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An Energy Consumption Study for a Malaysian University

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***Abstract*—**The increase in energy demand has raised concerns over adverse impacts on the environment from energy generation. It is important to understand the status of energy consumption for institutions such as Curtin Sarawak to ensure the sustainability of energy usage, and also to reduce its costs. In this study, a preliminary audit framework was developed and was conducted around the Malaysian campus to obtain information such as the number and specifications of electrical appliances, built-up area and ambient temperature to understand the relationship of these factors with energy consumption. It was found that the number and types of electrical appliances, population and activities in the campus impacted the energy consumption of Curtin Sarawak directly. However, the built-up area and ambient temperature showed no clear correlation with energy consumption. An investigation of the diurnal and seasonal energy consumption of the campus was also carried out. From the data, recommendations were made to improve the energy efficiency of the campus.

***Keywords*—**Energy audit, energy consumption, energy efficiency

I. Introduction

ENERGY generation today continues to be dominated by non-renewable sources. Malaysia has an abundant resource of coal and natural gas, thus contributing to a large fraction of energy production. However, these two resources are non-renewable resources and will diminish eventually. Hydropower on the other hand, is the only renewable energy technology which is commercially viable on a large scale in Malaysia [1]. Due to the increasing demand for energy; its availability, use, cost and environmental impacts has been a key issue throughout the last 30 years [2]. Nonetheless, energy consumption has already raised concerns over exhaustion of energy resources and heavy environmental impacts such as ozone layer depletion, global warming, climate change, etc. [3]. One of the major environmental issues resulting from energy consumption is the emission of carbon dioxide (CO_2) which contributes to global warming [4]. Unless other types of renewable energy resources can be successfully used to decrease the reliance on energy generated by non-renewable resources, it is essential to monitor, evaluate and eventually reduce the rate of consumption of those resources by more efficient energy use via methods like the energy audit.

The common factors which affect energy consumption in domestic, commercial and industrial sectors include the number of air-conditioners and electrical appliances in use, temperature, occupancy rate, occupant behavior, and size of buildings [5]. Energy consumption increases when more air-conditioners are turned on and more electrical devices are in use [5].

A study performed in Hong Kong showed that a 1°C increase in monthly ambient temperature will increase annual electricity consumption by 9.2%, 3.0% and 2.4% in the domestic, commercial and industrial sectors respectively [6]. The occupancy rate of a building has an indistinct direct impact on the total energy consumption. It is therefore safe to relate energy consumption to behavior of the occupants rather than the number of occupants [6]. Energy wastage due to poor occupants' behavior will increase energy consumption unnecessarily. Many researchers commented that the larger a building, and the nearer to spherical in shape, the less is its energy needs because of the simple reduction in the ration of surface area to volume while some others said that compact buildings cost more to erect and had higher energy running costs than sprawling ones [7].

Energy audits are carried out to understand the energy performance of buildings and facilities so that areas with potential for energy savings can be identified [4]. Energy audits are commonly classified as preliminary or walk-through audits and comprehensive or detailed audits, each differentiated by the level of detail involved and the depth of analysis undertaken [8]. Preliminary energy audits focus mainly on the gathering and analysis of historical data such as utility bills and invoices, a walk-through of the facility under consideration to familiarize with the facility operation and identify evident areas with energy inefficiency, taking meter readings as well as simple interviews with site operating personnel [9]. Detailed energy audits normally involve conducting of in-depth measurements and data inventory, possibly with the aid of energy simulation computer software, thus consuming more time.

This paper presents a study on the effect of energy consumption of buildings in an institution of higher learning in Malaysia (Curtin University Sarawak Campus) by conducting a preliminary or walk-through energy audit. A better understanding of the energy consumption pattern will lead to easier identification of more viable and cost-effective energy measures, thus reducing operating costs in the long run. Factors that contribute to energy consumption such as temperature, air-conditioning (chillers) and electrical appliances as well as peak hours are also investigated to determine their effects on energy consumption. The audit is carried out on the Curtin University Sarawak campus, which contains classrooms, laboratories, computer laboratories and administrative offices in its campus. The designated areas within its campus are named Hornbill, Prinia, Skylark and Heron. Further details are presented in Section III.

