International Journal of Physical Sciences Vol. 4 (12), pp. 752-757, December, 2009
Available online at http://www.academicjournals.org/ijps
ISSN 1992 - 1950 © 2009 Academic Journals

Full Length Research Paper

Energy performance of electrical support facilities: the case of adaptive re-used historical buildings in Malaysia

S. N. Kamaruzzaman[1]*, Azlan Shah Ali[1], Zulkiflee Abdul-Samad and Emma M. A. Zawawi[2]

[1]Building Performance and Diagnostic, Faculty of Built Environment, University of Malaya, 50603 Kuala Lumpur, Malaysia.
[2]Centre of Research and Graduate Studies, Faculty of Architecture, Planning and Surveying, University Technology MARA, 40450 Shah Alam, Malaysia.

Accepted 30 October, 2009

Electricity could be the most expensive form of energy used in buildings. Hence, reduction in electricity consumption may save more money than other cost-saving measures. Although the cost of providing and installing electrical equipment represents a relatively small proportion of the total mechanical and electrical (M&E) costs, in historic buildings, however, it is an increasingly significant element in saving the overall energy cost. This paper investigates the energy performance of electrical equipments - measured in kWh electrical and given in kWh/m2 per annum - in three adaptive re-use historical buildings (two office buildings and one hotel building) in Malaysia. Further analysis by comparing energy consumption with established energy benchmarking categories - electricity, office equipment and other electricity - was also conducted to give an indication of efficiency. The study found that although catering electricity consumptions for all buildings were below good practice level, all electrical equipments of the two office buildings fall below good practice benchmark. On the contrary, office equipment consumption for the hotel building falls high above typical level benchmark. Such comparison of energy consumption against established benchmarks provides a first indication of how well the buildings are performing and to identify any wastage of energy and what scope there is for design improvement.

Key words: Electrical equipments, historic buildings, energy performance, energy benchmark, Malaysia.

INTRODUCTION

Electrical equipment use in the commercial buildings sector is growing faster especially for office equipment. This includes computers, monitors, printers, facsimile machines, copiers and others. Energy use by electrical equipment is expected to grow by as much as 500% in the next decade (HP, 2005). Understanding electrical equipment energy use is particularly important because office equipment is widely believed to be the fastest growing electrical end use in the fastest growing sector. Historic buildings, in Malaysian context, are defined as buildings that were built in the past 80 - 100 years or more (Laws of Malaysia, 1976; Majid, 2003; Ahmad, 1997). Historical aspects, the uniqueness of the design and the characteristics are significant factors contributing to the important of these buildings to the country. Furthermore, these buildings have a lot of valuable historical elements which provide an important social, economic recreational and educational resource for next generation. From the historical aspects, old building can be as an evidence of the colonisation of a country. Other importance aspect is the uniqueness of the design that can be seen in certain element of the building. These characteristics make the building unique and valuable even the age has reached almost or more than 100 years. Nevertheless, most of the buildings are still in their original state but being fitted with electricity, water as well as air conditioning. Some of the buildings were also upgraded or renovated to more advanced services system, which end up using high consumption of electricity (DOE, 1995). It must be pointed out that electricity is the most

*Corresponding author. E-mail: syahrulnizam@um.edu.my.

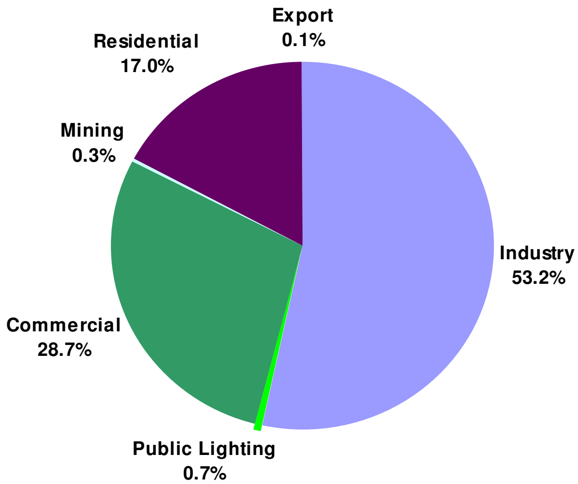


Figure 1. Electricity consumption in Malaysia (Source: DEGSM, 1998).

expensive form of energy used in buildings: consequently, reducing electricity consumption may save more money than many other cost-saving measures.

The cost of electrical equipment in a building is relatively small when compared to the total costs of mechanical and electrical (M&E) services. However, in the case of historic buildings, it is increasingly recognised that good performance of electrical equipment may result in significant saving in the overall energy consumption costs. This is because low energy consumption of electrical equipment is related to the uniqueness of the design and the characteristics of historical buildings - for example, ventilation, lightning, heating and cooling system, climate situation, orientation, occupants' behaviour, productivity, and so on. The primary objective of this study is thus, to investigate the electrical equipment consumption characteristics in Malaysian old buildings. Comparison with benchmark was performed with the aim of providing a first indication on how well the buildings are performing and to identify any wastage of energy in particular and the scope for improvement.

