Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 56 (2014) 621 – 633

Energy Procedia

11th Eco-Energy and Materials Science and Engineering (EMSES2013)

A study on energy efficiency improvement opportunities for plug loads in buildings in the equatorial region

Qi Jie Kwong[1], Sind Hoi Goh[1], Nor Mariah Adam[1] and Vijay R. Raghavan[2]

[1]Department of Mechanical and Manufacturing Engineering, Faculty of Engineering,
Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[2]OYL Research and Development Sdn Bhd,
47000 Sungai Buloh, Selangor, Malaysia

Abstract

The small plug loads in the tropical buildings are among the fastest growing sources of energy use. Yet, there are comparatively fewer studies that were focused on the energy efficiency improvement potentials of the office equipment due to its elusive, more diversified and sophisticated nature. This objective of this study is to identify the opportunity for energy efficiency improvement of the frequently used office equipment in a commercial building in Malaysia, by focusing on the occupant behaviour and software power management features. The outcomes show that about 19% of the total energy demand can be reduced if the office equipment not in use are turned off, unplugged or disconnected. This also led to a significant reduction in greenhouse gases emission. This finding is particularly important for good energy demand management, as more and more modern electric appliances are introduced into the local commercial buildings which are contributing to the increase in energy consumption and subsequently, the electric bill.

Peer-review under responsibility of COE of Sustainalble Energy System, Rajamangala University of Technology Thanyaburi (RMUTT)

Keywords: energy efficiency; plug loads; office equipment; tropical building; occupant behaviour; power management

1. Introduction

Buildings throughout the world used up approximately 79.8 quadrillion BTU in year 2008, which was about 21% of total delivered energy consumption [1]. The building sector in Malaysia represented about 13.1% of the total energy demand in 2010 and is expected to grow with an average rate of 5.1% annually [2]. Since the past decades, the energy usage in the tropical buildings has increased significantly due to several reasons: Modernisation of buildings, large influx of modern consumer electronics and increase in the use of air-conditioning system to improve comfort of occupants. The energy used up by the office equipment and other electronic appliances in buildings, which is often placed under the category of small plug loads is increasing drastically especially in the commercial buildings. In fact, the plug loads were identified as the fastest growing end-user of energy in the commercial sector as demand for new electric appliances continues to grow [3]. In Malaysia, the sales volume of the plug loads has reached RM 471

Peer-review under responsibility of COE of Sustainalble Energy System, Rajamangala University of Technology Thanyaburi (RMUTT)
doi:10.1016/j.egypro.2014.07.201

Million in 2011, which is a 20.8% growth in sales from 2010 [4]. Besides, some previous studies [5] – [8] noted that the plug loads often consumed between 15 – 30% of the total electricity consumption in commercial buildings and will continue to grow due to modernisation of such building type, which directly suggest that more attention should be given to this category of equipment for energy efficiency improvement in buildings. However, comparatively fewer studies were directed towards the small plug loads due to the wide diversity of the available electric appliances and operation of the devices are largely under the control of the users, which make the analysis of energy usage more difficult and challenging [9].

Several studies have noted that good power management and user behaviour are the important factors in managing efficient use of office equipment [10] – [11]. Over the past decades, there have been efforts by many governmental agencies and private organizations in development of new standards and improvement in technologies which helped in improved efficiency and power management features of the electric appliances. However, despite all these efforts, it is still not high enough to counterbalance the growth in the number of electric appliances in commercial buildings worldwide. This paper aims to identify the potential for energy conservation improvement in the use of the office equipment. A comprehensive field assessment, which consists of energy consumption measurement and questionnaire survey, was carried out during an energy savings campaign in a commercial building in Malaysia. The users' behaviour in handling of the selected office equipment was studied and the possible energy savings via software power management settings are highlighted in this study.