II. Methodology

The project was carried out in three main stages, namely the pre-audit stage, the audit stage and the post-audit stage.

A. Pre-Audit Stage

A suitable audit framework was developed from the Washington State University Energy Audit Workbook after

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reviewing available frameworks done by others. Due to space constraints, the energy audit framework is not shown here. Parts of the audit require a walk-through audit around campus to calculate the number of rooms and electrical appliances. Architectural drawings of the buildings and specifications of the appliances were needed from the campus authorities as well. Electric meter readings were also recorded to obtain the hourly electricity consumption of the buildings.

B. Audit Stage

A walk-through audit around campus was conducted only on academic buildings in Curtin Sarawak campus to calculate the number of rooms and electrical appliances in each room. Architectural drawings of the buildings and specifications of the appliances were also been obtained from the campus authorities. Effects of temperature and building floor areas as well as seasonal and diurnal variations were investigated. Meanwhile, hourly readings were taken from 8a.m. to 7p.m. daily to identify the total energy consumption during peak and off-peak hours. In addition, meter readings were taken during a study week, study free week and semester break to obtain the seasonal variations in energy consumption because these three periods represent the most significant change in variations during the year for Curtin Sarawak. Table I shows the assumed average operating hours of each major electrical appliance.

TABLE I
AVERAGE OPERATING HOURS OF APPLIANCES

Appliance	Operating Hours	Area
	9	Office, toilets
Lights	7	Staff rooms
	8	Classrooms
CPU	9	All
	7	Office & classrooms
Monitor	8	Classrooms
	6	Laboratories
Printer/Fax	3	Office & laboratories

C. Post Audit Stage

All data collected were analyzed, compared and discussed. Recommendations for more efficient energy use were made and calculations of energy saved were done. Savings were calculated based on reduction in energy required to operate an electrical appliance if hours of operation was reduced or a change in type is recommended.

III. RESULTS

A. Electricity Consumption Breakdown

Electricity consumption can be viewed in various ways such as total consumption by building, consumption by different types of lighting and breakdown of total consumption. The total number of each electrical appliance was multiplied with the specified power consumption and average operating hours to obtain the total power consumed by the appliances. Fig. 1 shows the percentage of consumption by each building.

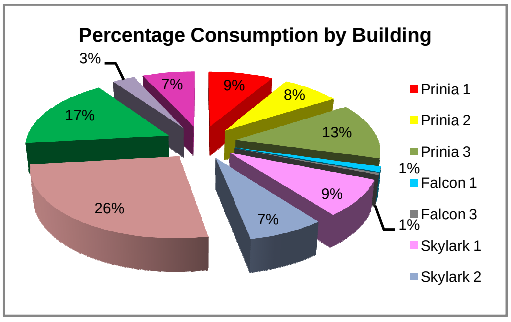

Fig. 1 Percentage Consumption by Building

The Hornbill building consumes the most electricity at 26% of the total consumption of the campus. Heron 1 ranks second with 17% followed by Prinia 3 with 13% of the total electricity consumption. Prinia 1 and Skylark 1 consume 9%, Prinia 2 consumes 8% while Skylark 2 and Heron 3 utilize 7% of electricity. Heron 2 and Falcon 1 consume 3% while Falcon 1 and Falcon 3 consume the least electricity compared to other buildings in the campus with only 1% of consumption. The academic buildings of Curtin Sarawak campus can be classified into a few main categories as summarized in Table II.

