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Energy and Environmental Sustainability of Malaysian Universities through Energy Conservation Measures

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ABSTRACT

Curtin University Malaysia, a significant education service provider in Sarawak state has been identified as one of the foremost electrical energy consumers in the state. Though past studies made on the Curtin campus brought out attainable suggestions, and they were subsequently implemented, still the per capita energy consumption needs to be reduced further. Hence, this situation necessitated an in-depth energy audit to determine how and where the energy is being consumed economically and efficiently or wasted instead. This paper aims at energy conservation measures based on a comprehensive load profile study conducted on the university campus. Based on the findings of the study, cost-effective and time-bound energy conservation tactics are suggested for scheming and controlling Curtin's colossal energy expenses.

Keywords: Energy Audit, Measures of Conservation, Energy Cost and Environmental Benefits
JEL Classifications: Q28, Q48, Q58

1. INTRODUCTION

The Ministry Education, Malaysia is encouraging every single educational establishment to ration energy in all conceivable routes as the monthly consumption charge has turned into the chief worry of public, private and global universities in Malaysia (Ahmad et al., 2012; Ishak et al., 2012; Wai et al., 2011; Yen et al., 2010). The public university, UTM and the international university, IIUM (Ahmad et al., 2012; Ishak et al., 2012) have a similar feeling that Malaysian universities as of now are experiencing serious energy wastage issues, bringing about a tremendous measure of yearly energy cost, and this milieu encumbrance the yearly spending plan of the universities. In various parts of the world, the energy use by academic institutions is relatively equal to the measure of energy utilization to that of medium-sized urban communities (Chung and Rhee, 2014; Enteria et al., 2015; Oyedepo 2012). Vast university land extent, climate, building introductions and their engineering configuration, maturing of the structures, under-usage of the building, working hours, and working society, students and staff populace, and obliviousness and carelessness of energy preservation strategies are a part of the reasons.

In light of the demand of the Sarawak State Government of East Malaysia to the Curtin University of Perth, Western Australia, the Curtin University, Malaysia was set up in 1999 with a land extent of 300 acres. It is the biggest seaward ground among the three seaward grounds viz. Singapore, Sri Lanka, and Malaysia with the student population of around 3500 including global students from more than 40 nations. To cater to the necessities of the students and staff, electrical energy is the prime source and its month to month consumption changes from 0.20 to 0.32 million kWh. The monthly energy charge is observed to be within the scope of 60,000 to 96,000 Malaysian Ringgit (Curtin, 2015: Palanichamy, 2015; Tang, 2012), which frames a noteworthy part of the yearly financial budget.

As a significant education provider, Curtin University, Malaysia has been shouldering the important mission of cost-effective education, science research and social services since 1999 in Malaysia. Be that as it may, the huge demand for electric energy and the related energy cost may confine its development about the framework, students' enlistment and administrations to the students' location. To resolve the wastage of energy use and to cut the annual budget burden, the team led by the authors conducted an in-depth energy audit. This paper draws out the result of the energy audit performed and the energy conservation measures proposed for energy efficiency and budgetary advantages.

2. LITERATURE REVIEW

Around the world, colleges and universities are experiencing the higher measure of unavoidable energy costs and it turns into an incredible weight for them to oblige it in the yearly budget (David et al., 2011). According to the approval of the "President's Climate Commitment" by more than 600 US educational establishments, new sustainable techniques are being created to handle the developing costs; be that as it may, the related natural issues are not completely dealt with (American College & University Presidents' Climate Commitment 2010).

The University of New Hampshire (UNH) has developed its students and staff the methods for diminishing energy wastage and the requirement for economical energy for what's to come. To abridge ozone-harming substance emanations, a GHG discharges stock instrument - Clear Air-Cool Planet Campus Carbon Calculator, has been created by UNH. The apparatus encourages the decrease in gas outflows in the university premises and an upsurge in money related investment funds to the university organization (Aber et al., 2009).

The University of California, in Berkeley, educated their students and staff to turn off their personal computers (both framework unit and screen) when they were not in their rooms and after available time, moreover. It played out an after-hours review to acquire electrical energy use information of 1,453 personal computers in its campus for a time of 4 h (David et al., 2011; Webber et al., 2004; Webber et al., 2006). The result of the review uncovered that 36% of students and staff turned off their personal computers and 32% of them turned off just the screens (that implies framework units were on). Among the accessible PCs, just 6% had a power administration plot (which implies both framework unit and screen had a power administration conspire) while 75% of the personal computer screens had a power administration plot. The overview result required an inside and out a successive examination to guarantee a financially sound energy-saving money on the university campus.

In order to decrease the ozone-depleting substance emanations in the areas of Stanford University, it presented possible energy effectiveness ventures for structures with a financial plan of around USD 900 million, which brought about an appealing rate of return on investment and a shorter payback period (The Princeton Review, 2016). As a result of the energy productivity measures, the university campus energy use gets decreased by 176 million kWh in a period traverse of 9 months and 20% lessening in ozone-harming substance emanations.

The contingent upon the students' way of life and their personal conduct, the energy squander winds up huge in colleges, universities and higher learning establishments (Galis and Gyberg, 2010; Lo et al., 2012; Parker, 2007). Mindfulness programs on energy sparing ideas and energy sparing conduct evaluations help energy conservation and environmental friendliness in worldwide and Malaysian universities. Malaysian universities started such mindfulness programs through their yearly budget plan (Clarke and Kouri, 2009; Ting et al., 2011) and course educational modules.

