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Energy Efficiency Analysis and Financial Assessment at Faculty of Engineering, UNISEL

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Abstract: Energy is an important factor in the development and growth of the economy. Therefore, the availability of adequate supplies of energy is a strategic issue for any country including Malaysia. Nowadays people are more concern about energy efficiency and conservation and one of the focal point is the energy consumption in buildings. This research focuses on energy efficiency analysis at Faculty of Engineering (FOE), UNISEL. Through successful implementation, the energy costs would be minimized, wastes and the environmental hazards would be reduced. A detailed load and energy audits were completed for FOE. Two major parts, which are efficient illumination design and occupancy control were examined. For efficient illumination design, the existing lighting design was reviewed and the potential energy saving by de-lamping the lights were determined and validated with actual photometric measurements. The energy saving through occupancy control was also determined. Both controls reduce energy usage. There is a general awareness of the opportunities for reducing the cost of electricity consumption in FOE but the progress in implementation is slow and stagnant. In FOE, there are several different uses of electrical energy such as lighting, air conditioning and other devices. The energy that contributes to the total electrical usage within the faculty was computed. Finally, the payback period is calculated.

Keywords: Efficient Illumination, De-lamping, Energy Saving, Energy Audit, & Occupancy Control

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1. Introduction

Nowadays the demand of energy is increasing, especially in commercial buildings. The energy consumption in the public and commercial buildings in Malaysia had increased by more than 50%. Unfortunately this leads to Carbon Dioxide emission. Therefore more efficient ways of consuming energy are required to overcome this problem [D. Yogi Goswami; Frank Kreith]. Energy efficiency analysis, also known as energy audit, plays a role to reduce the usage of energy (electricity). Energy efficiency is important for managing electricity and reducing the cost of operation. Cost saving can be achieved by using de-lamping method, that is, by reducing the lamps in each building, and by providing only the required amount of lux [Damon Wood; Lawrence Berkeley]. Lighting and air-conditioning systems are the two appliances that consume the most amount of energy in buildings. University of Selangor (UNISEL), located at Bestari Jaya, Selangor is chosen for study on saving energy and energy management. The premises for this study include classrooms, labs and lecturers' offices.

Faculty of Engineering, UNISEL building consumes more energy recently. This building has too many lighting. Energy usage at this faculty is not being maximized. Hence, analysis of energy usage is required to overcome this problem to provide efficient energy flow especially in terms of illumination.

2. Methodology

Methodology is explained in the following sections:

2.1 Loads and Energy Audit

The rating of all the installed equipment's in all rooms in the Faculty of Engineering, UNISEL is recorded. From the data collected, the total power consumed was determined and the percentage contribution of each type of load such as lighting, air-conditioning and equipment and their numbers are calculated. Then the energy audit is carried out by collecting data for the whole semester from the TNB meters which records the real power, the reactive power, and the power factor. From the load profile analysis calculation is performed to identify ways to save energy. The summary of the physical facilities of faculty is shown in Table 1.

Table 1. Faculty of Engineering, UNISEL Facilities Summary

Description	Specification	Location
Number of Floor	Ground floor 3 Floor above Ground Floor	Faculty of Engineering, UNISEL
Number of Class rooms	Total 43 classrooms (including 3 study room)	Overall Building
Number of Computer Labs	Total 3 Computer Labs	Ground Floor and Level 1
Number of Engineering Labs	Total 35 Labs	Ground Floor and Level 1
Recreation	Cafeteria Departmental store	Ground Floor and Level 1
Lecturers room		Level 2 and Level 3

2.2 Energy saving by efficient illumination design

In the lumens method of calculation was used in which the dimension, lamp fixture details and appearance were noted for all the rooms in Faculty of Engineering UNISEL. The lumens level required for each type of task required by the rooms was taken from the Illuminating Engineering Society (IES) standards and the required illuminance was determined [Jack F. Christensen; John E. Kaufman]. Then the installed lumens were calculated. From the difference obtained the extra or deficit lumens is calculated and the extra lamps installed was determined. By de-lamping the extra lamps installed the energy saving was determined [Illuminating Engineering Society of North America]. The actual photometric measurement is used for validity purpose.