2. Methodology

A comprehensive energy audit was carried out at the Faculty of Engineering, Universiti Putra Malaysia (UPM) which is one of the largest public institutions of learning in Malaysia. This audit was a part of the "Switch off when not in use" campaign that was officialised by the faculty in August 2012. An energy audit checklist which focused on the office equipment was developed with reference to the guidelines published by the Malaysian Energy Centre [12]. The energy audit consists of both field measurement and questionnaire survey, with the intention to understand the occupants' behaviour in using the office equipment. Prior to the actual audit, a pilot study was performed to identify the frequently used equipment in the administrative offices, computer laboratories, classrooms and lecturers' rooms and the list of equipment is tabulated in Table 1. Only the frequently used equipment were considered for further analysis as they were assumed to be major energy consumers. Besides, the power ratings and operating hours of these office equipment were recorded to calculate the energy consumption.

Table 1: List of Frequently Used Equipment

Administrative Office	Lecturers' Office	Classroom/ Lecture Hall	Computer Laboratory
Desktop (CPU)	Desktop (CPU)	Desktop (CPU)	Desktop (CPU)
CRT monitor	Portable computer	CRT monitor	CRT monitor
LCD monitor	CRT monitor	LCD projector	LCD monitor
Copier	LCD monitor	Overhead projector	
Laser printer	Laser printer		
Fax machine			

2.1. Power requirement of the office equipment

The electricity consumed by each of the frequently used office equipment was measured by using a digital clamp-on ammeter. The same type of office equipment may have different power requirement, depending on the manufacturers' technical specifications. The electrical power equation was used to calculate the power requirements for the commonly used equipment in the building under study.

$$\text{Power}, P = I \times V \times \cos \Phi \quad (1)$$

where
P – power in watts, W
V – voltage in volts, V (In Malaysia, 230 V was used)
I – current in amperes, A
$\cos \Phi$ – power factor of equipment

2.2. Questionnaire Survey

The purpose of using the questionnaire approach was to determine the operating hours for some of the office equipment, as it is required for calculation of energy consumption. For the computing devices in the computer laboratories and offices, the operating hours for each of the computers were user-dependent. Hence, it was necessary to study the user behaviour on computers and some questions related user behaviour, such as turning off computers during lunch break and after working hours were presented to the respondents. As for other office equipment like the copier, printer and fax machine, the operating hours for such equipment were assumed to be eight hours per day, as the working hours for offices in Malaysia was only eight hours per day, assuming that such equipment were turned off/entered low power mode during the one hour lunch break.

2.3. Energy consumption and cost analysis

The following equation was used to calculate the energy consumption in kilowatt-hour (kWh), after the power requirement and operating hours of the office equipment were identified:

$$E_i \text{ (kWh)} = P \text{ (W)} \times \text{Hours of Usage} / 1000 \quad (2)$$

where
E_i = energy consumption
W = Watt, the unit of measurement for the electric load

The total energy consumption for a type of office equipment was calculated by multiplying the number of the equipment with the kWh identified in Eq (2):

$$\text{Total energy consumption} = N_i \times E_i \quad (3)$$

where

N_i = number units of a certain type of equipment
E_i = energy consumption of a certain type of equipment

The total energy consumption for each type of equipment was necessary to determine the major energy consuming equipment and to identify the energy management opportunity.

In order to calculate the energy cost, the electricity tariff rate is required. For peninsular Malaysia, the electricity used is supplied by Tenaga Nasional Berhad (TNB). The electricity tariff information was obtained from the TNB official website [13]. The electricity tariff is in Ringgit Malaysia per kilowatt-hour (RM/kWh). For different tariff categories, the charged rate is different. The energy cost was calculated using the following equation:

$$\text{Utility cost (RM)} = E_i \times \text{Tariff Rate (RM/kWh)} \quad (4)$$

3. Results and Discussion

The monthly energy consumption for the building under study was downloaded by using an energy management device from the main electricity meter located at the administrative building. The energy consumption data from the 1st of January to 30th of June 2012 were obtained, as illustrated in Fig 1. The average monthly consumption for this commercial building was calculated as 173,300 kWh.

The power requirements of the frequently used office equipment were measured by using a digital clamp-on ammeter, as presented in Table 2. Based on the fact that some of the office equipment, especially the laser printer and fax machines were purchased from different manufacturers and had different power requirements, the typical power requirements were referred to in this study. In contrast, given that the power requirements obtained by measurement for desktop, portable computer and monitor were greater than the typical power requirements, the measured values were more suitable and accurate to be used for the calculation of energy consumption.