3. STATE OF THE ART

As energy conservation is a cost-effective and environmentally friendly option (Aan et al., 2017; Bozkurt and Destek, 2015), Curtin recognized the way that advancing energy conservancy through energy administration program is the convenient measure to be taken after to conspiring and controlling Curtin's energy costs. To build up an energy administration program, energy audit assumes a critical part (David et al., 2011; Chinnasamy et al., 2015; Palanichamy et al., 2015; Tang, 2012). Energy audit analyzes the energy consumption of the equipment or framework or structures to guarantee that energy is being utilized proficiently through a visual investigation of the premises (Walk-through audit) and furthermore through information accumulation, execution estimation of the current frameworks, and survey of useful practices (Detailed audit) (Energy Savings Toolbox, 2015; Palanichamy and Babu, 2005; Wang et al., 2013).

In line with the literature review, an initial energy consumption study for Curtin Sarawak has been performed (Tang, 2012) in 2012, which necessitated a detailed energy audit in the future. In 2016, an audit team led by the authors of this research, the last year electrical power engineering student, and few technical people associated with the campus services department, conducted an energy auditing throughout the university campus. The auditing period has been separated into two segments, considering the students' strength such as: ON semester (having many students and staff) and OFF Semester (having few students and staff). For both the periods, the different load categories have been identified; the connected load and maximum demand of each load category have been recorded together with their respective energy consumption. The monthly energy consumption charges from 2012 to 2015 were collected for analysis. Concisely, the analysis reveals that the heating, ventilation and air condition (HVAC) loads share a major part of the connected load at 70.08%, and the office equipment shares next. In a tropical country like Malaysia, that too for the green campus of Curtin, these quantities are much higher compared to the Middle East Universities' average HVAC share of 58% of their total connected load (Curtin, 2015: Palanichamy 2015; Tang, 2012).

4. CURTIN LOAD PROFILE

4.1. Main Switch Board

Curtin Sarawak is a widespread green campus with various precincts as portrayed in Table 1. The locations of the main switch

boards with their respective measuring instruments and energy meters are:
- Phase 2 meter monitors Heron 3 and Heron 2.
- AL100 m monitors Heron 1 and Prinia 1-3.
- The Chancellery meter only monitors the Chancellery building.
- The chiller meters are located in its location itself.
- ME100 m monitors the consumption of Skylark 1 and 2, Hornbill 1 and 2, and Falcon 1-3.

The meters installed are not smart meters, and they do not have the capability to log the data over a time period. Besides, they do not measure the real power demand (kW) of the campus at a particular time interval; instead measure the energy consumption (kWh) only.

4.2. Energy Audit

An energy audit has been conducted to develop an energy management program for Curtin. Although energy audits are often carried out by external consultants, the authors and their associated project team conducted the audit during a span of 4 months in 2016. University stock registers and asset documents were taken as the reference for the procurement and installation of the electrical equipment and their existence and working status are ascertained through physical verification by the auditing team. Curtin Sarawak is embraced with HVAC, lighting, office equipment/IT, engineering loads and miscellaneous loads.

The connected load of Curtin is 2851.478 kW, and they were installed in different periods of time from 1998. Table 2 presents the connected load details. HVAC systems (inclusive of three centrifugal chiller cooling units, six water cooled package units, and several standby split air conditions installed throughout the campus in every room) shares the highest load part (70.08%) followed by office equipment (13.54%). On a working day with the full strength of staff and students on campus, the hourly real power (kW) and reactive power (kVAR) demands are determined as in Figure 1.

Figure 2 shows the hourly kW demand from individual meter readings and the cumulative hourly kW demand for quick reference. The corresponding energy consumption is recorded as in Table 3 with a 24-h total consumption of 13381 kWh.

The detailed energy consumption by all the precincts for a 12 month period has been presented in Figure 3. It is observed that the chillers' consumption is the largest among all other load consumption of Curtin. The typical campus power factor on a day of the energy audit is shown in Figure 4.

Low power factor requires high reactive power (kVAR) and apparent power (kVA), which is the power that the electricity provider supplies. Therefore, a facility's low power factor forces the electricity provider to increase its generation and transmission capacity in order to handle this extra demand. By increasing the power factor, customers use less kVAR. This results in less kW, which equates to financial savings for the electricity provider.

Table 1: Precincts of Curtin Sarawak

Precincts of curtin sarawak		
Heron 1	Heron 2	Heron 3
Prinia 1	Prinia 2	Prinia 3
Skylark 1	Skylark 2	Hornbill 1
Hornbill 2	The chancellery	Falcon 1
Falcon 2	Falcon 3	Kingfisher 1-7

Table 2: Connected load of Curtin Sarawak

Load category	Connected load, kW
HVAC	2018
Lighting	232.478
Office equipment	386
Engineering	120
Miscellaneous	95
Total	2,851.478

Table 3: 24-h energy consumption

Hour	8.00	9.00	10.00	11.00	12.00	13.00
kWh	340	941	1059	922	1156	929
Hour	14.00	15.00	16.00	17.00	18.00	19.00
kWh	1012	1124	1001	937	824	654
Hour	20.00	21.00	22.00	23.00	24.00	01.00
kWh	458	227	174	174	174	174
Hour	02.00	03.00	04.00	05.00	06.00	07.00
kWh	174	174	174	174	174	231

Utility companies all around the world charge customers an additional surcharge when their power factor is <0.85. In fact, some utilities are not obliged to deliver electricity to their customers at any time the customer's power factor falls <0.85. Thus, the customer can avoid this additional surcharge by increasing power factor. In Malaysia, the energy provider is allowed through the Malaysian Grid Code and the Malaysian Electricity Distribution Code, to impose a surcharge to the customer if the power factor is <0.85 for customers receiving <132 kV.