The efficient illumination design is explained in the following steps:

Step 1: The required illuminance on the working plane is determined according to the IES (Illuminating Engineers Society):

The required illuminance is determined by considering the average age of the student, the type of the task to be performed, the accuracy and speed required for the task and the working space reflectance factor. The required illuminance levels and the weighting factor according to the IES standards depicted in Table 2.

In educational institutions types of activities performed are:

i. Visual task which are performed occasionally on the working area and are referred to category C and

ii. Visual tasks, which are performed on the working space of high contrast or larger size in nature and are referred to category D.

Step 2 : The room dimensions are collected in the following format :

For example classroom at ground floor (LR13 –LR21) is measured and tabulated as shown in Table 2 and the area is computed.

Table 2. Classroom Dimensions

Room	**Length of the room (L) (m)**	**Breath of the room (B) (m)**	**Mounting Height of lamp from working plane (Hm) (m)**	**Area (A) = L x B (square metres)**
LR13 – LR21	6.33	6.66	2.3	42.158

Step 3 : Determination of room index R.I :

The room index is determined using the equation 1

$$R.I = \frac{LxB}{H(L+B)} \qquad (1)$$

Where,
L is the length of the room in meters
B is the breadth of the room in meters
H_m is the mounting height of the lamp from the working plane in meters.

Step 4 : Determination of the utilization factor U_f :

The coefficient of utilization or utilization factor U_f is the amount of luminous flux directed downwards and directly reaches the working plane are without any reflection. It depends on:

i. The geometrical shape and size of the room. Its value is low for narrow room (R.I is small) and high for a wider room (R.I is large)

ii. The lamps distribution of light. The ratio is high for lamps emitting light with larger solid angle and low for those emitting with narrower beam.

iii. The light reflection from the room surfaces.

The manufacturer provides the utilization factor for the particular luminary from the photometric test report. The utilization factor is determined for different light fixtures for the known reflectance values of the wall, ceiling and floor. Some typical cavity reflectance values as per the IES standards are shown in Table 3.

Table 3. Cavity Reflectance Values

Colour	**Reflectance**
Pure white, milk white, light gray, light brown and light blue	70-90%
Medium grey, medium green, medium yellow, and medium brown	30-60%
Medium blue and dark grey	10-20%
Darker green, dark blue, dark wood paneling	5-10%

Step 5 : Determining the extra or deficit lumens and the number of lamps to be delamped :

The required lumens is calculated using the equation 2

$$Required\ Lumens = \frac{ExA}{U_f x M_f} \qquad (2)$$

Where,
E is the average illuminance required in lux
A is the area of the room in meter square
U_f is the utilization factor
M_f is the room maintenance factor.

For the LR13-LR21, illuminance *E* is taken as 300 lux from step 1 recommended by the IES standards, for area A = 42.158m^2 from step 2, U_f is 0.492 and the maintenance factor M_f is assumed to be 0.8 for the clean air-conditioned room. The maintenance factor is taken into account the lamp output over time deprecation and dirt accumulated on the lamp fitting and walls of the room. The required lumen is computed as 32133 lumens. The installed lumens is calculated using the equation 3

$$Installed\ Lumens = n\ x\ lumens\ output\ of\ the\ installed\ lamps \qquad (3)$$

Where *n* is the number of lamps installed.

Step 6: Determination of the average lux through the photometric measurement:

The average lux received from each room is measured through photometric. The average illuminance is found at different instances like morning, afternoon and evening. The average value should be equal to or more than IES recommended illuminance level for comfort of the occupants.

Steps 1 to 5 are repeated for all the rooms in the building and the total number of lamps that can be de-lamped is determined and hence the energy for an average of 9 hours per day which represents he institution operation hours from 8.30am until 5.30pm is then calculated. Finally, the annual energy saving that can be determined.

3. Energy saving through occupancy control

In this method, the time table of the classes for current semester is taken from the academic office. From the time table, the total number of hours, classroom that is unoccupied are noted. This is only done for the classrooms where as the other areas are occupied throughout the operation hours. Then, a visual monitoring is done for several unoccupied class to identify whether the class is occupied or not. The data is taken from Monday to Friday according to classes' time.