Electricity energy consumptions

Electricity was once thought of as a plentiful and relatively inexpensive power supply. Unfortunately, times have changed for the worse when it comes to power. The electricity demand growth in Peninsular Malaysia for the next five years is forecasted to increase at an annual average of 4.4% from 14,281 MW in year 2008 - 16,927 MW in year 2012. In line with the forecasted growth, the demand for electricity also is expected increase to 112,740 GWh in year 2012 from 95,106 GWh in year 2008. With the existing installed capacity, new capacities have to be planted up before the year 2010 and even more before 2020. In most countries, electricity consumption typically ranges from 15 - 40% of total electricity consumption. This energy is used by a variety of equipments providing water heating, food and space cooling, lighting and other end-uses. Figure 1 shows the electricity consumption in Malaysia according to categories of consumers. The total consumption was 48,862 GWh (DEGSM, 1998).

Buildings are a dominant feature in modern society. We work, eat, sleep and enjoy much of our leisure time inside them. Up to 80% of an individual's life is spent indoors (Peng, 1996). The function of the building has evolved from a simple shelter to an advanced, self-contained and tightly controlled environment which provides a wide variety of services to its occupants environmental conditioning, vertical transportation, sanitation, artificial lighting, communications and security. To perform this range of functions the building must consume energy.

All energy used within buildings can be classed under two main categories: high-grade and low-grade (Twidell and Weir, 1986) the grade of energy is determined by its ability to perform work. The prime example of high-grade energy is electricity, which can be efficiently converted to work via an electric motor. An example of low-grade energy encountered in buildings is the heat energy used to maintain conditions suitable for human comfort. Although the majority of the energy consumed within buildings is low-grade, it is the high-grade electrical energy, which is the more important. Electricity performs a greater variety of functions and is required in the transportation of low-grade energy from the point of production to the point of use, For example, the transportation of conditioned air through a ducting system using a fan.

Significant financial savings can result from the implementation of high-grade energy saving schemes, especially when it is considered that high-grade energy costs between 3 - 10 times as much per kWh, as the equivalent unit of low-grade energy (Department of Trade and Industry, 1992). Also note that high-grade electrical account for only 40% of energy consumption but these high-grade energy use account for 66% of energy expenditure. A reduction in electrical energy consumption at the point of consumption is achievable by numerous means: installing energy efficient lighting and appliances, improved control and monitoring of electrical equipment, shutting down non-essential equipment at times of peak loading, daylight and occupancy responsive controls for lighting.

Johnston, (1993) quoted that the built environment consumes up to 50% of delivered energy. A survey conducted by The Ove Arup Partnership, (1980) revealed that much of this energy is used inefficiently in buildings over 10 years old 30 - 40% of the energy consumed is wasted due to the poor condition of the building envelope and plant. In Malaysia, buildings over 10 years old account for 90% of the building stock (Abidin Idid, 1995).

Assuming a worst-case scenario from these figures, it is possible that 18% of all delivered energy is wasted due to the poor quality of the older building stock. This waste of energy has two major implications: environmental, and perhaps more importantly for the building owner, economic.

MATERIAL AND METHODS

Energy performance indicators and benchmarks

The overall energy performance of a building can be crudely expressed as an energy performance indicator, usually in kWh/m^2 for fossil fuel and electricity (CIBSE, 2004). Performance indicators for buildings are generally rated in terms of floor area, building volume and the amount of trade. With the correction on floor area, weather and hours of use, a 'Normalised Performance Indicator' can be obtained. This 'normalisation' is intended to improve comparison between buildings in different climatic regions or with different occupancy patterns (CIBSE, 2004). The analysis is performed on annual data, allowing comparison with published benchmarks to give an indication of efficiency (Action Energy, 1994). In this study, the energy benchmark refers to the CIBSE Guide F Energy Efficiency in Buildings published in 2004 that contains all the known UK energy and components benchmark.

Survey and data acquisition

A total of three historic buildings were chosen in this study. However, different type of building uses were selected but restricted to one architectural style, British. This would ensure more energy pattern could be investigated. The buildings comprised of two offices, and one hotel. One of the buildings was located in the capital city of Kuala Lumpur and the other two were in Penang. In order to retain the individual building anonymity, they are designated as Old Office 1, Old Office 2 and Old Hotel 3. In favour with BRECSU, (2000), each building selected are based on their size and types which represents air-conditioned standard (2000 - 8000 m^2), naturally ventilated open plan (500 - 4000 m^2), and air-conditioned prestige (4000 - 20 000 m^2) respectively.

