not functioning well since it is opened during the day time. In order to incorporate a more energy efficient lighting system, motion sensor technology can be implemented to the each of the office buildings. This motion sensor technology works by switch off the light in partition that does not have any movement and switch them back on when they detect movements. Apart from that, the design of UTP academic buildings is very suitable for day lighting to be utilized.

From internal office plug loads analysis, it is observed that computer and monitor are the largest plug loads energy users. Power management is not routinely or fully utilized since only small fraction of desktop computer automatically goes to sleep. Many are on after hours consuming energy unnecessarily. Plug loads are an important contributor to a building's peak air conditioning load and energy consumption. Plug loads over time have evolved to become a larger percentage of a building's overall heat gain.

From the overall findings, it can be concluded that the choices of proper building material and the achievement of good usage of building envelope will lead to positive impact on the energy efficiency of the building. The aspect of air-conditioning choices, operation in the building and finally continuous maintenance will create efficient energy usage in a building. Energy is saved in the lighting system by reducing illuminance levels, improving lighting system efficiency curtailing operating hours and by taking advantage of day lighting. Controlling office plug loads is among the least expensive and most straightforward efficiency measures in any office.

5.2 Recommendations

The followings are the recommendations from the present study to reduce energy consumption through energy efficient building envelope, effective practices of energy efficient lighting and managing office plug loads.

1. Suitable usage of construction materials and low U-value
2. The usage of internal or external shading devices
3. Implementing motion sensor technology to the each of the office buildings
4. Utilizing day lighting by raising the curtains or shades during the day and switch off any artificial lights.
5. Enabling power management settings and use of other control devices such as smart plug strips for internal plug loads.

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APPENDICES

APPENDIX 1: OTTV CALCULATION

$$OTTV = 19.1\alpha \times (1 - WWR) \times U_W + 194 \times WWR \times CF \times SC \qquad (2.2)$$

With solar absorption coefficient, $\alpha = 0.75$

For each orientation:

$OTTV_{SW} = 19.1\alpha \times (1 - WWR) \times U_W + 194 \times WWR \times CF \times SC$

$= 19.1(0.75) \times (1 - 0.90) \times 5.30 + 194 \times 0.90 \times 1.02 \times 0.65$

$= 123.48\ W/m^2$

$OTTV_{SE} = 19.1(0.75) \times (1 - 0.7) \times 5.30 + 194 \times 0.7 \times 1.02 \times 0.65$

$= 113.20\ W/m^2$

$OTTV_{NE} = 19.1(0.75) \times (1 - 0.5) \times 5.30 + 194 \times 0.5 \times 1.01 \times 0.7$

$= 107.18\ W/m^2$

$OTTV_{NW} = 19.1(0.75) \times (1 - 0.7) \times 5.30 + 194 \times 0.7 \times 0.83 \times 0.7$

$= 102.06\ W/m^2$

The OTTV of the whole exterior wall is given by the weighted average of the OTTVs of individual walls at different orientations, as below

$$OTTV = \frac{A_{oi} \times OTTV_i + A_{o1} \times OTTV_1 + A_{o2} \times OTTV_2 + .. A_{on} \times OTTV_n}{A_{oi} + A_{o1} + A_{o2} + .. A_{on}}$$

$$= \frac{(20.25 \times 123.48) + (104.14 \times 113.20) + (20.25 \times 107.18) + (104.14 \times 102.06)}{20.25 + 104.14 + 20.25 + 104.14}$$

$$= \frac{2500.47 + 11\ 788.65 + 2170.40 + 10628.53}{248.78}$$

$= \mathbf{108.88\ W/m^2}$

APPENDIX 2:

U- VALUE CALCULATION

$$U_0 = \frac{1}{R_0} \quad (2.6)$$

$$R_0 = R_{inside} + R_{surface} + R_{outside} \quad (2.7)$$

$$R_0 = \frac{1}{h} + \frac{l}{k} + \frac{1}{h} \quad (2.8)$$

External Wall

Optiwhite glass thermal conductivity, **k = 2.88kJ/hmK**; thickness, **L = 0.012 m**