During weekends data is not collected, as it is not mention in the time table. The total number of unoccupied hours for each classroom is calculated for a semester. From the number of lamps installed including ballast losses and knowing the power in watt, the total energy that can be saved is determined. The whole process will be repeated for next two semesters and the average will be calculated, then the annual energy saving will be determined. The whole procedure will be repeated with considering the de-lamping method from the previous section and overall energy saving will be evaluated [Ravi Lakshmanan; Rajendran Sinnadurai].

4. Results and Discussion

4.1 Loads and Energy Audit

Electrical energy consumption in this building is divided into 3 major categories. Firstly, the air-conditioning system was divided into the split unit air conditioning and the liquid chiller room (centralized system) which is using AHU (Air Handling Unit). Secondly, the lighting system, including all types of lighting inside the building: the classrooms and lecture rooms, engineering labs, corridor lights, and offices. Thirdly, the equipment: including devices such as computers, LCD projectors, and lab equipment.

Actual load has been carried out for the entire building in term of lighting, air conditioning and refrigerators, equipment's (desktop computers, laptops, projector and machines). From the load audit, it is observed that the total connected load is about 528 kW and it's distributed as shown in Table 4.

Table 4. Total Connected Load for LR 13 –LR21

Type of load	kW
Lighting	132
Air conditioner and Refrigerator	380.16
Equipment's	15.84
Total Connected Load	**528**

Lighting load consumes the lowest and air-conditioners and refrigerators load the highest of the total connected load. As shown in Figure 1 from the total connected load of 528 kW per week, lighting contributes 25% (132 kW), air conditioners and refrigerator 72% (380.16 kW) and other equipment's is 3% (15.84 kW).

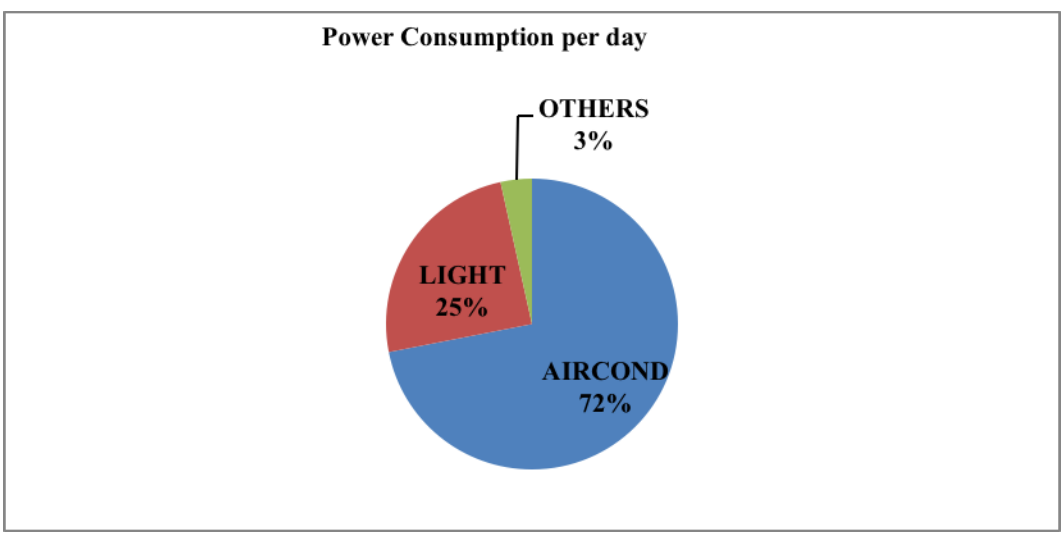


Figure 1: Power Consumption per day

4.2 Energy Saving by Efficient Illumination Design

In this method the number of installed luminaries with their power rating in watts and lumens output are recorded for all the rooms in the buildings. The length L, breadth B, and the mounting height H_m of the lamp from the working plane is measured for all the rooms using the measuring instrument. The room area is calculated by multiplying the length with the breadth. The room index is calculated using equation 1. For the calculated room index, the utilization factor is determined directly and interpolation from the manufacturer data sheet utilization factor. The maintenance factor is taken as per the IES standards, which based on the nature of the rooms. The required lux for the room is 300 for classrooms, 200 lux for computer labs, 350 for engineering labs and 300 lux for administrator office and lecturer's room, which are within IES standards.