4.3. Energy Consumption Billing

The energy supplier for Curtin Sarawak is Sarawak Energy Berhad (SESCO). There are generally three categories for billing: Residential, commercial and industrial. Each of these categories has its sub-categories for tariff fixing. Curtin University falls under the commercial billing category (Curtin, 2015). Since Curtin University is a commercial entity, it can be billed in two manners depending upon its choice.

4.3.1. Tariff C1 (consumption based)

Under this tariff, the University would be charged RM 0.40/kWh for the first 100 kWh/month, RM 0.34/kWh for the next 4900 kWh, and RM 0.30/kWh for any additional kWh/month. The minimum monthly charge with this type of tariff is RM 10.00.

4.3.2. Tariff C2 (demand based)

Under this tariff, the University would be charged RM 16.00 for each kW of maximum demand per month, and RM 0.25 for each kWh of energy consumed. The minimum monthly charge with this Tariff is RM 16.00 x Billing Demand (i.e., The peak demand recorded during the month), and the associated kWh charges.

Figure 1: (a) Campus hourly real and (b) Reactive power demand on September 2013

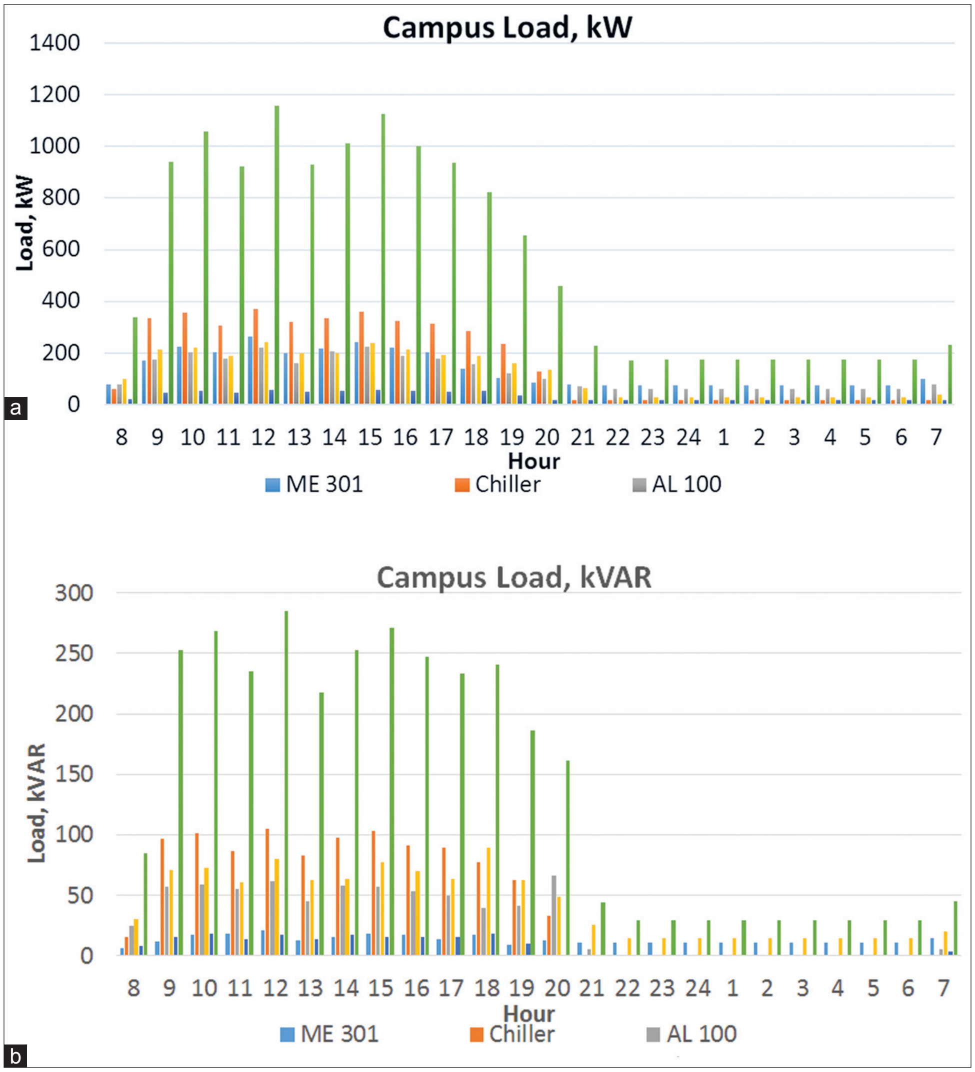
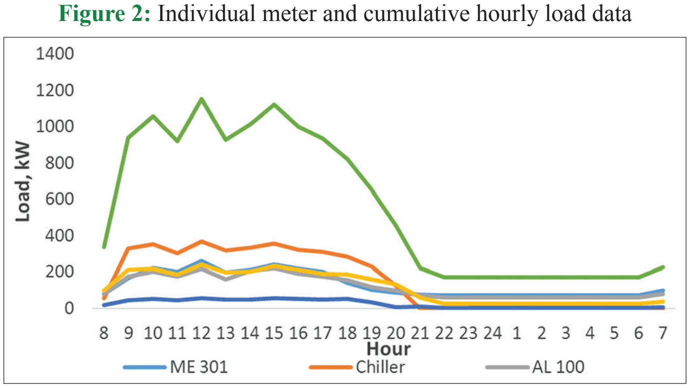