TABLE II
ELECTRICITY CONSUMPTION OF DIFFERENT BUILDING CATEGORIES

Category	Buildings	Consumption (kWh)
Office + Classrooms Computer Labs	Hornbill	1386
Classrooms + Computer Labs	Prinia 3	703
Laboratories only	Skylark 1	455
	Skylark 2	386
Office only	Prinia 1	448
Office + Classrooms	Prinia 2	417
	Heron 3	359

From Table II, the Hornbill building which contains offices, classrooms and computer laboratories consumes the highest amount of electricity. A building which consists of classrooms and computer laboratories (Prinia 3) consumes more electricity than a building with office only (Prinia 1), laboratories only (Skylark 1 and 2) or both office and classrooms (Prinia 2 and Heron 3). This suggests that electricity consumption is generally higher for buildings of more functionality. Besides, buildings with computer laboratories or more computers also consume more electricity compared to other buildings. Computers consume significantly more electricity in comparison with other electrical appliances such as light bulbs, fluorescent tubes and printers.

Although Skylark 2 contains more computers than Skylark 1, the electricity consumption of Skylark 1 is higher because it contains more laboratory equipments and machineries of high power consumption which are frequently used by students. A building with the combination of office and classrooms consumes the least energy because only lighting and a few computers contribute to the electricity consumption and these items consume lesser energy. Fig. 2 shows the breakdown of total electricity consumption.

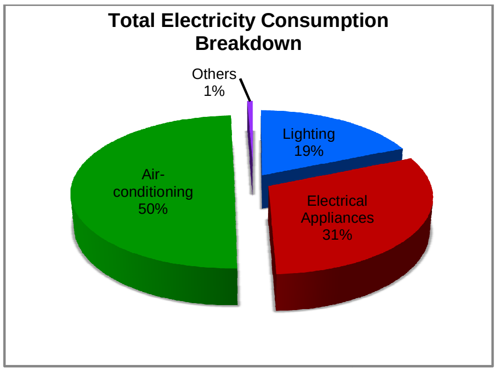

Fig. 2 Total Electricity Consumption Breakdown

Air-conditioning which uses 50% of the total electricity in campus is the major electricity consumer. Chillers always end up being the single biggest consumer in an air conditioning system [5]. A total of 30% of the total electricity is consumed by major electrical appliances such as computers, printers, fax machines and photocopy machines. Lighting follows at 19%. Other electrical equipments such as microwave ovens and fans consume the least electricity which is about only 1% of the total electricity consumption.

Lighting units play a major role in the consumption of electricity in the campus as shown in Fig. 2. A few types of lights are used throughout the campus; namely fluorescent lights (majority), stick bulbs, spiral bulbs, spotlights and globe bulbs used in the recreational hall. The percentage of electricity consumed by each type of lighting is illustrated in Fig. 3.

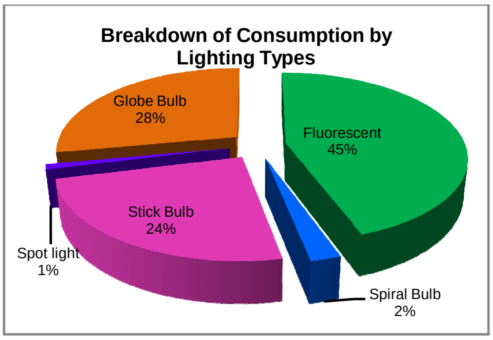

Fig. 3 Consumption by Different Lighting Types

From Fig. 3, fluorescent lights contribute to the highest percentage of electricity consumed by lighting units at 45%. Globe bulbs consume 28% while stick bulbs consume 24% of the total electricity consumption of lighting units. In addition, spiral bulbs and spot lights consume only 2% and 1% of the electricity respectively. The types of lighting used affect electricity consumption. Table III illustrates the power consumption of all lighting types. From Table III, fluorescent ballasts are widely used in the campus followed by stick bulbs, spiral bulbs, globe bulbs and spotlights. Globe bulbs require the highest power to operate while spiral bulbs require the least power.

Although the quantity of spiral bulbs exceeds the quantity of globe bulbs, the total electricity consumed by spiral bulbs per hour is far lower than that by globe bulbs.

