The Need for a Sustainable Hospital: Why and How?

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Abstract- Sustainable buildings are becoming a focus nowadays as they give impact towards society, environment and cost-effectiveness. Hospital has been categorized under commercial building category as the building built for commercial use is also aimed to be a sustainable hospital. Notably, sustainable hospital aims to serve health facilities for mankind and reduce greenhouse gasses emissions to the environment from the building at the same time. In term of energy consumption, generally, hospital consumes high electricity usage since it is operating non-stop for 24 hours a day which leads to high electricity cost and give impact towards the environment. In this paper, a study of electricity usage of electrical equipment in a public hospital nearby Kuala Lumpur, Malaysia has been conducted through preliminary energy audit in the hospital. Therefore, energy conservation measures (ECMs) are suggested to be applied in the hospital to reduce its electricity consumption. From the suggested ECMs which are unplugging campaign or awareness campaign, replacement of existing personal computer with laptop, regular maintenance and refrigerator replacement, it is expected that the total electricity saving, cost saving and CO_2 emission reduction are 429,743.39kWh/year, RM 152,127.57/year and 296,522.94 kg/year respectively.

Keywords- Sustainable Building, Hospital, Energy Efficiency

I. INTRODUCTION

In 2015, overall electricity consumption in Malaysia which is comprised by various sectors such as industry (45.9%), commercial (32.2%), residential (21.4%), transport (0.2%) and agriculture (0.4%) were 132,199 GWh of the total electricity consumption [1]. As electricity in Malaysia supplied mainly from power stations, it is reported that from non-renewable energy resources such as coal (47.2%), natural gas (40.4%), hydropower (10.8%), diesel oil (0.8%), and fuel oil (0.3%) meanwhile from renewable sources (0.3%) gave 33, 134 ktoe of energy input in power stations [1]. As a matter of fact, commercial sector consumed 32.2% out of the total electricity consumption mainly came from buildings [1]. Therefore, it can be said that commercial building is a contributor of greenhouse gas emissions for the country which is projected to reduce its emission by 23% and 30% respectively in 2020 and 2030 based on to 2005 levels [2]. For this reason, Malaysia is always concerned about energy efficiency issues of a building as it is an important aspect in supporting Malaysia's target to reduce 40% of carbon emission by 2020 while saving more energy and its cost which have been proven by the construction of Low Energy Office (LEO), Green Tech Malaysia Building and Diamond Building [2], [3].

A. *Support from Governmental and Non-Governmental Organization*

Another point to be made is that Malaysia has been supported energy efficiency aspect through the Ministry of Energy, Green Technology and Water as the ministry aims for a significant development and main achievement in building sector by adopting green technology in the construction, management, conservation and abolishment of the building [4]. Addition to this, other government agencies such as Malaysia Green Tech Corporation [5], Yayasan Hijau MY (YaHijau) [6], Energy Commission [7], [8], Sustainable Energy Development Authority (SEDA)[9], are also in line with the aim to promote energy efficiency through their roles and projects. Meanwhile non-governmental organization (NGO) such as Malaysia Green Building Confederation (MGBC) is also promoting sustainable buildings [3].

B. *Studies on energy efficiency of hospital buildings*

Furthermore, commercial building such as hospital has gain the attention from researchers around the world in order to implement various energy efficiency aspects in the building since hospital is a building which is operating everyday with 24 hours per day and leads to high energy consumption (See Table 1). The strategy may in term of engineering approaches [10] such as improvement in the system of building envelope, electrical, HVAC, central heating, cooling equipment, energy management control, compressed air, thermal energy storage (TES), charging/discharging of TES, cogeneration, heat recovery, and water management. Other strategies may in term of financial scheme or policies/regulations [11]. In 2016, it is reported that 11 hospitals have been recognized as green hospital in Malaysia under Green Building Index (GBI) Hospital Tool [12].