A site survey was conducted during the month of March, 2008 till May, 2008 to basically investigate the energy characteristics in historic buildings of Malaysia focusing on electricity. In this study, all the electrical equipment was considered. The quantity, power rating and modes and hours of operation were gathered from the inventory as well as through walk through survey. Power ratings were checked against the nameplates on the machines wherever possible. However, a pen type multi meter was used to measure the amps of some equipment due to unclear and worn off nameplates. By having the amps and volts multiplied, the wattage requirement of the appliance can be obtained. In theory, the power rating multiplied by the total hours of operation would give the total energy use for the equipment (Lam et al., 2004).

Description of buildings

A summary of key buildings features is shown in **Error! Reference source not found.** 1. The number of stories varies from one to four with a total gross floor are ranging from 7452 - 4625 m^2. Most of these building were being 80 - 100 years that was built during the pre-independence era (Figures 2 - 4).

RESULTS AND DISCUSSION

Based on data collected, a normalisation was done. The total electrical equipment energy use of a building can be

Table 1. Building descriptions and features.

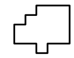
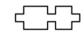
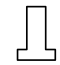
	Old Office1	Old Office 2	Old Hotel 3
Building shape			
Built	1900	1912	1926
Number of storeys	2	2	2
Gross floor area (m^2)	2860.0	745	4625
Floor to ceiling height	6.0	3.6	3.6(G/F), 3.3(F/F)
Window height (m)	2.9	2.5	2.5

Figure 2. Exterior of old building 1.

Figure 3. External facade of old building 2.

Figure 4. Exterior of old building 3.

used to calculate a measure of energy performance known as the 'Normalised Performance Indicators' (NPI) (CIBSE, 1991). NPI is basically the energy use per unit floor area and also known as the energy use index (BRECSU, 2000). This will allow a further comparison with established energy benchmarks. Table 2 shows the electrical equipment energy consumption for the three old buildings in kWh/yr/m^2.

The equipment load density varied from 9 - 43 kWh/m^2 with a mean density of 22 kWh/m^2. The large load densities in Old Building 3 were due to large electrical equipment with long usage hours and other room essential equipments. As for the other buildings, most of the electrical consumptions are from the offices equipments. According to CIBSE, (2004), office equipment consumption will probably continue to rise with the ever increasing use of IT equipment. However, advances in technology will probably result in gradual reduction in equipment loads (CIBSE, 2004).

Comparison with benchmarks

Comparisons at a more detailed level are important. A comparison with benchmarks of annual energy end-use per square meter of floor area will permit the standard of energy efficiency to be assessed and enable remedial action to be taken. For this reason electrical equipment consumption was compared with established energy benchmark. According to the energy benchmark (CIBSE, 1991, 1998, 2004), electrical equipment in a building can be divided in three categories, which are catering electricity, office equipment and other electricity. In this study, the electrical equipment consumption used was divided accordingly to obtain an effective comparison results.

As per Figure 5, it is found that catering electricity consumption for all buildings felt below good practice level. Surprisingly, all electrical equipment for both office building falls below good practice benchmark. However, this is probably because of the low computers and peripheral devices installations as well as small provision of consumption due to sharing practice in these buildings. Even though the energy performance is lower than the benchmark, there will still often be scope for further effective savings (BRECSU, 2000). On contrary, office equipment consumption for hotel building falls high above typical level benchmark. This is a 140% above typical level and 380% above good practice benchmark. The high usage of office equipment is merely because of this hotel operates on 24 h yearly as well as continuous operation time. However, according to CIBSE (2004), these figures could still be reduced by using energy star equipment as well as more energy efficient equipment.

Conclusion

A study was conducted investigating electrical equipment consumption in three historic buildings comprising of offices and hotel in Malaysia. The total annual electrical equipment energy use per unit gross floor area ranged from 9 - 43 kW h/m^2, with an average of 22 kWh/m^2. As per comparison with energy benchmark, office equipment for hotel type building needs further attention due to its high consumption. Nevertheless, electrical consumption for offices building could also be further investigates to identify any scope of improvement. Bare in mind that this finding was compared to the UK based energy benchmarks. These findings could have a better impact with the availabilities of Malaysian energy benchmark, which is highly recommended.

The study showed that serious consideration on the selection of electrical appliances and equipment must be given for use in historical buildings. This is because wrong choice or poor combination of electrical equipmenting such buildings may result in high consumption of energy which will eventually make energy bills expensive. Initiative such as energy star is seen as a promising measure to counter high energy consumption.

Therefore the overall energy costs in historical buildings can be reduced which promotes the concept of sustainable built environment.