For each room the required lumens and the installed lumens are calculated using the equation 2 and 3 respectively and the extra or deficit lumen is the different between the required lumens and the installed lumens. The number of lamps to be delamped is then calculated by dividing the extra lumens by 3350 lumens (Philips lamps lumens output of 36 watt 4 feet lamp). To validate the calculated results, actual photometric measurements are made. In the classroom LR13 – LR21 from the table is noted that there are eight Philips twin tube fixture of 4 feet lamp T8 TLD 36W/840 cool white with 3350 lumens output and total lumens is (8 x 2 lamps x 3350 lumens) = 53600 lumens.

The extra or deficit lumens are then computed as the difference in the installed lumens and the required lumens for example the classroom LR 13 to LR 21, are 18299 lumens (53600-35301 lumens). The number of lamps to be delamped is then obtained by dividing the extra lumens installed by the lamps lumens output. Hence the 36W 4 feet fluorescent tubes with lumens output of 3350 lumens is delamped, then the number of lamp that to be delamped is given by,

No . of lamp to be delamped = 18299/ 3350 = 5.46 = 5 lamps

Thus by de-lamping five single fluorescent lamps, total of 210 watts, daily energy of 1.89 kWh (9 hours operation) and annual (255 days) energy of 481.95KWh can be saved excluded weekends and public holidays. To validate these results for classroom LR13 – LR21 actual photometric measurements are taken, analyzed and validated.

The efficient illumination design using lumens method is validated by conducting photometric measurements in the classroom LR13- LR21. The photometric measurement using point measurement method is performing on a cloudy day taking into account, the photometric measurement for average sunny days to be much better than a cloudy day. The photometric measurements are made using Pro kit lux meter. The measurements was recorded for three different session morning, afternoon and evening with different combinations window, all lights ON, all lights OFF and five Fluorescent lamps OFF.

The photometric lux measurement was made in the morning when the outside climate was cloudy around 9am to 10am, with window. The measured lux values were recorded in Table 5. It is observed from table that in the morning the average illuminance measured maximum of 366 lux, minimum of 182 lux and average is 307 lux. By de-lamping 5 TLD 4 feet florescent lamps the average illuminance is 302 lux, which is more than the IES recommended levels. It is also observed that the illuminance levels are higher and better in the morning. Thus it is recommended to use the natural daylight along with the required lamps ON.

The photometric measurements were made in the afternoon when the outside climate was still cloudy around 12noon until 1.00pm. The measured lux values were recorded in table and the variations of the illuminance are depicted in Figure 2.

Table 5. Photometric Measurement In the Morning

Photometric Measurements Morning (9am to 10am)		
Table No	**All Light On**	**5x36W TLD OFF**
1	322	311
2	317	315
3	269	270
4	382	355
5	355	355
6	320	310
7	302	297
8	366	340
9	333	327
10	324	300
11	282	266
12	255	241
13	300	300
14	297	297
15	182	180
Minimum	**182**	**180**
Average	**307**	**302**
Maximum	**366**	**355**