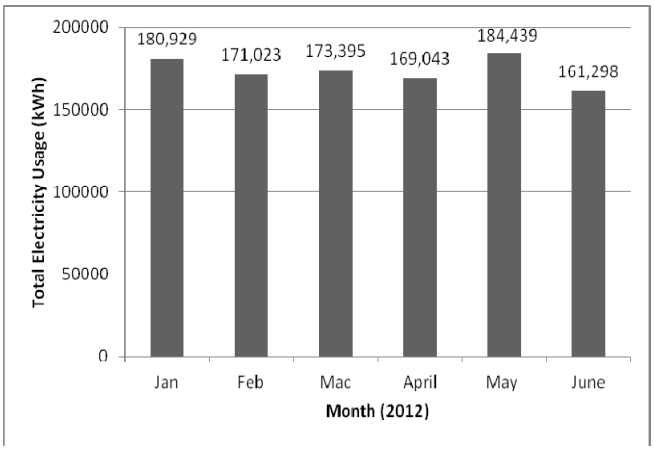

Fig. 1. Energy consumption in the Faculty of Engineering, UPM (January to June 2012)

Table 2: Typical electrical power requirements and the measured power requirements

Equipment	Typical Power Requirements[1] (Watts)	Electrical Current Measured (Ampere)	Voltage (Volt)	Power Requirements By Measurement (Watts)
Desktop	55	0.3	230	69
Laptop	20	0.1	230	23
CRT monitor	85	0.2	230	46
LCD monitor	15	0.1	230	23
Copier	310	0.8	230	192(STB*)
Laser printer	60	0.1	230	24 (STB*)
Fax machine	35	0.0	230	-
LCD projector	N/A	0.9	230	207
Overhead projector	N/A	0.4	230	92

*STB – Standby Mode
[1] Source - Office Equipment Energy Savings Calculator, LBL

3.1. Quantities of Equipment

The quantities of equipment in the administrative offices, lecture halls and lecturers' offices are tabulated in Table 3, Table 4 and Table 5 respectively. As for the computer laboratories, a total of 200 desktops (50 units for each laboratory) were identified and there was only 1 LCD monitor for the use of a management staff. All other monitors were of CRT models. Table 3 presents the quantity of office equipment in the administrative offices of the faculty. It was found that the computers constituted the highest percentage of all office equipment, followed by laser printer and the fax machine. All the lecture halls and classrooms were equipped with computers and projectors, except for the small tutorial rooms where only overhead projectors were available.

As for the lecturers' offices, due to their inherent portability, the accounting for portable computers was difficult [14]. Hence, we assumed that all of the teaching staff was using one portable computer for each of them only. Besides, it was identified that almost all of the lecturers are provided with desktops and a large portion of them received LCD monitors. Printers constituted the highest percentage among all office equipment in this building category.

Table 3: Quantities of office equipment in the administrative offices

Administrative Offices	Quantity of equipment					
	Desktop (CPU)	CRT monitor	LCD monitor	Copier	Laser printer	Fax
Academic Division	9	0	9	2	9	1
Maintenance Division	11	8	3	1	6	0
Information Technology Unit	10	2	8	3	7	1
Student Activity Centre	5	2	3	0	4	0
Graduate Research Division	14	2	12	1	14	1
Development Division	15	0	15	2	8	1
Quality Assurance Unit	9	1	8	1	8	1
Dean's Office	13	3	10	2	3	1
Departmental Offices	47	3	44	8	47	8
Total	133	21	112	20	106	14

Table 4: Quantities of equipment in the Lecture halls/ rooms

Locations	Equipment quantity				
	Desktop (CPU)	CRT monitor	LCD monitor	LCD projector	Overhead projector
Lecture Hall	8	8	0	8	8
Lecture Room	18	18	0	18	18
Tutorial Room	0	0	0	0	12
Total	26	26	0	26	38