TABLE III
ENERGY CONSUMPTION OF DIFFERENT LIGHTING TYPES

Types of Lighting	Unit power (W)	Number of units	Total (kWh)
Fluorescent	36	2492	89.71
Stick bulb	65	834	54.21
Spiral bulb	20	439	8.78
Spotlight	50	76	3.80
Globe bulb	250	189	47.25

B. Electricity Consumption Pattern

The electricity consumption patterns had been generated based on readings taken from four electric meters. A total of three sets of data were recorded for the following weeks.

a) Semester One 2011 Tuition Free Week (25 April – 1 May)
b) June-July Semester Break 2011 (27 June – 3 July)
c) Week 1 of Semester Two 2011 (18 July – 24 July)

These periods were chosen to study the possible seasonal variations in electricity consumption during teaching weeks when normal class sessions are conducted; and non-teaching weeks when normal class sessions are not conducted. The meter numbers and buildings where the electricity consumption is recorded by each meter are listed in Table IV. Readings were taken daily from 8a.m to 7p.m at an interval of 1 to 2 hours. Readings at intermediate hours which were not taken were interpolated. Fig. 4, Fig. 5 and Fig. 6 show the electricity consumption patterns during the three different seasons for Block B and Block C.

TABLE IV
METER NUMBERS AND LIST OF BUILDINGS MONITORED

Meter Number	Block	Buildings
9822474	A	Hornbill 1 & 2, Falcon 1, 2 & 3, Skylark 1 & 2
9822338	B	Central Chiller System of all buildings except Heron 2 & 3
9822548	C	Heron 1, Prinia 1, 2 & 3
E07CT00197	D	Heron 2 & 3, Central Chiller System of Heron 2 & 3