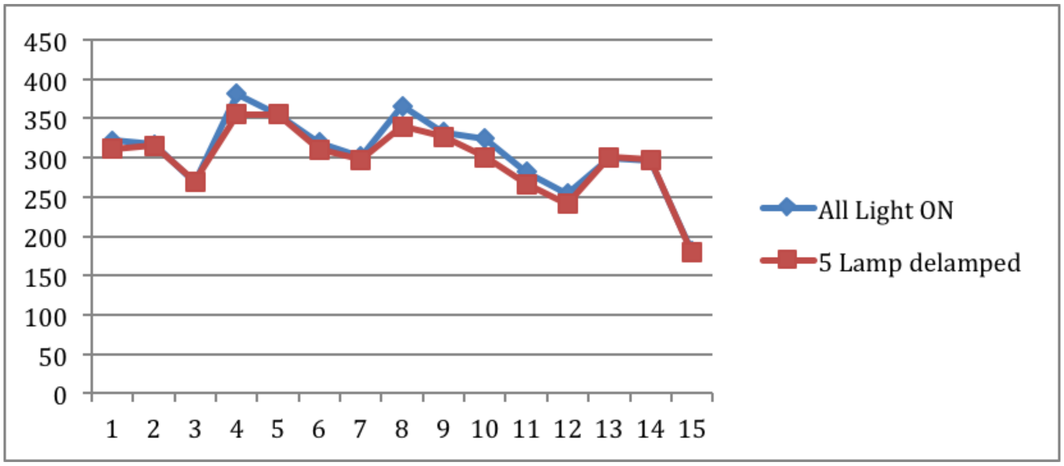


Figure 2. Variation of the Illuminance in the morning

The photograph taken in the evening session during lux measurements with all the combinations are depicted in Figure 3.

(a). Brightness of the classroom in the evening.

(b). Brightness of the classroom before de-lamping

(c). Brightness of the classroom after delamped 5 lamps

(d). Brightness near window with light OFF

Figure 3. Lux measurement with all combinations

To summarize the average illuminance in all the combinations varies between 302 lux to 323 lux after de-lamping the lamps. The average illuminance is well above the minimum level required 200 lux as per IES standards. It is also observed that the average illuminance is higher while using the natural daylight. The procedures explained previously are repeated for all rooms in the Faculty of engineering UNISEL.

4.3 Energy Saving by Occupancy Control

Energy saving by occupancy control is carried out only for the classrooms because the remaining rooms are mostly being used during normal operating hours. The actual timetable data is collected for a period of four months from January 2014 until April 2014 for analysis. The durations for which each classroom when not occupied is recorded in a table form and the total unoccupied hours for each day are noted and the energy saving is determined. Then considering the de-lamping of lamps explained in the previous section, the overall energy saving is determined.

From the data collected by occupancy control method, it is observed that from January 2014 until April 2014, LR 19 is the least utilized with an energy saving of 33.088 kWh without de-lamping and after de-lamping 29.488 kWh. The classroom LR 14 is the most utilized with an energy saving of 363.176 kWh without de-lamping and 359.576 kWh after de-lamping. The total energy that can be saved in the month of January is 2461.768 kWh without de-lamping and 1522.816 kWh after de-lamping.