Figure 2: Individual meter and cumulative hourly load data



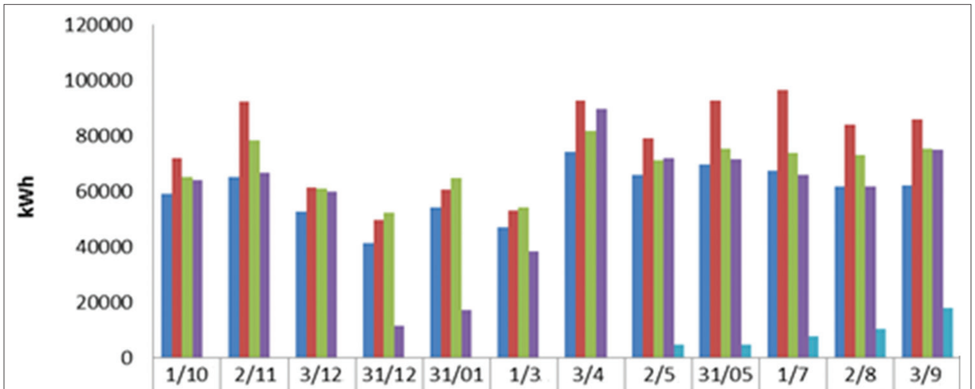
Currently, Curtin University, Malaysia is billed under Tariff C1 (Consumption based). Figure 5 presents the monthly energy billing for a 12 month period under Tariff C1.

5. CURTIN LOAD PROFILE REVIEW

The standard office hours for the campus is between 8:00 am and 5:00 pm and there are no specific lunch hours for students; be that as it may, managerial and other office staff have the meal break between 12:00 noon to 1:00 pm. From Figure 2, numerous perceptions can be made. Right off the bat, there is a sudden change in the real power use of 340 kW at 8:00 am to 941 kW at 9:00 am. This is very normal as this is the time at which the campus begins its activity. It can be seen that there are three request crests: 1059 kW at 10:00 am, 1156 kW at 12:00 noon, and 1124 kW at 3:00 pm. Among the three pinnacles, the most elevated is 1156 kW at 12:00 noon. A while later, it drops to the most minimal estimation of 929 kW at 1:00 pm because of the planned meal break for regulatory and other office staff. There are no level areas in the load profile amid the available time. This implies the load is of the profound factor nature, and not in any way consistent. This is very regularly for a college domain where students' lectures and study hours are broken and because of the changing co-curricular exercises of the day. Comparative perceptions depended on 12 days checking (from 8.00 am to 7.00 am the following day for a time of 24 h ceaselessly) amid the reviewing time frame and a similar example of intensity utilization was seen yet with various hourly utilizations as appeared in Figure 3.

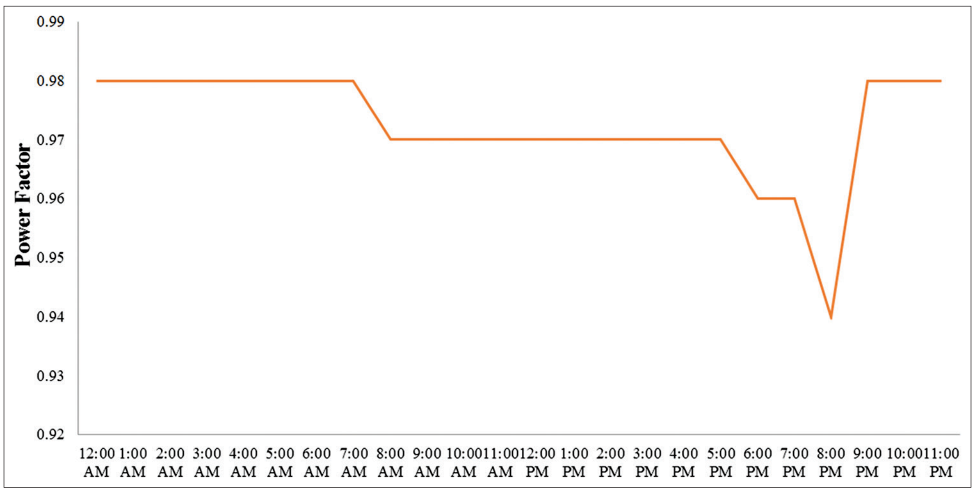
The daily average load demand during office hours is observed to be around 942.10 kW (81.50% of the peak demand), which keep going for 6 h out of the 9 available hours. Besides, it is seen

Figure 3: Detailed energy consumption



	1/10	2/11	3/12	31/12	31/01	1/3	3/4	2/5	31/05	1/7	2/8	3/9
Me 301	58966	65188	52855	41404	54211	46899	74340	65785	69538	67264	61692	62001
Chiller	71877	92198	61378	49678	60577	53054	92843	79099	92721	96666	83868	85951
Al100	64993	78172	61173	52359	64857	54066	81597	71229	75422	73910	73228	75522
Phase 2	64105	66645	59770	11548	17096	38217	89711	72065	71625	66006	61896	74972
Chancellery	0	0	0	0	0	0	0	4640	4640	7879	10373	17939

Figure 4: Campus power factor



that after the office hours (i.e., After 5:00 pm), the demand does not fall unexpectedly not surprisingly; rather it takes a smooth curve till 9:0 pm. During the 4-h frame, the only service that is working till 9:00 pm in the recreation hall, which does not have a high demand as the highest demanding application such as the water cooling package units. This warrants for inspection as it is expected that the demand should fall abruptly after office hours, but in reality, it is not so. The load demand at night starting from 9:00 pm is observed to be 174 kW, which remains constant until the university starts again the next morning. In other words, the minimum demand lasts for 10 h at 15% of the daily demand's peak value.