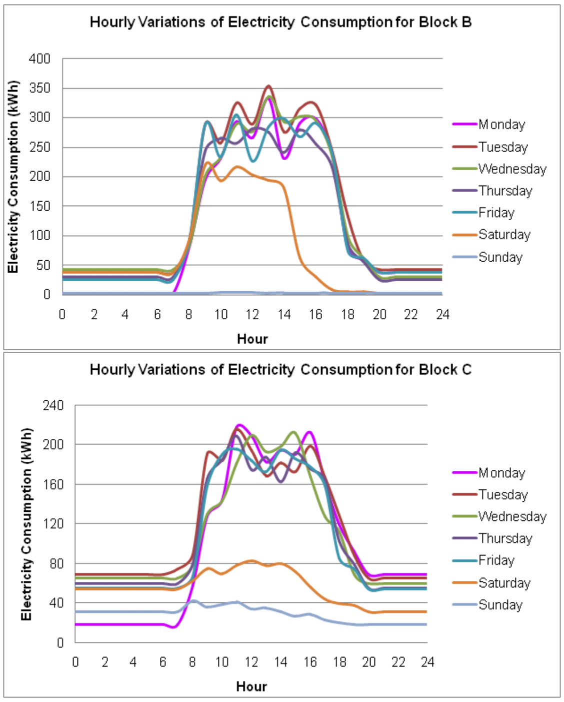

Fig. 4 Tuition Free Week Electricity Consumption Hourly Variations

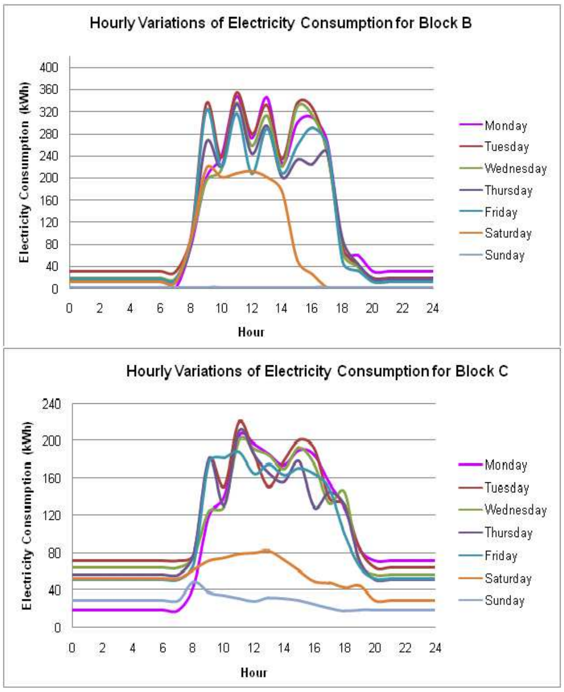

Fig. 5 Semester Break Electricity Consumption Hourly Variations

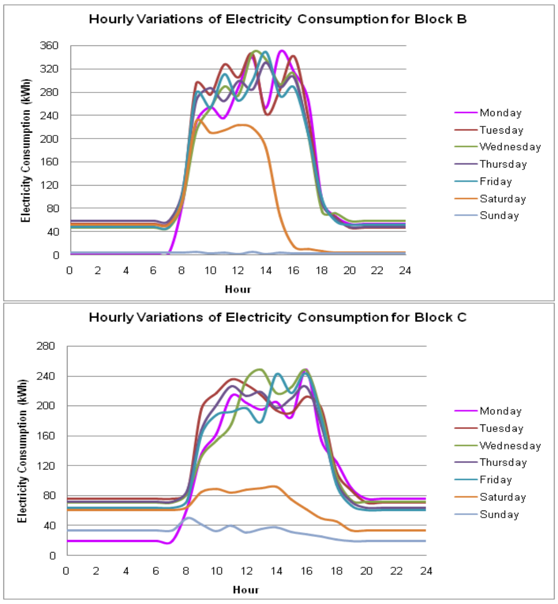

Fig. 6 Week One Electricity Consumption Hourly Variations

From Fig. 4 to Fig. 6, it can be observed that the total electricity consumption on Saturday is at least half the maximum total consumption on a weekday for all four blocks. he population in campus is lesser on Saturdays, with corresponding lesser activities around campus. Some areas are operational within the university on Saturdays, such as the library, reception and the security office. On Sundays, activities are not carried out and only minimal staffs are working such as staffs in the security office as well as some lecturers and other staffs who return to the campus for a short duration to finish off certain works. Classes are not conducted on Saturdays and Sundays and thus contribute to a significant reduction in energy consumption of both days. This observation further proves that population and student activities contribute to a major role in electricity consumption of the campus.

From the diurnal electricity consumption patterns, fluctuations are observed in the hourly consumption. The consumption patterns show several peaks and troughs throughout the day. Electricity consumption for the centralized chiller system (Block B) fluctuates due to the change in load capacity of the system (S. H. Lee, personal communication August 18, 2011). When the system has reached the targeted load capacity set (specified temperature), the system automatically switches to running at partial load and blows out less cool air, thus requires less electricity. When the system detects an increase in room temperature and needs to blow out more cool air into the buildings, it runs again at full load and consumes more electricity.

A constant cyclic pattern of domestic power consumption between 2a.m. to 8a.m. represents the power consumption of the continuously switched on appliances and the appliances in standby mode while several high peaks found were caused by appliances with high power consumption such as a kettle and also the switching on of appliances previously in standby mode such as televisions and other consumer electronics [10]. This proves that the fluctuations are influenced by the types of electrical appliances in use at different times of the day.

In addition, there is significant difference in the seasonal consumption of the blocks. Population and activities played important roles in the electricity consumption of Curtin Sarawak campus. Higher population and more activities contribute to higher electricity consumption. Consumption during week one is the highest followed by the tuition free week and lastly the semester break. Table V shows a summary of the estimated population and activities carried out during the three different seasons.

TABLE V
SUMMARY OF ESTIMATED POPULATION AND ONGOING ACTIVITIES

Season	Estimated population	Ongoing activities
Week one	4000 (300 staffs and 3500 students)	- Orientation - Promotion of club activities - All classes commence - Office hours - Centralized chiller
Tuition free week	2500	- Extra classes - Group study and revision in computer laboratories or library - Office hours - Centralized chiller
Semester break	1000	- Final year project laboratory - Talks, school meetings and trainings - Centralized chiller

C. Total Peak and Off-Peak Electricity Consumption

The total electricity consumption patterns had been generated based on readings taken from the electric meters and were divided into total peak and total off-peak hour consumptions. Peak hour is regarded as the period from 8a.m. to 6p.m. while off-peak hour is defined as the period from 6p.m. to 8a.m. on the following day. This is to differentiate the patterns of electricity consumption when classes and activities are conducted actively and when they are less active. The comparisons of total peak and off-peak electricity consumption between tuition free week, semester break and week one of Semester Two are illustrated in Fig. 7 and Fig. 8 respectively.