As the Malaysian economic has seen rapid growth, so has energy needs seen phenomenal increase especially electricity. However, with the current introduction of energy star equipment and energy efficiency program, it is hope that these energy-saving features can reduce product energy consumption, improve efficiency and help maintain electric loads. Apart from that, energy awareness program should also be introduced and practiced especially for the building occupants. The main purpose should be to increase the occupants' awareness of how energy is consumed and to teach them to use and maintain the energy-saving measures installed in their building. Furthermore, with the Malaysian government great emphasis and commitments to promote the attain-

Table 2. Electrical equipment energy consumption for the three old buildings.

Building	Electrical equipments	No.	Watts	Hr/wk	Wk/yr	Energy Used (kWh/yr)	Load densities (kWh/m^2)
Old Office 1	PC and Monitor	68	120	24	50	19976	15
	Printer	20	130	12	50	1591	
	Fax Machine	4	40	3	50	49	
	Photocopier	4	1320	12	50	3231	
	Kettle	3	1850	12	50	3397	
	Refrigerator-Freezer	1	420	168	50	7197	
	Television	4	150	16.5	50	505	
	Radio	8	500	11	50	2244	
	Sound system	1	1000	3	50	153	
	Fan	8	75	45	50	1377	
Old Office 2	PC and Monitor	10	240	24	50	2880	9
	Printer	3	130	12	50	234	
	Photocopier	2	1320	12	50	1584	
	Fax machine	2	40	3	50	12	
	Television	1	250	33	50	413	
	Kettle	1	1850	12	50	1110	
Old Hotel 3	Television	96	150	21	52	15725	43
	Exhaust Fan	8	150	56	52	3494	
	Water Heater	96	1100	14	52	76877	
	Kettle	96	1200	7	52	41933	
	PC and Monitor	2	340	48	52	1697	
	Fridge	96	33	168	52	27676	
	Photocopier	1	1320	12	52	824	
	Fax machine	2	40	6	52	25	
					Total		67

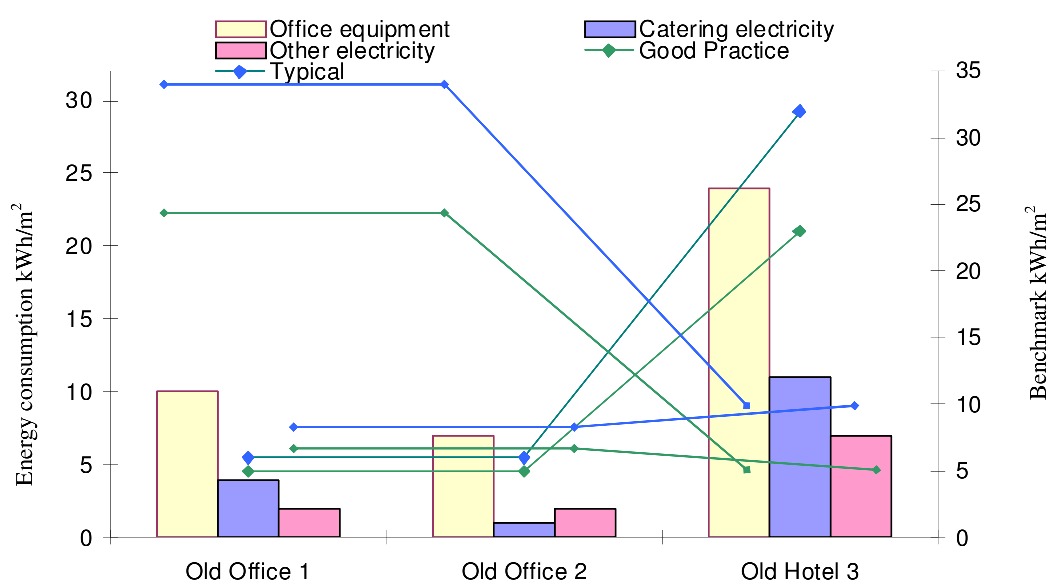


Figure 5. Electrical equipment consumption with compare to energy benchmarks.

ment of a sustainable development path, including a rational efficient and wise use of energy, these figures are expected to deep down in the near future. Development of energy benchmark in Malaysia is also in desperate need for a more accurate and precise indication of building energy performance.

It can be concluded that establishment of Energy Service Companies (ESCOs) and Energy Efficiency (EE) Providers is seen as a major initiative towards efficient global energy management and conservation. Even though Energy Efficiency (EE) is a relatively new industry in Malaysia but with the support and facilities provided by the Government, local Energy Efficiency Providers have a conducive environment and perfect test-bed for continuous research and development. Above all, this study has been able to identify and give a good indication of the electrical equipment consumption characteristics of old buildings in Malaysia.

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