Another review is the load factor (Curtin, 2015). Load factor is a measure of the utilization rate or efficiency of electrical energy usage. It is the ratio of total energy (kWh) used in the billing period divided by the possible total energy used within the period if used at the peak demand (kW) during the entire period. For example, the daily load factor is defined in terms of energy consumption and the peak demand as:

$$\text{Daily Load Factor } (\%) = \frac{kWh\, consumed\, in\, a\, day}{Peak\, kW\; x\, 24\, hrs} \text{ X } 100$$

Load factor is a useful indicator for describing the consumption characteristics of electricity over a period. The demand rate billing structure provides an incentive for members to improve their load factor. Because load factor expresses electrical energy usage compared to peak demand, members can have the same amount of kWh usage for 1 month to the next and still cause their average cost per kWh to decrease by reducing the peak demand. This can be done by distributing energy usage over time to decrease peak demand.

In view of the energy consumption of 13381 kWh for a 24-h period with 1156 kW as peak demand, the daily load factor is worked out to be 48.23%, which is not an appealing figure for an educational campus. On the off-chance that the peak demand is observed to be 1000 kW (say.), at that point for a similar energy consumption, the load factor would be 55.75%. The higher the load factor, lesser will be the energy cost!

Considering the student enrollment statistics from 2012 to 2016 as in Table 4, the average number of students' enrollment per annum will be taken as 3162. The daily energy consumption is observed to be 10624 kWh, as per the energy audit. Hence, the energy consumption/student/day arrives at 3.36 kWh, and the average energy cost/student/day is RM 1.02.

Everyday normal power factor as appeared in Figure 4 is very great and empowering. It shifts from 0.94 to 0.98 lagging not just for the concerned day of the energy audit, however for all billing months as well. Just when the billing period (month to month) power factor goes below 0.85 lagging, the low power factor penalty cost will be included while billing. All in all, the power factor remedy isn't a necessity as of now for Curtin Sarawak as long as a similar power factor level is kept up. The energy audit by the authors in 2016 likewise affirms that the power factor is all around kept up over 0.85.

6. PROPOSED CONSERVATION MEASURES

This section addresses various energy conservation measures for Curtin Sarawak.

6.1. Load Balancing and Scheduling

- Load Balancing and Scheduling is primarily used in electrical distribution networks and high tension consumers such as heavy industries, higher learning institutions, etc. (Chung and Rhee, 2014; Energy Saving Toolbox, 2015; Wai et al., 2011) to decrease energy consumption.
- Energy Audit Outcome - The Curtin load flow review depicts the fact that the connected loads of the three phases are well-balanced. The Fluke power quality analyzer and power loggers are utilized for the analysis. The graphical representation of voltage imbalance in vector format facilitates the correct and detailed analysis.
- Recommendations - In spite of the connected loads of Curtin Sarawak are adjusted, still, there is a probability of enhancing its load factor by spreading its loads consistently to the degree conceivable. This could be best accomplished by planning the lecture classes to such an extent that a uniform number of classes are being directed at different timings of a day within the stipulated working hours. Since the peak demands happen from 10:00 am to 12:00 noon, cutting down a portion of the load as of now enhances the load factor of the campus. Additionally, at 8:00 am itself, regular classes should be begun. Much the same as regulatory and other office staff, meal break for the students at a similar planning must be given. Subsequently, during this period, the synchronous activity of the load could be lessened as it were. Thus, the three peaks of load demand are lessened to double peak demand.
- Implications - As discussed, a virtual load scheduling has been done by suitably modifying the weekly timetable of the 3rd week of May 2016. By doing so, the three demand peaks: 1059 kW at 10:00 am, 1156 kW at 12:00 noon, and 1124 kW at 3:00 pm (Figure 2) are modified to double peaks as shown in Figure 6. The double peaks are having demand values of 975 kW and 1000 kW. The change in timetable catered the energy needs of the same number of students and staff, which is 13383 kWh. Hence, the daily load factor is improved from 48.23% to 55.76%. Following this situation, the timetable for the later semesters could be given priority for load factor improvement through load scheduling. Such an energy conservation measure does not involve any real financial commitments.