Table 5: Quantities of equipment in the lecturers' offices

Locations (Offices only)	Equipment quantity				
	Desktop (CPU)	Laptop	CRT monitor	LCD monitor	Printer
Dept of AE	49	16	5	44	53
Dept of EE	58	24	7	51	61
Dept of ME	56	20	8	48	59
Dept of CE	57	16	7	50	57
Total	220	76	27	193	230

3.2. Operating hours

The operating hours for the office equipment were determined by using three approaches – i) Based on normal working hours, ii) questionnaire survey and iii) field observation. The working hours for Malaysian offices are from 8.30am to 5.30pm, which are 9 hours in total. Therefore, the office equipment in the administrative offices such as printer, copier and fax machine were assumed to be in use for 8 hours daily, excluding the one hour lunch break from 1pm to 2pm.

The questionnaire survey together with observation was used to identify the operating hours of computers. Table 6 presents the findings from the questionnaire survey on the user behaviour on computer usage. It was found that 95% and 82% of the respondents from the administrative offices and lecturers' offices respectively did not turn off their computers during lunch time. However, about 77% of the administrative staffs and 58% of lecturers claimed that their computers were shut down after office hours.

Table 6: User behaviour on computer usage

Location	Turn-off computer during lunch break			Turn-off computer after office hours		
	Yes	No	Monitor only	Yes	No	Monitor Only
Administrative offices	5%	95%	0%	77%	8%	15%
Lecturers' Offices	4%	82%	14%	58%	26 %	16%

Table 7: Operating hours of equipment in the lecture halls and classrooms

Location	Equipment usage	Avg. lecture hours	Equipment usage – non lecture	Operating hours per day
Lecture Hall				
- Desktop	68%	3.5	4%	2.6
- CRT Monitor	68%	3.5	4%	2.6
- LCD Projector	68%	3.5	4%	2.6
- OHP	14%	3.5	0%	0.5
Classrooms				
- Desktop	55%	5.5	6%	2.1

-	CRT Monitor	55%	5.5	6%	2.1
-	LCD Projector	55%	5.5	6%	2.1
-	OHP	12%	5.5	0%	0.4

OHP* - Overhead projector

The time table for the lecture halls and classrooms were obtained from the management office prior to the audit to ensure that data can be collected during lectures. A total of 8 lecture halls and 17 classrooms were audited. Each of the lecture halls and classrooms was equipped with a desktop, a CRT monitor, a LCD projector and an overhead projector as teaching aids. The operating hours of these devices is shown in Table 7. It was identified that 68% of the lectures conducted in the lecture halls were assisted with the use of computers and LCD projectors. Overhead projectors were less preferable, as they were only used in 14% of the lectures conducted in the lecture halls. Similar outcome was found in the classrooms, where 55% of the lectures were conducted using the computers and LCD projectors while the usage of overhead projectors was only 12%.

The computer laboratories have different working hours as compared to the offices and lecture rooms. The operating hours of the computers were controlled by a programmed system, in which the computers were turned on and off at a preset time. These laboratories operated 14 hours during weekdays from 8.00am to 10.00 pm and also on Saturday, from 8.00am to 2.00pm. From our observation, it was found that all the computers in the laboratories were turned on during the operating period even though there were no users. The system settings of the computers were checked and it was soon discovered that no power management was enabled.

3.3. Energy savings potential

The commercial building under study was categorised under low voltage commercial building in Malaysia and falls under electricity Tariff B rate, in which a rate of RM 0.397/kWh was charged for overall monthly consumption more than or equal to 200 kWh. The assumptions made for the energy consumption calculation were that working hours was 8 hours per day except for equipment which were not turned off during lunch time or after working hours, and working days were 23 days per month except for the computer laboratories which operated 26 days in a month.