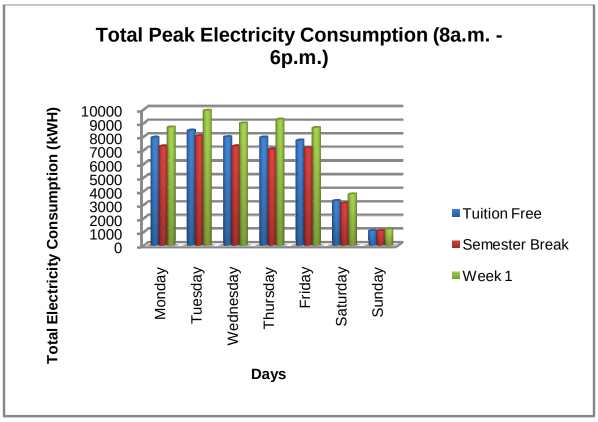

Fig. 7 Total Peak Electricity Consumption

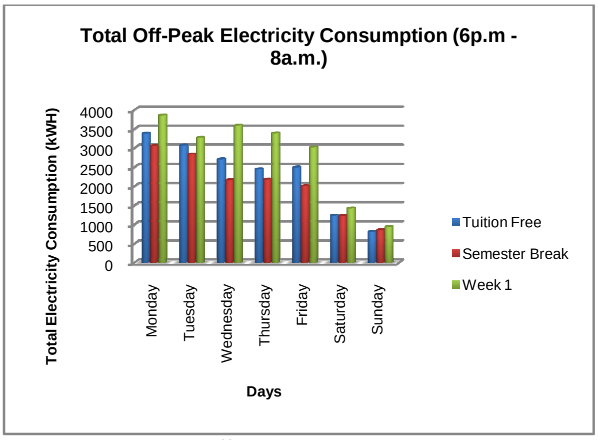

Fig. 8 Total Off-Peak Electricity Consumption

From Fig. 7 and Fig. 8, the peak and off-peak electricity consumptions for Week 1 are the highest, followed by the tuition free week and lastly the semester break except for Sundays when the peak and off-peak consumptions of the semester break is higher than the tuition free week. The total electricity consumption during off-peak hours is generally less than the total consumption during peak hours as expected. During off-peak hours, there is still electricity consumed due to sources such as street lights and walkway lights, continuous operation of wastewater treatment plants, 24-hr computer laboratory, security office and study area. Besides, most classes in Heron 2 are conducted beyond the peak hour with some classes ending at around 8p.m. and therefore the centralized chiller system is set to shut off only after these classes have ended. Although these items and activities consume far less electricity compared to the appliances used and activities during peak hours, they contribute to a significant amount of the off-peak electricity consumption.

D. Building Built-Up Area and Temperature versus Electricity Consumption

Many researchers commented that the larger a building, and the nearer to spherical in shape, the less is its energy needs [6]. A comparison of the relationship between the total building built-up area in Curtin Sarawak campus and ambient temperature versus the total electricity consumption was completed and shown in Fig. 9 and Fig. 10 respectively.