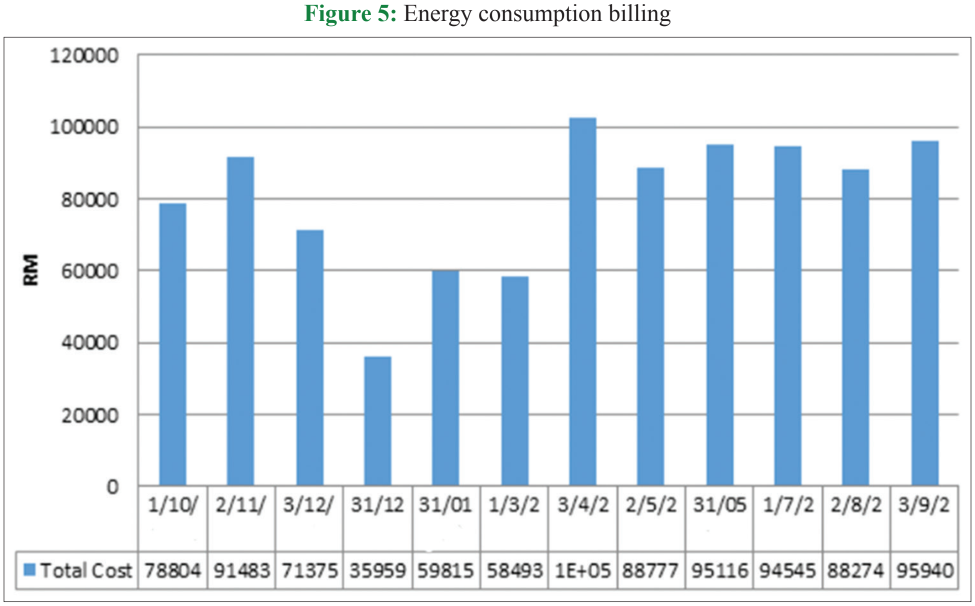
Table 4: Students enrollments

Year	Enrollment
2012	2874
2013	2987
2014	3085
2015	3323
2016	3544

6.2. Peak Shaving

Figure 7 shows that the three peaks of load variations occur at 10:00 am, 12:00 noon and at 3:00 pm. The minimum demand during the period 9:00 am to 5:00 pm is 922 kW. Taking this

Figure 5: Energy consumption billing

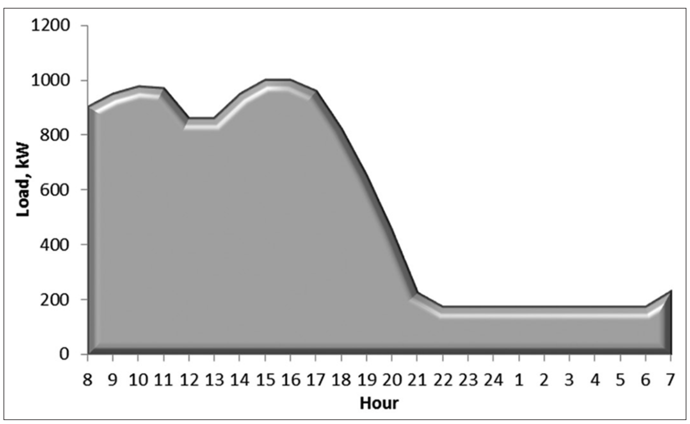


load as the reference, the excess loads above 922 kW last for 8 h of a working day. If these excess loads are met with some well-established renewable energy systems like wind turbines, PV solar systems or fuel cells with energy storage systems, it would result in demand reduction and energy-saving (Aigner et al., 2012; BIZEE, 2016; Chang, 2006; Farhani and Ben, 2012; Oriti et al., 2015).

A 250 kW building rooftop PV solar system is proposed.
The number of 250 W PV panels required: 1000
Number of inverters required: 20
Cost of each panel with installation: RM 1015
Cost of each inverter with energy backup: RM 11288
Total cost of 250 kW PV systems: RM 1240760
Interest & depreciation: 7%
Operation & Maintenance charge/year: RM 21000
Expected lifetime: 20-25 years

The forecasted average energy generated on Curtin Sarawak campus during a normal day by the proposed 250 kW PV system is 960 kWh. The ensued unit energy cost is RM 0.31/kWh. The rate of return is estimated at 8.47%, and the payback period is 11.8 years. The total carbon offset/year would be 208 tons.

Figure 6: Load scheduling



Assuming 90% efficiency of the PV system, the reduction in maximum demand is 225 kW due to the proposed PV systems. Hence, the maximum demand of Curtin becomes 931 kW (1156 kW-225 kW). So, for the same amount of energy requirement of 13383 kWh, the expected daily load factor improvement would be 59.90% after the complete installation of the proposed 250 kW system. Curtin shall go for renewable energy grants for implementing the proposed PV system in a sequential manner.

6.3. Change of Tariff Option

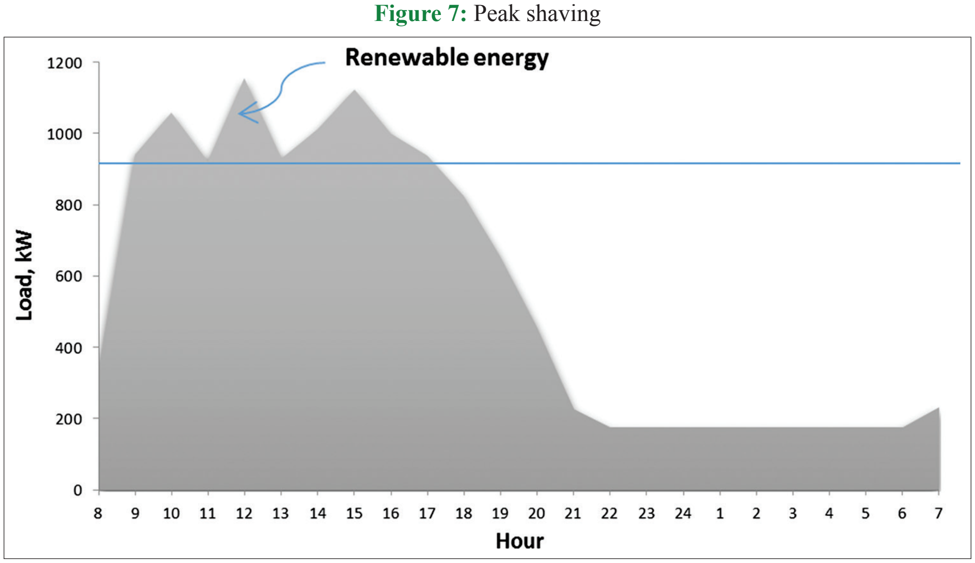
Curtin has opted for Consumption based Tariff C1. From the 9th month records, the monthly energy consumption was said to be 316,385 kWh. The energy consumption bill under this tariff is shown with breakups:
For the first 100 kWh: RM 40.00
For the next 4900 kWh: RM 1666.00
For any additional kWh: RM 93415.50
Total monthly bill: RM 95121.50