TABLE I. ENERGY EFFICIENCY STRATEGIES FOR HOSPITAL

Year	Location	ECMs	Reference
2010	Malaysia	• Use high- efficiency motors • Use variable speed drive	[13]
2011	United States	• Turn off all computers after office hour	[14]
2013	Malaysia	• Balance the electricity usage in each	[15]

		peak and off-peak time separately • Shifting the electricity usage from peak time to off-peak time therefore reduce the maximum demand and peak time energy usage	
2013	Italy	• Building envelope refurbishment	[16]
2014	Naples, Italy	• Adopt radiators thermostatic valves and AHU regulations • Install roofs thermal insulations	[17]
2014	Ireland	• In radiology department; suggest to upgrade the equipment to support hibernate and sleep mode. • Create a workgroup policy to implement the plan of hibernating machines at a certain times each day • Introduce a programme to recycle the packaging which is associated with catheters and other devices in the radiology suite. • Install motion sensor to switch off lighting automatically as it detects the room is empty	[18]
2014	Ireland	• Change behaviour of staff by switch off all lightings and computers after work-hour	[19]
2016	Egypt	• Apply Demand Control Ventilation (DCV) system to improve indoor air quality • To apply building construction regulations are a must for all governmental buildings and private sector	[20]
2016	Italy	• Innovative financial strategies by providing capital to retrofit the hospital via Energy Performance Contracting; 77% and 35-40% energy can be saved up for high cost investments and low cost investments respectively.	[21]
2016	Ireland	• Implement systematic environmental initiatives which are taking into account of these aspects: environmental concern, supports bodies and voluntary environmental initiatives, informing and involving groups, environmental education and green-charter and continuity	[22]
2017	Egypt	• Apply simple retrofit strategies such as solar shading, window glazing, air tightness and insulation	[23]
2017	Spain	• Increase the time spent for preventive maintenance therefore reduce the demand for corrective maintenance and energy consumption	[24]
2017	China	• Implementation of web-based online control system in a chiller plant	[25]
2018	Italy	• (Simulation Study) - Retrofit the building by installing smart rotating windows with sealing hydraulic gasket and LED system give the shortest payback period.	[26]

In this study, a public hospital nearby Kuala Lumpur, Malaysia has been chosen as the study case. Data are collected through preliminary energy audit. This paper also highlights the electrical saving potential that can be captured from the usage of electrical equipment in various departments.

II. Methodology

This section describes flow of the data collection through walk-through energy audit, the process of energy audit and formulation used to calculate electricity consumption.

A. Data Collection: Walk-through Energy Audit

Based on the “Electrical Energy Audit Guideline for Building” by Energy Commission of Malaysia [27], an energy audit is conducted in order to collect information of the equipment. Fig. 1 shows the flowchart of the audit.

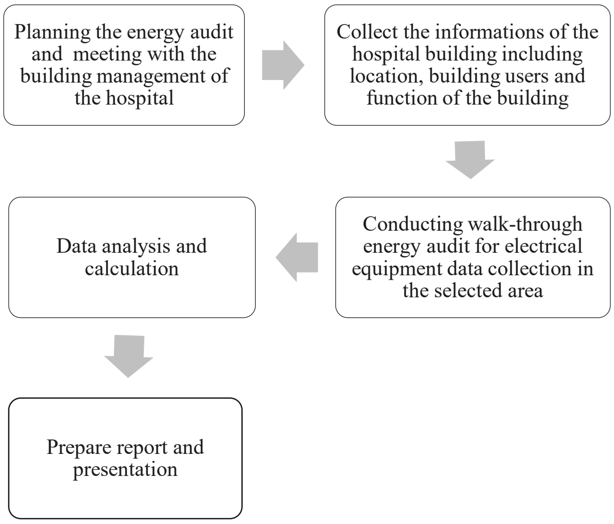

Fig. 1. Preliminary Energy Audit Flowchart

B. Formulation for Electricity Consumption

In order to analysis the data taken, formulation for electricity consumption is calculated. Thus, from the results, suitable energy conservation measures are suggested.

The measurement of the total electricity consumption is measured and calculated by using the build load data which are collected through desktop and field data collection methods. It is the summation of electricity consumption of all equipment which is assumed to operate in full capacity. Equation (1) shows the calculation to measure the electricity consumption for each type of equipment [13] as E is electricity consumption (kWh), P is power rating of the equipment, M is operation hour and N_{eq} is number of equipment. Moreover, the reading are only calculated for weekdays which are from Monday until Friday and it is assumed which of the total daily electricity consumption is the same throughout a year and only 260 days (52 weeks × 5 days).

$$E=P\times M\times N_{eq} \tag{1}$$

III. Results and Discussion

A. Electricity Consumption

All of the equipment that has been audited from walk-through audit is categorized into 5 groups which are: (i) Office equipment, (ii) Medical equipment, (iii) Electrical appliances, (iv) Refrigerator/Chillers and (v) Kitchen utensils. In overall, the total number of appliances that occupied in the clinical building is 3422 units. These appliances include assets and non-assets appliances of the hospital.