R_{glass} = L/k

= 4.1667×10^{-3} hm^2K/kJ

R_{total} (include outside & inside air film) = (1/27) + 4.1667×10^{-3} + (1/90)

= 0.0523 hm^2K/kJ

U_o = 1 / R_{total}

= 1 / 0.0523

= 19.12 $kJ/hm^2K \times \frac{1 hour}{3600\, secs} \times \frac{1000}{1k}$

= **5.30 W/m^2K**

Inside Wall

Steel thermal conductivity, **k = 54 kJ/hmK**; thickness, **L_1 = 0.005m, L_2 = 0.0011 m**

$R_{steel,1}$ = L/k

= 9.2593×10^{-5} hm^2K/kJ

$R_{steel,2}$ = L/k

= 2.0370×10^{-5} hm^2K/kJ

R_{total} (include outside & inside air film) = (1/27) + 9.2593×10^{-5} + 2.0370×10^{-5} + (1/90)

= 0.0483 hm^2K/kJ

U_o = 1 / R_{total}

= 1 / 0.0483

= 20.72 $kJ/hm^2K \times \frac{1 hour}{3600\, secs} \times \frac{1000}{1k}$

= **5.76 W/m^2K**

Floor

Common Concrete thermal conductivity, **k = 7.56 kJ/hmK** ; thickness, **L = 0.100 m**

Cement Mortar thermal conductivity, **k = 5.04 kJ/hmK**; thickness, **L = 0.005**

Tile thermal conductivity, **k = 3.6 kJ/hmK**; thickness, **L = 0.005m**

Consider R_{layer} is in series.

R_{layers} = L/k

= 0.1 / 7.56 + 0.005 / 5.04 + 0.005/3.6 = 0.0156 hm^2K/kJ

R_{total} (include outside & inside air film) = (1/27) + 0.0156 + (1/90)

= 0.0638 hm^2K/kJ

U_o = 1 / R_{total}

= 1 / 0.0638

= $15.68\ kJ/hm^2K \times \frac{1 hour}{3600\ secs} \times \frac{1000}{1k}$

= **4.36 W/m^2K**

Roof

Aluminium thermal conductivity, **k = 846 kJ/hmK** ; thickness, **L = 0.001 m**

Rockwool thermal conductivity, **k = 0.162 kJ/hmK** ; thickness, **L = 0.025 m**

Aluminium thermal conductivity, **k = 846 kJ/hmK** ; thickness, **L = 0.001 m**

Common Concrete thermal conductivity, **k = 7.56kJ/hmK** ; thickness, **L = 0.010 m**

Consider R_{layer} is in series

R_{layers} = L/k

= 0.001 / 846 + 0.025 / 0.162 + 0.001 / 846 + 0.010 / 7.56

= 0.1543 hm^2K/kJ

R_{total} (include outside & inside air film) = (1/27) +0.1543 + (1/90)

= 0.2025 hm^2K/kJ

U_o = 1 / R_{total}

= 1 / 0.2025

= $4.9382\ kJ/hm^2K \times \frac{1 hour}{3600\ secs} \times \frac{1000}{1k}$

= **1.37 W/m^2K**

APPENDIX 3: BUILDING HEAT GAIN CALCULATION

Latent Heat

Based on Psychrometrics Chart;

Max Dry Bulb Temperature = 26.7° Relative Humidity (1) = 68.9% $\omega_1 = 6.3$

Min Dry Bulb Temperature = 26.7° Relative Humidity (2) = 74.1% $\omega_2 = 16.6$

ma = 10 kg/s ; assumption from Maintenance Department(2009)

$$Q_{latent} = h_{we}\,\rho\,q\,\Delta\omega \tag{2.16}$$

$= 2465.56$ kJ/kg * 1.202 * 10 m/s * (16.6- 6.3)

= **305.3 kW**

Sensible Heat

From building survey;

Surface area of the glass = 248.78 m^2

U – Value for glass = 5.30 W/m^2K

Outside air temperature = 32 °C (305K)

Room air temperature = 24 °C (297 K)

Where;

$$Q_g = A_g \, . \, U_g \,(t_o - t_r) \tag{2.17}$$

$= 248.78\ m^2 \times 5.30\ W/m^2K \times (305 - 297)$

= **10.548 kW**

APPENDIX 4:

ESTIMATED ENERGY CONSUMPTION FOR TYPICAL PLUG LOADS

Computer

37 units × (55 Watts × 9 hours/day × 365 days/year) ÷ 1000
= 6684.05 kWh × 33 cents/kWh
= **RM 2 206.04/year**

Monitor

37 units × (35 Watts × 9 hours/day × 365 days/year) ÷ 1000
= 4254.08 kWh × 33 cents/kWh
= **RM 1 403.84/year**

Laser printer

2 units × (60 Watts × 9 hours/day × 365 days/year) ÷ 1000
= 394.2 kWh × 33 cents/kWh
= **RM 130.07/year**

Fax Machine

2 units × (35 Watts × 24 hours/day × 365 days/year) ÷ 1000
= 613.2 kWh × 33 cents/kWh
= **RM 202.36/year**

Copier

2 units × (310 Watts × 2 hours/day × 365 days/year) + (2 watts x 7 hours x 365 days) ÷ 1000
= 462.82 kWh × 33 cents/kWh
= **RM 152.73/year**

APPENDIX 5:

ESTIMATED SAVING COST FOR LIGHTING SYSTEM WITH RESPECT TO REDUCTION OF HOURS USED

From lighting survey:

Fluorescent Lamp

Wattage 43 Watt
Number of lamps = 160

Operation hours (12 hours/day) = 5 days/week x 12 hrs/day x 52 weeks/year = 3120 hrs
Energy Use = 160 (43 Watt x 3,120 hrs/year) ÷ 1000 = 21 465 kWh
Energy Cost/Year = 21 465.6 kWh x 33 cents/kWh = **RM 7 083.65**

Operation hours (8 hours/day) = 5 days/week x 8 hrs/day x 52 weeks/year = 2080 hrs
Energy Use = 160 (43 Watt x 2 080 hrs/year) ÷ 1000 = 14 310 kWh
Energy Cost/Year = 14 310 kWh x 33 cents/kWh = **RM 4 722.43**

Operation hours (4 hours/day) = 5 days/week x 4 hrs/day x 52 weeks/year = 1040 hrs
Energy Use = 160 (43 Watt x 1 040 hrs/year) ÷ 1000 = 7 155.2 kWh
Energy Cost/Year = 7 155.2 kWh x 33 cents/kWh = **RM 2 361.22**

Compact Fluorescent

Wattage 35 Watt
Number of lamps = 76

Operation hours (12 hours/day) = 5 days/week x 12 hrs/day x 52 weeks/year = 3120 hrs
Energy Use = 76 (35 Watt x 3,120 hrs/year) ÷ 1000 = 8 299.2 kWh
Energy Cost/Year = 8 299.2 kWh x 33 cents/kWh = **RM 2 738.74**

Operation hours (8 hours/day) = 5 days/week x 8 hrs/day x 52 weeks/year = 2080 hrs
Energy Use = 76 (35 Watt x 2080 hrs/year) ÷ 1000 = 5 532.8 kWh
Energy Cost/Year = 5 532.8 kWh x 33 cents/kWh = **RM 1 825.82**

Operation hours (4 hours/day) = 5 days/week x 4 hrs/day x 52 weeks/year = 1040 hrs
Energy Use = 76 (35 Watt x 1040 hrs/year) ÷ 1000 = 2 766.4 kWh
Energy Cost/Year = 2 766.4 kWh x 33 cents/kWh = **RM 912.91**

APPENDIX 6:

GANTT CHARTS

Gantt chart for FYP I

Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of project topic and submission of proposal														
Research on selected topic														
Preparation and submission of preliminary report														
Project work														
Submission of progress report														
Seminar														
Project work continue														
Submission of Interim Report Final Draft														
Oral Presentation														

Gantt chart for FYP II

Activities/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Building survey and data gathering														
Improvement on literature review														
OTTV calculation														
U- value calculation														
Conduct building heat gain simulation using TRNSYS														
Submission of progress report														
Lighting system evaluation														
Internal office plug loads evaluation														
Results analyses and submission of poster														
Draft report														
Technical and final report submission														
Oral presentation														