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BUILDING ENERGY INDEX (BEI): A STUDY OF GOVERNMENT OFFICE BUILDING IN MALAYSIAN PUBLIC UNIVERSITY

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Abstract

Energy consumption in developing countries such as Malaysia is certainly growing in line with current economic growth and development of commercial as well as residential areas. Thus, various initiatives can be seen, in particular by the role of the government in ensuring the optimum and efficiency usage of energy in the building. Therefore, MS1525 standard is a standard that takes into account the energy efficiency of a building as a reference to determines to what extent the building meets the current standard. Then, this paper presents the Building Energy Index (BEI) for the Chancellery building in Universiti Utara Malaysia (UUM). The aim is to study BEI for the buildings whether this building achieved the standard requirement. The objective of the study was achieved by collecting data of monthly energy usage, gross floor area of the buildings and calculating BEI to get actual results. Preliminary audit which involves a brief review of utility and building operation, observation and a walkthrough in the buildings are used. In order to get a better understanding of major energy consumption in the selected buildings, general audit have been conducted to collect more detailed information about building operation. Based on MS 1525:2007 any building which implements energy efficient measures can achieved the BEI of 136 kWh/ m^2/ year. Hence, the government's target towards more energy efficiency can be archived. Suggestion on how to improve energy saving and enhancement for building performance will be concluded.

Keywords: Building energy index, Energy efficiency, Energy audit, Performance index, Energy management.

1. Introduction

The Universiti Utara Malaysia (UUM) main campus is located on a 1,061 hectares site in Sintok, Kedah (see Fig.1). Among the main buildings of the campus are the Sultanah Bahiyah Library, the Chancellery, the Sultan Badlishah Mosque, the Mu'adzam Shah Hall, the Tan Sri Othman Hall, the Sports Complex, the Varsity Mall, the Budi Siswa building and the Convention Complex. In UUM, energy plays an important role in everyday operation, especially when it involves a huge amount of electricity consumption for the campus such as HVAC system (heating, ventilating, and air conditioning) which provides acceptable thermal comfort and indoor air quality. Most of the office buildings in Malaysia use energy in form of electricity to run lifts, office equipment and air conditioning as part of Mechanical and Electrical (M&E) systems in building, which consume more energy in the operation stage [1].

UUM is in the state of Kedah Darul Aman, Malaysia; being located in north Malaysia, it benefits from a tropical climate with high temperatures and high humidity throughout the year in these climatic conditions, UUM certainly uses a lot of energy in the office buildings that requires a method for determining the rate of energy consumption in a building. As energy consumption in Malaysia is high [2] then no exception of UUM campus and studies show that the commercial sector and residential use half the amount of electricity generated [2]. Therefore, it is important to look at energy efficiency in buildings, by taking into account the objectives of this study. The Chancellery building at UUM is selected as a case study for this research being the main office building with fairly regular occupancy and substantial electrical load.

Fig. 1. Universiti Utara Malaysia map and the chancellery building location.

2. Malaysia Climate

Malaysia climate is fairly consistent throughout the year. According to Malaysian Meteorological Department, the climate of Malaysia is uniform temperature, high humidity and copious rainfall. Winds are generally light. It is extremely rare to have a full day with completely clear sky even during periods of severe drought. On the other hand, it is also rare to have a stretch of a few days with completely no sunshine except during the northeast monsoon seasons. The seasonal wind flow patterns coupled with the local topographic features determine the rainfall distribution patterns over the country. During the northeast monsoon season, the exposed areas like the east coast of Peninsular Malaysia, Western Sarawak and the northeast coast of Sabah experience heavy rain spells. On the other hand, inland areas or areas which are sheltered by mountain ranges are relatively free from its influence. It is best to describe the rainfall distribution of the country according to seasons.

2.1. Rainfall

As Universiti Utara Malaysia is located in Penisular Malaysia, there are three types of seasonal variation of rainfall in Peninsular Malaysia. First, the months with maximum rainfall over the east coast states are November, December and January, while the driest months in most districts are June and July. Secondly, the monthly rainfall pattern over the rest of the Peninsula with the exception of the southwest coastal area shows two periods of maximum rainfall separated by two periods of minimum rainfall. The primary maximum generally occurs in October - November while the secondary maximum generally occurs in April - May. Over the northwestern region, the primary minimum occurs in January - February with the secondary minimum in June - July while elsewhere the primary minimum occurs in June - July with the secondary minimum in February. Last but not lease, the rainfall pattern over the southwest coastal area is from May to August with the result that the double maximum and minimum pattern is no longer distinguishable. October and November are the months with maximum rainfalls and February the month with the minimum rainfall. The March - April - May maximum and the June -July minimum rainfalls are absent or indistinct.