Table 8: Total energy consumption and electricity cost for each type of equipment

Equipment	Qty	Energy consumption		Rate (RM/kWh)	Cost/month (RM)
		kWh/day	kWh/month		
Desktop	579	543.49	13,047.58	0.397	5179.89
Portable computer	76	9.12	209.77	0.397	83.28
CRT monitor	273	150.11	3,815.61	0.397	1514.80
LCD monitor	306	84.88	1,953.16	0.397	775.40
LCD projector	26	12.66	291.12	0.397	115.57
Overhead projector	38	2.8	64.47	0.397	25.59
Copier	20	49.6	1140.9	0.397	452.94

Laser printer	336	161.28	3,709.44	0.397	1472.65
Fax machine	14	3.92	90.16	0.397	35.79
Total		1,017.86	24,322.21	0.397	9,655.92

Table 9: Total energy consumption based on locations

Division	Energy consumption		Energy cost	
	kWh/day	kWh/month	Rate (RM/kWh)	Cost/month (RM)
Administrative offices	261.32	6010.37	0.397	2386.12
Lecturers' offices	430.27	9896.24	0.397	3928.81
Lecture locations	22.49	517.33	0.397	205.38
Computer laboratory	303.78	7898.17	0.397	3135.57
Total	1017.86	24322.12	0.397	9655.88

From Table 8 and 9, it is clearly shown that the plug loads consumed about 24,000 kWh per month, which was about 14% of the total energy consumption in the selected commercial building which turns into an utility cost of approximately RM 9700 (USD 3100) every month. This result is slightly lower than the findings of some of the previous studies [15, 17], as some of the equipment such as network devices and consumer electronics were not considered in this study.

For energy efficiency improvement in this building, the energy management opportunities (EMOs) for the office equipment were identified. Energy savings can be achieved through the implementation of 'no cost' measures or measures that involve cost investment. In this study, only the EMOs without capital expenditure were considered, as any additional cost to reduce energy consumption may not be desirable for building owners. It was suggested in a previous study [15] that the power management and the user behaviour were the two important factors in reducing the energy consumption of the equipment without any operating expenses or investment. Therefore, these two factors were focused on in this study.

3.4. Power management

Power management is one of the two major factors in efficient use of the office equipment. It refers to a set of strategies used to reduce energy consumption of devices when they are not in active use. In this study, it was identified that some of the office equipment in the faculty did not have proper power management. Only the copiers and fax machines were pre-programmed to enter sleep-mode/standby mode after a short period of inactivity. Other devices, such as the monitors and the desktops in the offices, were not set to enter low-power sleep mode or standby mode when not in use. The energy wasted in this form can be prevented if the equipment are configured properly for power management [16] – [17]. In fact, it was noted that desktops which entered low-power mode only use up 45% of the electricity required during active mode, whereas portable computers required only 20% of energy in active mode if the sleep mode was enabled [18].

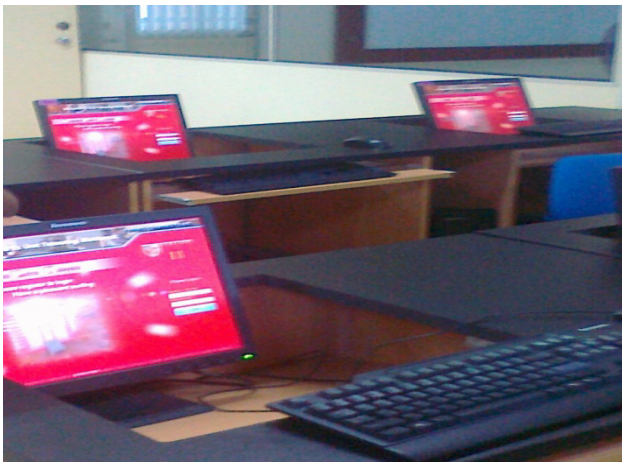

Fig.2. Computers without enabling proper power management features

As shown in Table 8, the computers were found to be the largest energy consumer in both offices and laboratories, and thus the energy savings potentials were focused on the desktops and the monitors. As the office equipment in standby or sleep mode consume less energy than during active mode, the research team assumed that if all the monitors and desktops in the administrative offices, lecturer offices, lecture halls and the computer laboratories were set to turn off or enter standby mode after 2 minutes of inactivity, the operating time can be reduced for approximately 1 hour per day. From here, the potential cost saving per month was calculated as RM423.80 if the power management features of the computers were enabled, as shown in Table 10. It should be noted that the phenomenon of "leaking electricity" was not considered in this study.