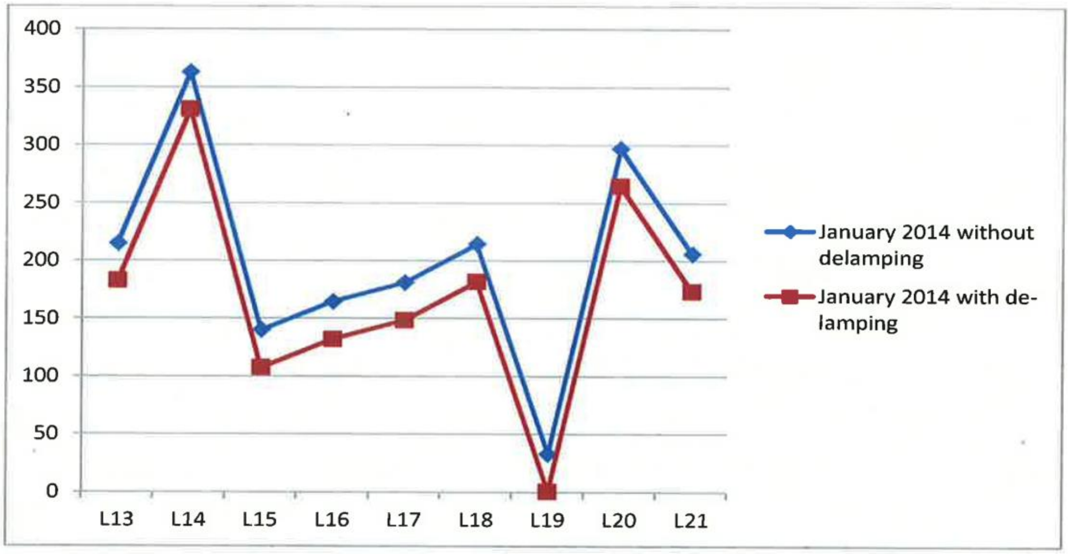
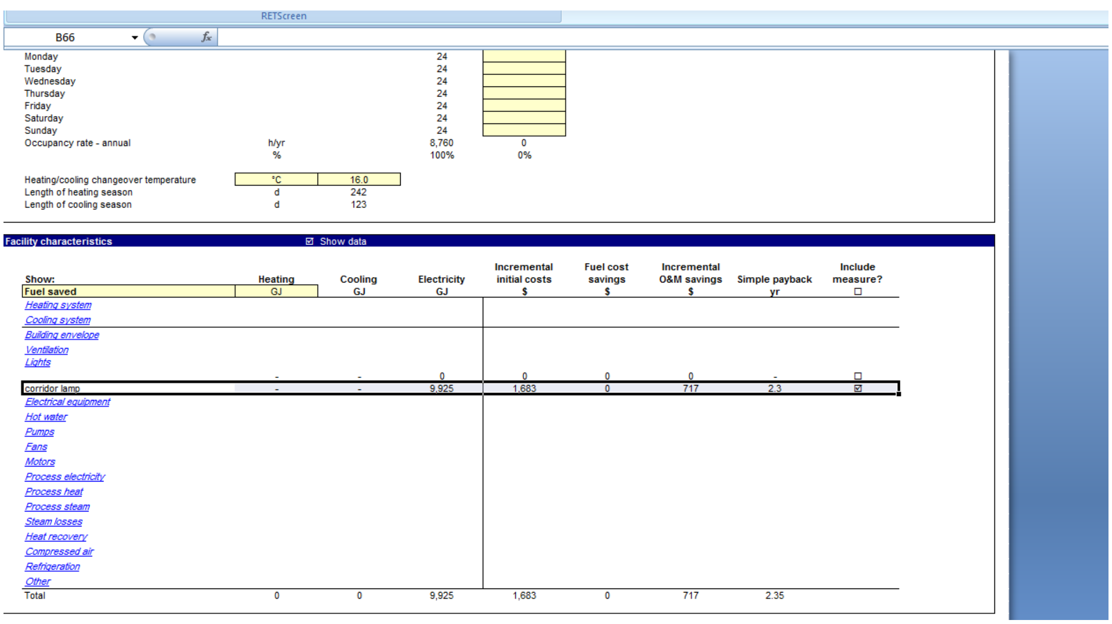


Figure 4. Energy saving by occupancy control for January 2014 to April 2014

4.4 Lighting Energy Saving Through Replacement for the Corridor

Assuming the 36-W fluorescent lamp cost RM 4.50 each and last for 8000 hours, and the 18-Watt lamps cost RM 9 each and last for 12000 hours, and the electricity tariff is RM0.509sen/kWh, then by replacing the 36W fluorescent lamp with 18W compact fluorescent lamp, then the annual saving is RM 717.31.



RETScreen

B66

Monday		24	
Tuesday		24	
Wednesday		24	
Thursday		24	
Friday		24	
Saturday		24	
Sunday		24	
Occupancy rate - annual	h/yr	8,760	0
	%	100%	0%
Heating/cooling changeover temperature	°C	16.0	
Length of heating season	d	242	
Length of cooling season	d	123	

Facility characteristics ☑ Show data

Show:	Heating	Cooling	Electricity	Incremental initial costs	Fuel cost savings	Incremental O&M savings	Simple payback	Include measure?
Fuel saved	GJ	GJ	GJ	$	$	$	yr	☐
Heating system								
Cooling system								
Building envelope								
Ventilation								
Lights								
	-	-	0	0	0	0	-	☐
corridor lamp	-	-	9,925	1,683	0	717	2.3	☑
Electrical equipment								
Hot water								
Pumps								
Fans								
Motors								
Process electricity								
Process heat								
Process steam								
Steam losses								
Heat recovery								
Compressed air								
Refrigeration								
Other								
Total	0	0	9,925	1,683	0	717	2.35	

Figure 5. Payback period Calculated for Corridor Lamp replacement using Retscreen Software.