2.2. Sunshine and solar radiation

In fact, Malaysia located in South East Asia naturally has abundant sunshine and thus solar radiation. Based on the previous data of Meteorological Department, rarely to have a full day with perfectly clear sky even in periods of severe drought. The cloud cover cuts off a substantial amount of sunshine and thus solar radiation with the average, receives about 6 hours of sunshine every day. In this case, there are seasonal and spatial variations in the amount of sunshine received such as UUM receive about 7 hours per day of sunshine while university in Kuching, Sarawak (east Malaysia) receives only 5 hours on the average.

3. Energy Efficiency

Generally, energy efficiency is defined as a way of managing and restraining the growth in energy consumption. Energy consumption in the building is efficient if it delivers more services for the same energy input, or the same services for less energy input [3]. Energy efficiency as the energy services provided per unit of energy input into the production of desired energy services such as heating, lighting and motion [4]. Therefore, typical building in Malaysia can implement energy efficiency programs with a wide range of methods, and it can be seen from variety methods of energy efficiency measures. It might involve a high cost in terms of the use of up to date or modern technological tools and equipment or methods with a low-cost savings measures such as energy efficiency awareness campaigns and educating people. Many energy-saving methods applied, require huge amount of implementation and management costs. However, with the right strategy and concepts, the appropriate key energy management practices have a big potential to achieve energy efficiency that can be implemented immediately without spending huge amounts of money but able to achieve energy savings as needed with good results.

Typically, in Malaysia which has a hot and humid tropical climate, conventional office buildings consume more than half of energy usage (in form of electricity) for air-conditioning. Therefore, the energy efficiency of buildings become a prime concern for anyone wishing to identify factors that become barriers to energy savings [5]. Concerning efforts to identify factors that contribute to higher energy consumptions, in fact, many past researchers have implemented several approaches in order to optimized energy consumption in the building as well as minimizing operational cost.

4. Building Energy Index

Based on the guidelines published by Suruhanjaya Tenaga (Energy Commission), there are three frequently used methods in energy auditing; benchmarking, preliminary audit and general audit. Establishing benchmarking consumption mainly consists of comparing the measured consumption to other similar buildings (office buildings). It is necessary to identify building energy saving potential, which in this study researcher used Building Energy Index (BEI) as a performance index. Common practice, to compare energy use in buildings is based on this index. In fact, BEI is used for comparing energy use in buildings and usually expressed as kWh/ m^2/ year which measure the total energy used in a building for one year in kilowatts hours divided by the gross floor area of the building in square meters. BEI is used for comparing energy consumption in the building as a standard measurement to evaluate the energy consumption in buildings for one year [1,6–10].

The index is used based on the normalizing factor to compare building energy consumption for the whole year. According to [11] architects basically use the gross floor area as normalizing factor to compare building depending on the intended application of the index. While preliminary audit is known as the simplest and quickest type of audit, involves minimal interviews, a brief review of utility bills and other operating data and a walkthrough to become familiar with the building operation. This type of audit usually covers major problem areas only. Last but not lease, general audit method expands on the preliminary audit by collecting more detailed information about building operation. In this study, utility bills are collected for 12-months period for the past four years to evaluate energy usage profiles.

5. The Chancellery

Chancellery building in UUM is an iconic main office building, being used as administration office and located in the prime area of the UUM campus nearby Sultanah Bahiyah Library and U-Assist Unit. The imposing 25-year-old building houses several main offices for the administration of UUM such as Vice-

Chancellor's Office, Office of the Deputy Vice-Chancellor, Registrar's Department, Treasury Department, Department of Student Affairs and the UUM Gallery as well. Among the advantages of this building is that it is located in a green valley surrounded by tall trees and hills as shown in Fig. 2. There is no skyscraper or other nearby building which may reflect excessive light during the afternoon. This indirectly helps to prevent the reflection of light radiate heat directly into the building. The building is a six-storey building and its operation hours are from 7.45am to 5.30pm.