As a result, medical equipment has the highest electricity consumption throughout the year which is consumed about 71.85% (See Fig. 2) from the total electricity consumption by electrical equipment of the hospital which is 11,255,203.45 kWh/year.

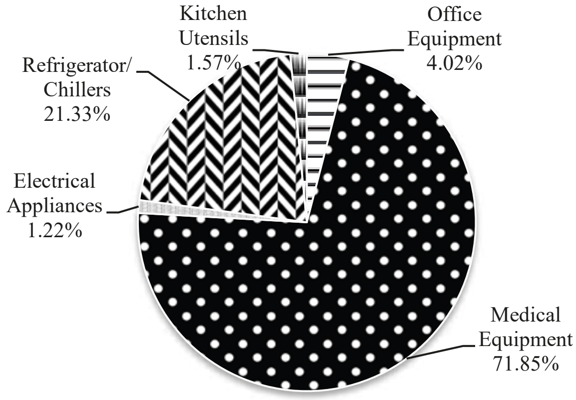

Fig. 2. Percentage of electricity consumption by categories

As a matter of fact, most of the audited floor gave the similar pattern of the result which of medical equipment consumed the highest electricity usage. In basement floor, ground floor and second floor, medical equipment contributed 75.72%, 49.08% and 90.6% of electricity consumption respectively. Meanwhile for first floor, the highest electricity consumption is contributed from office equipment with 34.12% and medical equipment falls under the second highest electricity consumption with 30.02%.

Previously, a study done in another public hospital in Malaysia shows that lighting consumed the highest electricity usage among electrical appliances and then followed by biomedical equipment and office equipment [13]. In addition, there were studies which aimed to save electricity through the usage of electrical equipment in Radiology department [14], [18], [19] as they found that Radiology Department consumed high electricity usage in the hospital. They explored the usage of energy in the department were potentially can be reduced by turning off computer and other office appliances when are not in used. Similarly, this study discovered that Radiology Department has contributed a significant electricity usage as it consumed the highest electricity in ground floor of the hospital. Meanwhile Radiotherapy and Oncology Department, Psychiatry and Labor area and Operation Theater Complex consumed the highest electricity respectively for basement floor, first floor and second floor.

B. *Cost of Electricity*

Based on the TNB Tariff- C2, the usage of electricity is calculated. Regardless the fact that for each kW of maximum demand per month during the peak period should be considered, only all kWh during peak and off-peak period are calculated. The cost of electricity is calculated by multiplying the total electricity consumption with the rate of electricity. As a result, the total of electricity cost for all electrical equipment in the hospital is RM 3,900,467.64/year. Needless to say, the electricity cost depends heavily on the electricity usage of a building.

IV. ENERGY CONSERVATION MEASURES (ECMS)

The audit team has come up with a few solutions that can be implemented to reduce the energy consumption of the audited area. These solutions are called energy conservation measures or ECMs and categorized into active and passive action. Active actions need cost meanwhile passive actions need no cost or low cost.

A. *ECM #1: Unplugging campaign/Awareness campaign*

A low cost ECM that can be implemented for energy saving is to conduct basic energy-awareness activities within the centres and clinics in the building. The programme is focus on cost savings and environmental issues associated with energy use. The information can be disseminated through web site or newsletter. This measure is primary focus on lighting system and computer system that usually switched on during operation hours.

For this clinical building, a passive ECM can be implemented by conducting an awareness campaign to educate and discipline the staff on how to change their bad habit such as leaving computer on during rest hour and leaving other appliances such as microwave, electric kettle and water heater on standby mode most of the time. Phantom power are constantly being draw when appliances are turn off but still plugged to power outlet [28]. Therefore, it is strongly recommended to connect office equipment like computers, printers, and copier on a single power strip so that they can be switch off all together and unplugging campaign would be easier to implement.

According to [29], computer drawing about 2.84 Wh of energy during off mode on average. If unplugging campaign is implemented, 2.84 Wh of energy can be saved by one computer for one hour. For instance, first floor has the highest number of computers among other floors about 318 units of computers. Therefore unplugging for one hour can save about 903.12 Wh/day and 234.81 kWh/year. In term of money which based on TNB tariff of 0.365 RM/kWh, RM 85.70/year can be saved. If unplugging campaign can be implemented to many appliances, the saving would be higher. Likewise a study done in Radiology Department, they found that turning off computer after work-hours could save electricity usage up to 25,040 kWh/year [18].