Proposing Curtin to go for Demand-based Tariff C2. In the same month and for the same energy consumption with 1156 kW as the monthly maximum demand, the energy bill following the rate RM 16/kW and RM 0.25/kWh would be:
Maximum demand charge: RM 18496.00
Energy consumption charges: RM 79096.25
Total monthly bill: RM 97592.25

At this stage, if Curtin opts for Tariff C2, it has to incur an additional expense of RM 2470.75 per month; hence it is not advisable. If Curtin goes for load balancing option, the monthly energy bill based on the new maximum demand (1000 kW) and the same energy consumption would be:
Maximum demand charge: RM 16000.00
Energy consumption charges: RM 79096.25
Total monthly bill: RM 95096.25

In this case, there is a saving of RM 25.25 per month; of course, it is not a great amount. Assuming, Curtin goes for peak shaving option, the monthly energy bill based on the new maximum

Figure 7: Peak shaving



demand (931 kW) and the reduced energy consumption due to the renewable energy contribution (316385 kWh – 30 × 960 kWh = 287585 kWh) would be:
Maximum demand charge: RM 14896.00
Energy consumption charges: RM 71896.25
Total monthly bill: RM 86792.25

In this case, there is a saving of RM 8329.25 per month, which accounts to be an 8.76% reduction in the monthly energy consumption charges. Besides, there is a carbon emission reduction of 37.29 tons/year. Hence, Curtin shall look into the renewable energy option at a large scale to scheming and controlling its colossal energy expenses.

6.4. HVAC

- Energy audit outcome - HVAC is the largest load category at Curtin and warrants the most inspection for finding energy management opportunities. The maximum connected demand for all the HVAC systems, including the two centrifugal chiller cooling units of identical capacities 450 kW each, are not in operating status is 2018 kW. However, during normal working hours, the peak demand is found to 930 kW. This is assuming that the AHU, ventilation fans, and split air conditioners located at Hornbill 1 and Hornbill 2 are operating at 100% capacity, which is rarely the case.
- Recommendations - A Cooling Degree Day (CDD) idea has been proposed [43], which gives a promise of recognizing the best level of energy consumption that is achievable by a facility. CDDs are units that are applied to estimating the measure of time and how much the outside temperature was over a predefined level. It is extremely useful in determining the energy used by the cooling system in the facility. Since the utilization of a cooling system is much more mind-boggling than only a typical appliance, degree days are utilized to look at how the utilization of the cooling system changes as in outside temperature.

For calculating CDD, first, a base indoor temperature at which comfort may be maintained is established. In the case of Curtin Sarawak, the base indoor temperature at which comfort is assured is set at 24°C. In the event that the outside temperature is beneath this level, at that point there is extremely no requirement for cooling; however, in tropical Miri, temperatures rarely go <24°C during peak hours of a day.

An online tool (BIZEE, 2016) shown in Figure 8 gives the month to month information on degree days in a specific region. The tool gets information from the weather stations far and wide. The strategy for utilizing this tool is extremely straightforward. It requires the global ID for the closest weather station and the indoor base temperature. The closest weather station to Curtin Sarawak is the Miri Airport with a global weather station ID as WBGR.

- Implementation and Analysis - For Curtin Sarawak, the actual energy consumption by the HVAC systems for the 12 month period has been recorded in Table 5. Moreover, the CDDs and the anticipated consumption with reference to the base temperature were computed and exhibited. The distinction between the actual and anticipated energy consumption and the Cumulative Sum of Differences (CUSUM) are additionally shown for analysis purpose.

From the CUSUM, it can be seen that the energy consumption does not follow any specific pattern. This implies the chillers were not being managed at steady operating conditions. No measures were being taken to control the consumption of the chillers. During the initial 3 months, it can be seen that the CUSUM is increasing all over the months. Over the time of 1/01-1/02, the energy consumption stays nearly the same, which implies that the chillers were regulated during that time. This was the OFF semester time frame; along these lines, controlling the chillers was straightforward around then. During the following 3 months' time frame (1/03-1/05), there is a declining tendency in the energy consumption, implying that improvements were not made to the optimum value especially during 1/05. However, in the following month, the consumption yet again has skyrocketed. At long last, over the most recent 2 months, the consumption pattern takes a declining course. Hence, the best energy conservation option for Curtin's HVAC system is Real-time Monitoring and Control (Vakiloroaya et al., 2014).

An analysis has been done in light of the ON Semester (April to November) and OFF Semester (December to March) periods. During the OFF Semester, the HVAC energy consumption is significantly less; hence the HVAC will be regulated following the minimum energy consumption of 520 kWh/CDD (i.e., 56699 kWh/109 CDD). Similarly, HVAC will be directed during the ON Semester following the minimum energy consumption of 676 kWh/CDD (i.e., 84537 kWh/125 CDD). Under these control settings, the expected energy consumption would be as in Table 6 and Figure 9. Thus, the expected energy consumption is reduced from 941395 kWh to 755788 kWh or 19.72% decrease of the actual energy consumption. The total carbon offset/year would be 241.29 tons.