Fig. 2. The Chancellery building and its surrounding area.

The details area measurements of the building are summarized in Table 1 below.

Table 1. Buildings floor area.

Building	Storey	Gross floor area (m^2)
Chancellery	6 storeys	8,983

Table 1 shows that, Chancellery building is a multi-storey building with gross floor area of 8,983m^2. Gross floor area is the total floor area of all floors in the building, within the building measured to the outside surfaces of the exterior walls and frequently measured in square feet or meters. Gross floor area would include stairwells, elevator, but would not include areas such as basements and open space or uncovered car parks.

Located in front of the building is a spacious parking area and surrounded by ornamental plants and flowers. While behind the building there is a very wide area known as Dataran Perdana (Prime Square). The square has a fountain located in the middle, there is a leisure area and a sitting area, ornamental plants, flowers and flanked by a library building in the north and building U-Assist Unit in the south.

5.1. Monthly electricity usage

Overall, energy used in the Chancellery building is mainly for air conditioning system, lighting system and office equipment. The electricity consumption for the building was recorded (as shown in Table 2) through the collection of monthly electricity bills for the past three years from 2012 to 2014. Originally, the data was collected until 2015 but due to some errors in the data for year 2015 because of meter malfunction, only data from 2012 until 2014 were taken into account.

Table 2. Energy consumption in 2012 until 2014.

Month	2012	2013	2014
Jan	126000	101039	125041
Feb	156000	104007	125809
Mar	110000	230350	193034
Apr	130000	182993	127888
May	141751	186726	132752
Jun	153445	102710	131690
Jul	157872	130906	141379
Aug	167766	117816	141379
Sep	168166	155690	149056
Oct	66111	118305	235234
Nov	150889	198985	195234
Dec	163961	117210	116273

Fig. 3 shows the monthly energy consumption throughout the year 2012 until 2014. Through the electric usage data in 2012, at the beginning of the year, there was slightly increases in energy usage for February amounted to 156,000 kWh that is, an increase of 30,000 kWh than the previous month. However, there is a sudden decline a month after that with 110,000 kWh in Mac before rising again starting from April to September. Although semester break was usually in mid-January to mid-February, a week off in April and two months semester break at the end of June until September, but did not show any significant change to the pattern of energy usage in this building. But the rate of electricity consumption goes down in October with a total consumption recorded was 66,111 kWh before returning with a rather ordinary usage of 150,889 kWh in November and 163,961kWh in December 2012. Total energy consumption for the year 2012 is 1,691,961 kWh.

The energy consumption of the building in 2013 began with quite low energy usage but increased in February and a sharp increase from March (230,350 kWh). Then the energy consumption in April and May decreased significantly to the amount around 180,000 kWh. Next, June recorded the second lowest consumption for the year was probably caused by the long semester break. Then, the energy consumption in the Chancellery is experiencing ups and downs until November 2013 it was 198.985 kWh which is the second highest of energy usage after March. Total energy consumption in the year increased to 1,746,737 kWh.

Energy consumption in 2014 appears as two peaks showing how the higher usage of energy occurred sharply in March (193,034 kWh) and October (235,234 kWh). Others, the total energy consumption is much lower, which is not more than 150,000 kWh per month. High energy consumption in March and October can be attributed to the influx of new students and seniors in mid-January and September, which may involve high data throughput, especially involving the office of the Registrar and Bursar located in the Chancellery building. Despite high energy consumption also occurred in March last year which reached 230,000 kWh.

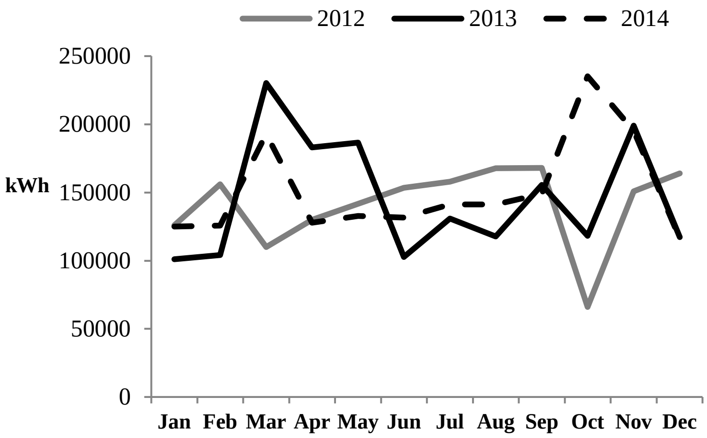

Fig. 3. Monthly energy consumption throughout the year 2012 until 2014.