B. *ECM #2: Replacement of existing personal computer with laptop*

It is suggested to adopt an active ECM by replacing computers with laptop as it is assumed lifespan and the investment/cost to rent the computer and laptop are the same. Logically, laptop can be functioning even if only uses its battery compared to the existing personal computer which needs continuous electrical supply. Since laptop is using battery, only the battery itself that needs to be charged. For instance, from the calculation that has been made, replacement of 318 laptop in first floor; their laptop chargers will consume about 14,892.32 kWh/year compared to the energy usage of the existing personal computers there which is 138,860.8 kWh/year. This figure shows that 89% of electricity (123,968 kWh/year) can be saved up from the replacement of the existing personal computers into laptop. In term of money, RM 45,248.32 (1.16%) can be reduced every year out of from the total electricity cost of the clinical building of this hospital.

C. *ECM #3: Regular maintenance*

Equipment's working condition play a major role in its efficiency and energy consumption. Periodic maintenance of electrical equipment is important for it to operate at optimum level performance. Malfunctioned appliances not only possesses hazard to the occupants but also reducing the efficiency of the system. Repair and maintenance of the sub-par electrical equipment should be conduct as soon as possible to minimize the unnecessary loss. Energy savings account for approximately 7 percent if preventive maintenance and corrective maintenance are conducted for the appliances compare to the appliances that do not follow the regular for maintenance [30]. However, there will be additional maintenance cost incurred to perform these maintenance as this is an active ECM and we will assume 5 percent of maintenance cost from the electrical consumption, hence we can still achieve 2 percent of cost saving each year. As a result, 22,104.069 kWh/year of electricity can be saved which is equally to RM 82,162.99

D. *ECM #4: Refrigerator replacement*

During walk-through energy audit, we found some very old model of refrigerators without any energy efficient star rating in various centres and clinics either for medical storage purposes or general use (as in pantry) purposes when conducting the site audit. For instance, there are about 60 refrigerators totally found in ground floor. They are all operated 24 hour per day and 365 days per year to ensure the items are kept fresh. Therefore it is advisable to change the refrigerators to 5-star rated energy efficient refrigerators as an active ECM which could save up to 20% of energy compared with 3-star rated [31]. Nevertheless, it will be not have to immediately change out all of the refrigerators which are still in good condition. Rather if we only replace these older refrigerators once they are malfunctioned for the 5-star rated one then this is virtually cost free strategy. As a result, the electricity saving and cost saving are 80,436.61 kWh/year and RM 24,630.55/year respectively with ~2 years of simple payback period.

V. Electricity Saving, Cost Saving, Emission Reduction

By applying all the suggested ECMs, electricity saving, cost saving and the reduction amount of Carbon Dioxide (CO_2) emission (emission factor: 0.69 kg/kWh [32]) has been calculated. Therefore Table 2 shows the summary of the results.

From Table 2, it shows that 3.82% of electricity usage is expected can be saved up annually by implementing all of the ECMs which is equal to RM 152,127.57/year of cost saving and 296,522.94 kg/year of CO_2 reduction.

TABLE II. Electricity saving, cost saving and emission reduction

ECMs	Electricity saving (kWh/year)	Cost saving (RM/year)	CO_2 emission reduction (kg/year)
ECM #1	234.81	85.71	162.02
ECM #2	123,968.00	45,248.32	85,537.92
ECM #3	225,104.07	82,162.99	155,321.81
ECM #4	80,436.51	24,630.55	55,501.19
Total	429,743.39	152,127.57	296,522.94

Another point to be made is that the main barrier recognized to adopt energy efficiency aspects in this hospital is financial issue. For instance, a big funding is needed to improve the efficiency of some equipment with high power rating or replace them with a better one. Therefore, it is suggested to implement ECM #1 and ECM #2 first as both of the ECMs do not need additional cost. Despite the fact that their small percentage of electricity saving, the cost saving from the implementation of ECM #1 and ECM #2 could be used to implement ECM #3 and ECM #4 later.

VI. Conclusion

In conclusion, four ECMs have been suggested from the recognized energy saving potentials in a public hospital nearby Kuala Lumpur, Malaysia. From the total electricity consumption of the hospital which is 11,255,203.45 kWh/year, its consumption is expected to reduce by 3.82% per year equally to RM 152,127.57/year of cost saving and 296,522.94 kg/year of CO_2 reduction by implementing all of the suggested energy saving measures. Thus, it is recommended to the hospital to implement the suggested ECMs in order to reduce its electricity consumption, electricity cost and CO_2 emission.

Acknowledgement

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