4.5 Air Conditioning (Split Unit)

Table 6 shows the air conducing (split unit) location in each location at ground floor and first floor for each room. Compare AHU unit, Split unit was used in all classrooms and labs.

Table 6. Data collected for Classroom and Laboratories at Ground and First Floor

Floor	Location	Air-cond Split unit	Lighting	Quantity
Ground	Lecture Room	21x 2 x 1HP	21 x 8 x 2 TLD 36W flourescent	336
Ground	Toilet		8 x 4 x 2 TLD 18W flourescent	64
Ground	Drawing Studio		4 x 6 x 2 TLD 36W flourescent	48
Ground	Enviromental Lab		12 x 2 TLD 36W flourescent	24
Ground	Chemical		13 x 2 TLD 36W flourescent	26
Ground	Geomatric Lab		4 x 150W Nikkor	4
Ground	Microprocessor Lab		32 x 2 TLD 36W Flourescent	64
Ground	Electric Machine Lab		4 x 2 150W Nikkor	8
Ground	Power System Lab		4 x 2 150W Nikkor	8
Ground	Lecture Theater		35 x 2 TLD 36W flourescent	70
Ground	Engineering Room		12 x 3 TLD 36W flourescent	36
First	Lecture Room	20 x 2 x 1HP	21 x 8 x 2 TLD 36W flourescent	336
First	Toilet		8 x 4 x 2 TLD 18W flourescent	64
First	DK 4		32 x 2 TLD 36W Flourescent	64
First	Surau	1 x 1HP	4 x 2 TLD 36W flourescent	8
First	Communication Lab		30 x 2 TLD 36W flourescent	60
First	Electrical Technology Lab		4 x 8 TLD 36W flourescent	32
First	Electronic Lab		7 x 4 TLD 36W flourescent	28
First	Measurement and Instrument Lab		7 x 4 TLD 36W flourescent	28
First	Corridor lamp		62 TLD 36W flourescent	62

4.6 Total Savings for Faculty of Engineering, UNISEL

Unisel electrical bill could even reduce more on energy saving on the lighting and air-condition. By implementing few saving method and devices can reduce the amount of electrical consumption per month. Table 7 shows the estimation amount saving for Faculty of Engineering, Unisel per month. This is only estimated theoretical value calculated referring to PTM (Pusat Tenaga Malaysia) and illumination design that have been done in classrooms. The amount of RM 5181.02 can be saved after installation of the suggested saving devices. It can save more than 5% of the total one month of energy consumption.

Table 7. Total Energy Saving for Faculty of Engineering, UNISEL

September 2014 Energy Consumption		**Percentage Energy Saving after Installation**		
Type	**RM**	**Electronics Ballast**	**Variable Speed Drive**	**Illumination Design**
		50%	30%	
Lighting	3344.13			1757.63
Lighting at Corridor	791.6	395.8		
Split Unit Air Conditioner	10662.37		7463.65	
Total Bill for September 2014	**14,798.10**			
New Total Bill September 2014	**9617.08**			
Total Saving	**5181.02**			

5. Conclusion

This research has identified the areas in saving the electrical energy consumption in the Faculty of Engineering, UNISEL. The energy consumption was audited. Efficient illumination design is achieved by switching **OFF** 235 lamps due to excess illuminations as required as per IES standards. It resulted in a total power saving of 8.46 kW per day, with 9 hours taken as the normal operation hours. The total energy saved per day is 76.14 kWh. Average annual energy saving is 19415.7 kWh, excluding weekends and public holidays, which contributes to 1.5 % of total energy consumption. More energy saving can be achieved by utilizing daylight and switching of more lamps during sunny days.

Energy can be saved through occupancy control. Before de-lamping, an approximate average of consumption was 2461.768 kWh/month and after de-lamping, the consumption was about 1522.81 kWh/month. The saving was 938.95 kWh/month. An overall energy of 11267.42 kWh was saved annually.

There must be an awareness of energy conservation among the community of UNISEL. Energy saving is important, as it not only saves the energy consumption cost, but provides better and greener environment for everybody.

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