5.2. Energy usage comparison

There were varieties of electric density load and those were all depended largely on functional and aesthetic requirements, and the operating hours. There were also other minor electrical appliances, such as the audio/ visual and office equipment.

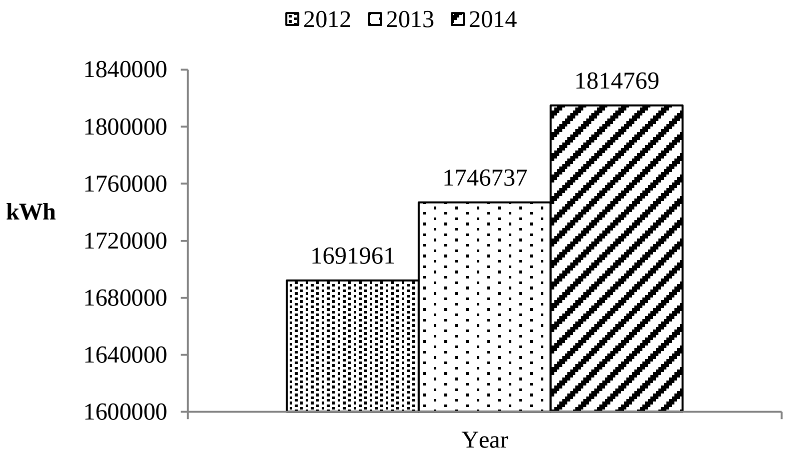

Fig. 4. Yearly usage comparison from 2012 until 2014.

Based on the monthly electricity consumption history, the energy consumption (kWh) of Chancellery buildings was very high throughout the 12 months periods because the buildings occupied throughout the year. Fig. 4 shows the yearly usage comparison from 2012 until 2014.

The electrical system for the buildings is distributed to the use of lightings, plug loads and others while artificial lighting system is used to illuminate interior office space and external areas such corridor and building façade. Basically, there are two parameters that are used to evaluate the lighting efficiency namely lighting power density and luminance level.

Overall, electricity usage of the Chancellery building is very uneven throughout the year. Calculation for Building Energy Index (BEI).

$$BEI = \frac{Total\ energy\ used\ (\frac{kWh}{year})}{Gross\ floor\ area\ (m^2)} \quad (1)$$

Table 3. Building energy index.

	Chancellery		
	2012	**2013**	**2014**
Annual Energy Consumption (kWh)	1,691,961	1,746,737	1,814,769
Gross Floor Area (m^2)	8983	8983	8983
Building Energy Index (BEI) kWh/m^2/year	188.35	194.45	202.02

In fact, the MS 1525:2007 Standard indicates that any building which implements energy efficient measures can achieved the BEI of 136 kWh/ m^2/ year. According to Aun [11], based on the energy audit results show majority of Malaysia office buildings had the BEI in the range of 200 to 250 kWh/ m^2/ year. Currently, based on BEI of the Chancellery building in Table 3, it has the BEI in the range of 180 to 210 kWh/ m^2/ year and the potential energy reduction is very high and could be achieved if all necessary measures have been taken into account.

Table 4. Potential of energy reduction.

	Chancellery		
	2012	**2013**	**2014**
Building Energy Index (BEI) kWh/m^2/year	188.35	194.45	202.02
Building Energy Index MS1525:2007, kWh/m^2/year	136	136	136
Potential energy savings, kWh/m^2/year	52.35	58.45	66.02

Average, potential energy savings (kWh/m^2/year) was calculated as:

52.35 + 58.45 + 66.02 (kWh/m^2/year) ÷ 3 years = 59.63 kWh/ m^2 per year

Based on the previous records of monthly electricity consumption, the Chancellery building has a potential to reduce 52.35 kWh/ m^2/ year in 2012, 58.45 kWh/ m^2/ year (2013) and 66.02 kWh/ m^2/ year (2014) of energy consumption (Table 4). Based on the annual rate of BEI reduction to meet the standards, then the average 59.63 kWh/ m^2 per year is very high and the potential for savings is made up of the Chancellery building. The current electricity rate is RM0.509 per kWh and the total cost of energy consumption for the year 2014 is about RM923,717. We assume that if it reaches the standard utilization rate of 136 kWh/ m^2/ year then the total energy consumption for year 2014 is equivalent to 1,221,688 kWh/ m^2/ year to a cost of RM621,839.192. Means the potential saving for energy consumption in 2014 is about RM301,878 (RM923,717 - RM621,839).

6. Conclusions

Through BEI formula that has been shown by calculation in the preceding paragraph, clearly demonstrates that the rate of energy consumption in Chancellery is very high. The latest annual energy consumption for this building is quite high in 2014 (1,814,769) and the BEI is about 202.02 kWh/m^2/year compare to the standard of MS 1525:2007 of 136 kWh/ m^2/ year. It is more than 60 kWh/m^2/year compare to the best BEI practice 136 kWh/m^2/year. Look at data in 2014, it shows that potential savings up to RM300,000 per annum is very high. Since this building is the main office building in the campus, it is fully utilized during the BEI calculation. The result of this study is considered accurate and based on data obtained from actual energy consumption for the past four years. The considered monthly usage from 2012 to 2014 and it clearly shows that the rate of energy consumption in the Chancellery building is very high and the BEI calculation surpassed 200 kWh / m2 / year in 2014. While the building may also be affected by the semester break and involves matters related to students, but generally Chancellery building was not involved student activity such as in academic buildings whether faculty buildings, libraries or student activity centre. Then, further study may be to identify the factors such as weather patterns and heat wave that may affect the volatility of energy consumption in office buildings in certain months and also to conduct polls or interviews with selected respondents. These efforts will be continued to determine the actual usage of electricity for 2015 and also the latest data for 2016 as well as to identify factors affecting the energy usage throughout the year.

References

1. Tahir, M.Z.; Nawi, M.N.M.; and Rajemi, M.F. (2015). Building energy index : a case study of three government office buildings in Malaysia. *Advanced Science Letters*, 21 (6), 1799–1802.
2. Choong, W.W.; Chong, Y.F.; Low, S.T.; and Hakim, A. (2012). Implementation of energy management key practices in Malaysian Universities. *International Journal of Emerging Sciences*, 2(3), 455-477.
3. International Energy Agency (2015). International energy agency. Retrieved from October 30, 2015, from http://www.iea.org/topics/energyefficiency/.
4 Gillingham, K.; Newell, R.G.; and Palmer, K. (2009). Energy efficiency economics and policy. *Annual Review of Resource Economics*, 1(1), 597-620.
5. Li, X.; Bowers, C.P.; and Schnier, T. (2010). Classification of energy consumption in buildings with outlier detection. *IEEE Transactions on Industrial Electronics*, 57(11), 3639-3644.
6. Noranai, Z.; and Kammalluden, M.N. (2012). Study of building energy index in Universiti Tun Hussein Onn Malaysia. *Academic Journal of Science*, 1(2), 429-433.
7. Kannan, K.S. (2007). Development of an energy rating system for office buildings. *Conference on Sustainable Building South East Asia*. 71-76.

8. Tahir, M.Z.; Mohd Nawi, M.N.; and Ibrahim, A. (2016). Value management (VM): A strategic approach for improving energy efficiency. *International Journal of Supply Chain Management*, 5(4), 201-208.
9. Sodangi, M.; Khamdi, M.F.; Idrus, A.; Hammad, D.B.; and AhmedUmar, A. (2014). Best practice criteria for sustainable maintenance management of heritage buildings in Malaysia. *Procedia Engineering*, 77, 11-19.
10. Xin, H.Z.; and Rao, S.P. (2013). Active energy conserving strategies of the Malaysia energy commission diamond building. *Procedia Environmental Sciences*, 17, 775-784.
11. Aun, C.S. (2009). Green building index-MS1525: applying MS1525: 2007 code for Practice on energy efficiency and use of renewable energy for non residential buildings. *Continuing Professional Development-CPD Seminar*. Kuala Lumpur.