7. CONCLUSIONS

This paper addressed the energy audit outcome of Curtin Sarawak. The load profile brought out the fact that, HVAC loads constitute

Figure 8: Cooling degree days' calculation

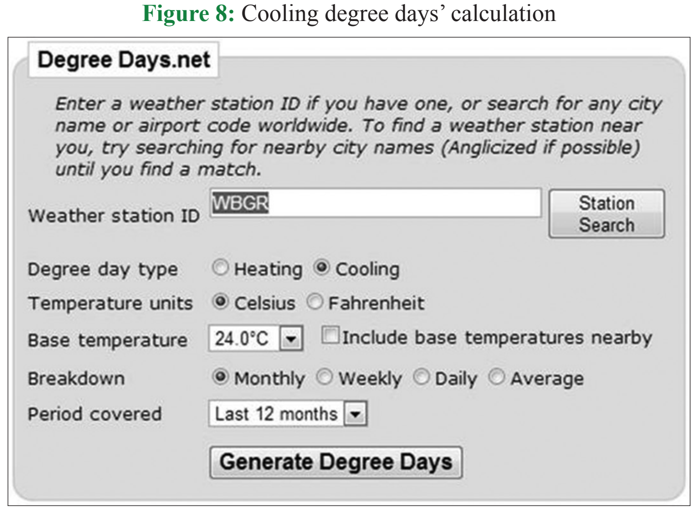


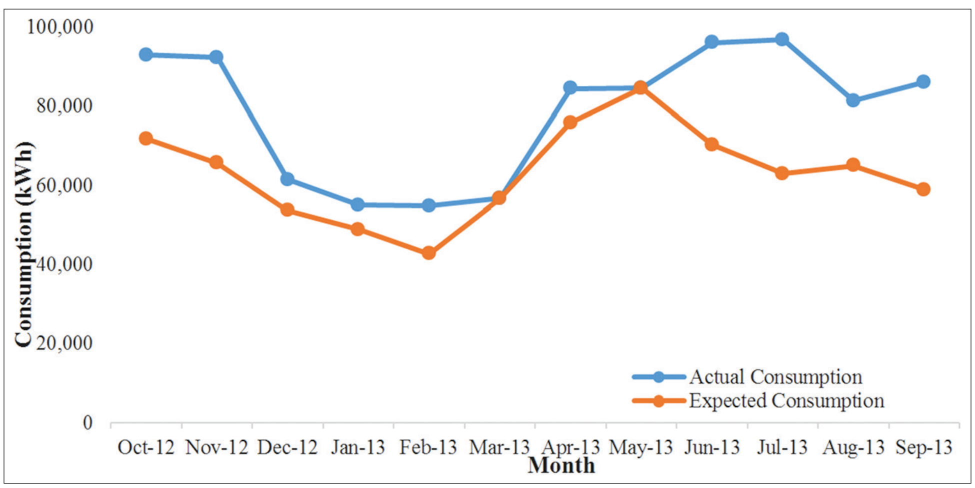
Table 5: Cumulative sum of differences (CUSUM)

Day/month	CDD	Actual consum. (kWh)	Predicted consum. (kWh)	Difference (kWh)	CUSUM (kWh)
1/10	106	92,814	89,165	3649	3649
1/11	97	92,192	89,3553	2837	6486
1/12	103	61,349	58,036	3313	9799
1/01	90	54,994	55,997	−1003	8796
1/02	82	54,712	54,742	−30	8766
1/03	109	56,699	58,977	−2278	6488
1/04	112	84,390	89,039	−4649	1839
1/05	125	84,537	88,765	−4228	−2389
1/06	117	95,910	88,933	6977	4588
1/07	93	96,658	89,440	7218	11806
1/08	96	81,220	89,378	−8158	3648
1/09	87	85,920	89,566	−3646	2

Table 6: HVAC control – An analysis

Day/month	Semester	Cooling degree days	Actual consumption (kWh)	Expected consumption (kWh)
1/10	ON	106	92,814	71,656
1/11	ON	97	92,192	65,572
1/12	OFF	103	61,349	53,560
1/01	OFF	90	54,994	48,800
1/02	OFF	82	54,712	42,640
1/03	OFF	109	56,699	56,680
1/04	ON	112	84,390	75,712
1/05	ON	125	84,537	84,500
1/06	ON	117	95,910	70,092
1/07	ON	93	96,658	62,868
1/08	ON	96	81,220	64,896
1/09	ON	87	85,920	58,812
		Total	941395	755788

Figure 9: Comparison of energy consumptions



the highest share in the total connected load as well in the energy consumption pattern as well. The present load factor is <50% and it necessitated the need for load factor improvement. Successful implementation of the proposed 250 kW PV systems would improve the load factor to almost 60% and reduces the fossil fuel energy consumption resulting in an economic and environmental friendliness. Moreover, the unit cost of energy generation is RM 0.31, which is as attractive as that of the SESCO energy tariff. The only burden on Curtin is the amount of investment. Curtin shall go for time-bound investments in stages such that the annual budget would be less and it shall apply for renewable energy grants as well. It is beneficial to Curtin to go for the change of the tariff from C1 to C2 if Curtin is serious about introducing renewable energy option as suggested.

The real-time monitoring and control of HVAC systems are inevitable. The control with respect to the base temperature as suggested is an efficient and cost-effective option to practice with immediate effect. As observed, there are some activities even after office hours that also use chillers and other huge energy-consuming machinery. These activities shall be planned without the use of huge energy-consuming facilities or in a different environment.

In conclusion, Curtin needs to look into the suggested energy conservation measures in stages following a time-bound target.

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