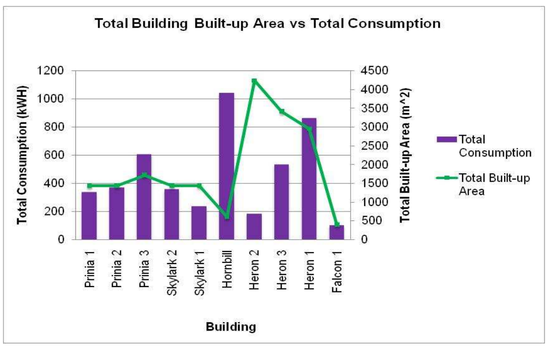

Fig. 9 Relationship between Building Built-Up Area and Total Electricity Consumption

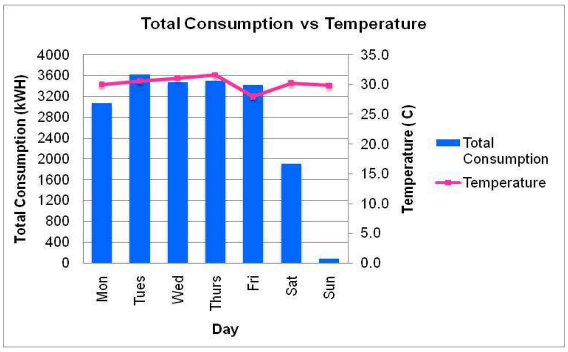

Fig. 10 Relationship between Temperature and Consumption

There is no clear correlation between the total built-up area of buildings in Curtin Sarawak Campus and the total electricity consumption of each building as shown in Fig. 9. Although the built-up area of Prinia 3 is significantly larger than Prinia 1, Prinia 2, Skylark 1 and Skylark 2, the total energy consumption of this building is extremely high. On the other hand, the total energy consumption of Falcon 1 is exceptionally low even though the total built-up area of the building is rather small. This means that the total built-up area of the buildings in Curtin campus does not affect its consumption.

There is no apparent correlation as well between ambient temperature and the total consumption as illustrated in Fig. 10. The ambient temperature on Wednesday which is 30°C is higher than the temperatures on Monday and Tuesday. Yet, the total consumption of electricity on Wednesday is lower. The ambient temperature on Friday which is comparatively lower than other days consumes a rather high amount of electricity. One main reason is due to the use of centralized air-conditioning, which adjusts its temperature automatically. Thus, the chiller system may mostly operate with excess capacity, without regard for population.

Thus, the total built-up area and ambient temperature had no apparent impact on the electricity consumption of Curtin Sarawak campus. Energy consumption of a building is governed by other more significant factors such as the purpose of the building, activities and population in the building as well as electrical appliances used in the building.

E. Information Technology (IT) Equipments versus Electricity Consumption

The influence of Information Technology (IT) equipments on the electricity consumption of each building cannot be underestimated. IT equipments such as computers, projectors and printers require high power to operate, and it was found that computers impose the most significant impact on the total electricity consumption of a building compared with other IT equipments due to the large number of computers found in the campus. The relationship between total electricity consumption and the number of computers in each building is depicted in Fig. 11.

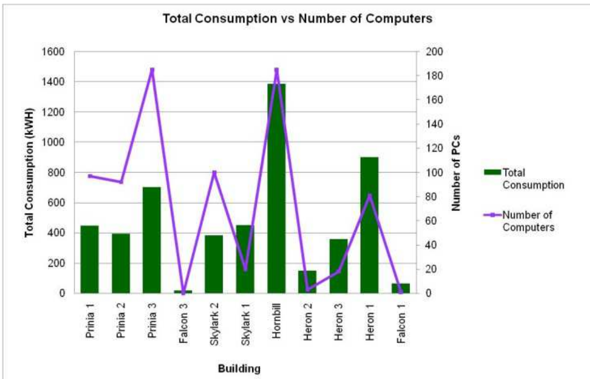

Fig. 11 Relationship between Number of Computers and Total Electricity Consumption

It can be deduced that the number of computers available in a building is linearly proportional to its total electricity consumption. This is because the Central Processing Units (CPU) in campus consume 235W and monitors consume 160W per hour each, which are higher than the power consumed by most other standard equipments found in the building. A computer consumes about 400W of electricity per hour. Therefore, when computers and other electrical appliances are present in a building, the amount of computers governs the amount of total electricity consumed in the building.