Table 10: Desktop and monitor energy and cost saving with proper power management

Equipment	Qty	Power requirement (Watts)	Con. for 9 hours (kWh/day)	Con. for 8 hours (kWh/day)	Savings in Cost/month* (RM)
CRT monitor	273	48	106.70	94.85	108.25
LCD monitor	306	24	66.10	58.75	67.06
Desktop	579	47 (72 AM – 25 SM)	244.92	221.70	248.48
Total			417.72	375.30	423.80

AM – Active Mode, SM - Standby Mode

3.5. User behaviour

The operating time of the electric appliances is largely depending on the occupants' behaviour. Hence, the office equipment energy use can be reduced by modifying the users' behaviour in handling them. If all the computers were turned off or set to enter sleep mode after working hours, it was estimated that a cost savings of RM 1396.70 (About 450 USD) per month can be obtained, as highlighted in Table 11. The potential cost savings for turning off the equipment after working hours is much higher than the

power management strategy in this study, as a significant number of computers were left turned on when they were not in use. Therefore, the use of external control strategies, such as installation of timers to automatically shut down the power supply in the building after working hours can be considered after a cost analysis on payback period is carried out.

Table 11: Potential cost saving if computers are turned off after working hour

Locations	Energy consumption (24 hours op.)	Energy consumption (9 hours op.)	Savings in kWh/ month	Monthly Cost Savings (RM)
Administrative offices	1378.98	517.11	861.87	342.16
Lecturer's offices	4250.09	1593.78	2656.31	1054.56

3.6. Total potential cost savings for EMOs without capital expenditure

The total monthly cost savings of RM1820.52 (about 580 USD) per month can be obtained if both the EMOs identified are implemented properly, as shown in Table 12. The amount of saving is equivalent to 18.85% reduction in the total energy cost per month, which leads to an estimated reduction of 7900 lbs.CO_2 per month. The authors believed that more savings can be obtained if other plug loads, such as the modern network devices and other electronic gadgets were considered in this study. Table 13 summarizes the estimated savings from some of the previous studies together with the key results of this study.

Table 12: Total potential cost saving for EMOs without capital expenditure

EMOs	Cost saving	
	RM/month	RM/annual
Power management	423.8	5085.56
User behaviour	1396.72	16760.64
Total	1820.52	21846.2

Table 13: Energy efficiency improvement opportunity of the office equipment

Authors	Year	Country/ Building Type	Office equipment percentage	Percentage of savings achievable
Mungwititkul and Mohanty [10]	1997	Thailand/ Commercial building	2.2 – 5.6%	15 – 26%
Kawamoto et al [18]	2004	Japan/ Office building	19%	2% (PM* only)
Roth et al [17]	2008	USA/ Residential	24%	-
Mercier and Moorefield [19]	2011	USA/ Office building	17%	19 – 40%
Present study	2012	Malaysia/ Commercial building	14%	19%

*PM – Power Management

4. Conclusion

The energy consumption for the category of plug loads is expected to rise in the near future due to modernisation of buildings and introduction of new consumer electronics. Although there are improvements in both efficiency and power management features for some of the electric appliances, this is not enough to offset the growth in the number of commercial offices and the associated increase in requirement for new office equipment which contribute to the increase in energy consumption. The following conclusions are drawn from the outcomes of this study:

i) Percentage of plug loads in the commercial building under study - In this study, the office equipment in the building accounted for about 14% of the total energy demand. The lecturers' offices were identified to be the most energy consuming location in this tropical commercial building, followed by the computer laboratories and administrative offices. However, it should be noted that the consumer electronics and other kitchen appliances were not considered in this study.

ii) Saving potential in behavioural changes and power management - It was estimated that about 19% of the electricity consumption and 7900 lbs.CO_2 per month can be reduced by introducing good power management and change in user behaviour. The user behaviour was identified as the more significant factor in reducing the plug loads in this study, as it accounted for about 77% of the achievable savings in the EMOs.

iii) Control strategies - For the administrative offices and academicians' offices, the use of hardware control strategies to automatically powers down the computers after working hours can be considered. Replacement of old and inefficient equipment with the more efficient ones should be considered after a careful analysis on the payback period. More studies on the trend and usage of the office equipment should be carried out in the future, especially in large commercial buildings in the equatorial region because the energy consumption associated with the use of plug loads is increasing drastically due to the large influx of the modern electronics.

Acknowledgements

The authors would like to thank the Research University Grant Scheme, Universiti Putra Malaysia (Grant No: 9345300) for the financial support provided.

References

[1] U.S. Energy Information Administration (EIA) 2011. World energy consumption, 1990 – 2035. International Energy Outlook 2011, DOE/EIA-0484(2011), September 2011.

[2] United Nation Development Programme (UNDP). Achieving industrial energy efficiency in Malaysia. United Nation Development Programme, Malaysia, 2006.

[3] U.S. Energy Information Administration (EIA) 2012. Annual energy outlook 2012 with projection to 2035. DOE/EIA-0383(2012), June 2012

[4] GFK Retail and Technology Malaysia SB. Press Release – Results of GfK TEMAX Malaysia for the fourth quarter 2011. Kuala Lumpur, Malaysia, 2011.

[5] Brown GA. Energy audit tool office equipment. Australian Greenhouse Office, Department of Environment and Heritage, 2005.

[6] Lam JC, Li DHW, Cheung SO. An analysis of electricity end-use in air-conditioned office buildings in Hong Kong. *Building & Environment 2003;* **38**: 493 – 498.

[7] Ministry of Energy, Water and Communications Malaysia (MEWC). Low energy office building. Retrieved on September 15, 2008 from the World Wide Web: http://www.ktak.gov.my/leo/performance_equip.asp - 28th October 2008.

[8] Lombard L, Ortiz J, Pout C. A review on buildings energy consumption information. *Energy and Buildings* 2008; **40**: 394–398.

[9] Hendron R, Eastment M. Development of an Energy-Savings Calculation Methodology for Residential Miscellaneous Electric Loads. *ACEEE Conference Paper, 13 – 18 August 2006.* Pacific Grove, California.

[10] Mungwititkul W, Mohanty B. Energy efficiency of office equipment in commercial buildings: The case of Thailand. *Energy* 1997; **22** (7): 673 – 680.

[11]Webber CA, Roberson JA, McWhinney MC, Brown RE, Pinckard MJ, Busch JF. After-hours power status of office equipment in the USA. *Energy* 2006; **31(14)**: 2823-2838.

[12] Malaysian Association of Energy Services Companies (MAESCO), Part 1: Guidelines for conducting energy audits in commercial buildings. Pusat Tenaga Malaysia, 2004.

[13] Tenaga Nasional Berhad (TNB) Website: http://www.tnb.com.my.

[14] Roberson JA, Webber CA, McWhinney MC, Brown RE, Pinckard MJ, Busch JF. After-hours power status of office equipment and energy use of miscellaneous plug-load equipment. LBNL-53729-Revised. Retrieved on December 20, 2011 from the World Wide Web: http://enduse.lbl.gov/Projects/OffEqpt.html

[15] Kawamoto K, Shimoda Y, Mizuno M. Energy saving potential of office equipment power management, *Energy and Buildings* 2004; **36**: 915 – 923.

[16] Capron HL. Computers – tools for an information age, 6th Edition, Prentice Hall; 2000.

[17] Roth K, McKenney K, Brodrick J. Small devices, big loads. *ASHRAE Journal* 2008; **50 (6)**: 64 – 65.

[18] Kawamoto K, Koomey J, Ting M, Nordman B, Brown R, Piette MA, Meier A. Electricity Used by Office Equipment and Network Equipment in the U.S.: Detailed Report and Appendices. Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-45917, 2001.

[19] Mercier C, Moorefield L. Commercial Office Plug Load Savings and Assessment: Executive Summary. California Energy Commission. December 2011.