F. Measures to Improve Energy Efficiency

It was found that fluorescent ballasts dominate the lighting in the campus at 2492 units (see Table III). There is a high potential of energy conservation if all fluorescent ballasts which require 36W of electricity each are switched to spiral bulbs which require only 20W of electricity each, resulting in significant savings as shown in Table VI. An average of 9 operating hours a day and 6 days of operation a week were assumed to estimate the amount of electricity savings per annum.

Besides lighting, the use of IT equipments should also be considered. A CPU consumes 235W when in active mode while in sleep mode, it consumes less than 15W. In addition, a monitor consumes 160W when in active mode and consumes less than 4W in sleep mode. The present settings of the computers in the campus are such that the monitors turn off in 20minutes and the CPUs are never turned off. The present settings of the computers are energy inefficient as the CPUs which consume very high power are operating at maximum capacity although this is not required at most times. If the idle time set for the monitor to turn off is reduced to 10minutes, which is half of the present setting time, energy consumption can be reduced significantly. CPUs should also be set to sleep mode when not in use rather than allowing them to be in active mode. The computers were assumed to be in active mode for 7 hours and sleep mode for 2 hours a day with 300 days of operation.

There is potential for energy saving in the operating hours of the centralized air-conditioning system since it is a significant energy consumer.

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Energy saving equipments that are easily accessible in the market for the chiller system can be installed to improve the efficiency of the system. These equipments work to optimize the chiller compressors by preventing the system to operate with excess capacity which will consume an unnecessary amount of energy. Besides, the hours of operation of the chiller system can be reduced to only during working hours which is until 5p.m. Any classes conducted after 5p.m. should be conducted in rooms with split unit air-conditioners which consume lesser energy compared with centralized air-conditioners. Assumptions made when calculating the energy saving achieved for a reduction in one hour of operation were that the centralized air-conditioner ran on an average of 300kWh and there is a unit of 2HP split unit air-conditioners which operates at 1875W per hour in each classroom (a total of 9 rooms on the ground floor). Table VI shows a summary of the energy savings with the new recommended settings.

TABLE VI
SUMMARY OF ESTIMATED POPULATION AND ONGOING ACTIVITIES

Type of electrical appliance	**Recommended settings**	**Annual savings (kWh)**	**Annual savings (RM)**
Lighting	Fluorescent ballasts to spiral bulbs	103348	31004
IT equipment	Reduce monitor turn off time from 20minutes to 10minutes	10792	3237.60
	Turn on CPU sleep mode	103224	30967.20
Centralized chiller	Reduce operating hour	67920	20376

Besides enhancing the efficiency of electrical appliances, better management practices should also be adopted. Students and staffs should be educated to switch off the lights directly at the end of the day when not in use. It is important to unplug electrical appliances which are seldom used because these appliances will consume little energy when plugged continuously although they are switched off.

IV. CONCLUSION

An energy audit framework was created based on a preliminary audit with walk-throughs to assess the the energy consumption of Curtin University. The guideline was mainly based on the Hong Kong and Europe Guideline, with a few modifications made to suit the condition of the campus. The consumption pattern of Curtin can be divided into diurnal and seasonal variations. Consumption during weekdays is higher than consumption during weekends. Fluctuations were seen throughout the day because different types of electrical appliances were used. The peak hour of Curtin Sarawak (8a.m. to 6p.m.) consumes higher amount of energy compared with the off-peak hour (6p.m. to 8a.m.). Comparison between the tuition free week, semester break and study week showed difference in energy consumption. The study week was shown to consume the highest amount of energy among the three periods, followed by a tuition free week and a semester break uses the least energy.

It was also found that the electricity consumption of Curtin Sarawak is affected by the population in campus, activities conducted and also the types of electrical appliances used. When higher population is present in the campus, energy consumption tends to be higher. Moreover, buildings of more functionality consume more electricity as more types of appliances are used for different functions. Buildings with more computers were found to consume more energy because computers require higher power compared with other appliances such as lighting and printers. Temperature and building built-up area showed no clear correlation with the energy consumption in Curtin Sarawak campus because consumption of a building is governed by other more significant factors such as the purpose of the building, activities and population in the building as well as electrical appliances used in the building.

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