ENERGY EFFICIENCY ACTION PLAN FOR A PUBLIC HOSPITAL IN MALAYSIA

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ABSTRACT

Sustainable buildings are becoming a focus nowadays because they are cost effective and affect our society and environment. Hospitals, which are categorized as commercial buildings, also aim to become sustainable. Sustainable hospitals hope to provide health facilities to humankind while reducing their greenhouse gas emissions to the environment. In terms of energy consumption, hospitals consume much electricity because of their non-stop operation 24 hours a day. This high electricity consumption leads to high electricity costs and adversely affects the environment. This study examines the electricity usage of a public hospital near Kuala Lumpur, Malaysia, through a preliminary energy audit. Energy conservation measures (ECMs) are recommended to the hospital to reduce its electricity consumption. The recommended ECMs, namely, unplugging or awareness campaign, replacement of existing personal computers with laptops and regular maintenance and replacement of refrigerators, are expected to achieve a total electricity saving, cost saving and CO_2 emission reduction of 429,743.39 kWh/year, RM 152,127.57/year and 296,522.94 kg/year, respectively.

Keywords: *: Energy Efficiency, Hospital, Sustainable Building*

1. INTRODUCTION

In 2015, the overall electricity consumption of Malaysia was 132,199 GWh, from which industrial, commercial, residential, transport and agricultural sectors accounted for 45.9%, 32.2%, 21.4%, 0.2% and 0.4%, respectively [Suruhanjaya Tenaga (Malaysian Energy Comission), 2015]. The electricity in Malaysia is mainly supplied by power stations, and reports have shown that non-renewable energy sources, such as coal (47.2%), natural gas (40.4%), hydropower (10.8%), diesel oil (0.8%) and fuel oil (0.3%), and renewable sources (0.3%) provided a total of 33,134 ktoe of energy input to power stations in 2015 [Suruhanjaya Tenaga (Malaysian Energy Comission), 2015]. The commercial sector, especially buildings, consumed 32.2% of the total electricity consumption [Suruhanjaya Tenaga (Malaysian Energy Comission), 2015]. Therefore, commercial buildings are contributors to the country's greenhouse gas emission, which is projected to decrease by 23% and 30% in 2020 and 2030, respectively, relative to 2005 levels (Sion et al., 2013). Malaysia is concerned about the energy efficiency of buildings because it is an important factor in achieving Malaysia's target of reducing 40% of its carbon emission by 2020 whilst saving energy and costs; this importance has been proven by the construction of the Low Energy Office (LEO), Green Tech Malaysia Building and Diamond Building (Hameed et al., 2016; Sion et al., 2013).

1.1 Support from Governmental and Non-Governmental Organizations

Malaysia has been supporting energy-saving efforts through the Ministry of Energy, Green Technology and Water as the ministry aims to achieve considerable development in the building sector by adopting green technology in the construction, management, conservation and abolishment of buildings (‘Sektor Utama Dasar Teknologi Hijau Negara’, 2018). Additionally, other government agencies, such as Malaysia Green Tech Corporation (‘Who We Are - GreenTech Malaysia’, 2016), Yayasan Hijau MY (YaHijau) (‘Yayasan Hijau Malaysia (YaHijau)’, 2018), Energy Commission (National Energy Efficiency Action Plan, 2014, ‘Roles and Functions’, 2015) and Sustainable Energy Development Authority (SEDA) (‘Overview of SEDA’, 2018), strive to promote energy efficiency through their roles and projects. Meanwhile, non-governmental organizations (NGOs), such as Malaysia Green Building Confederation (MGBC), are promoting sustainable buildings (Hameed et al., 2016).

1.2 Studies on the Energy Efficiency of Hospital Buildings

Commercial buildings, such as hospitals, have elicited the attention of researchers worldwide. Various energy efficiency strategies must be implemented in hospital buildings because they operate 24 hours a day, leading to high energy consumption (Table 1). These strategies may be in the form of engineering approaches (Krarti, 2011), such as improvement of heating, ventilation and air-conditioning (HVAC) systems, the building envelope, electrical usage, 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 involve financial schemes or policies/regulations (Yong and Hor, 2017). In 2016, 11 hospitals in Malaysia were recognized as green hospitals under the Green Building Index (GBI) Hospital Tool (Tan, 2016).

Table 1: Energy efficiency strategies for hospitals

Year	Location	ECMs	Reference
2010	Malaysia	▪ Use high- efficiency motors ▪ Use variable speed drive	(Saidur et al., 2010)
2011	United States	▪ Turn off all computers after office hour	(Prasanna et al., 2011)
2013	Malaysia	▪ Balance the electricity usage in each 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	(Moghimi et al., 2013)
2013	Italy	▪ Building envelope refurbishment	(Ascione, Bianco, De Masi, & Vanoli, 2013)
2014	Naples, Italy	▪ Adopt radiators thermostatic valves and AHU regulations ▪ Install roofs thermal insulations	(Buonomano, Calise, Ferruzzi, & Palombo, 2014)
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	(McCarthy et al., 2014)
2014	Ireland	▪ Change behaviour of staff by switch off all lightings and computers after work-hour	(Burke & Stowe, 2014)
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	(Radwan, Hanafy, Elhelw, & El-Sayed, 2016)
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.	(Principi, Roberto, Carbonari, & Lemma, 2016)
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	(Ryan-fogarty, Regan, & Moles, 2016)
2017	Egypt	▪ Apply simple retrofit strategies such as solar shading, window glazing, air tightness and insulation	(El-Darwish & Gomaa, 2017)
2017	Spain	▪ Increase the time spent for preventive maintenance therefore reduce the demand for corrective maintenance and energy consumption	(García-Sanz-Calcedo & Gómez-Chaparro, 2017)
2017	China	▪ Implementation of web-based online control system in a chiller plant	(Zhao, 2017)
2018	Italy	▪ (Simulation Study) - Retrofit the building by installing smart rotating windows with sealing hydraulic gasket and LED system give the shortest payback period.	(Silenzi, Priarone, & Fossa, 2018)

2. METHODOLOGY

In this study, a public hospital near Kuala Lumpur, Malaysia, was selected as the study case. The criteria of the selected hospital as the study case is based on the electricity consumption which is more than 3,000,000 kWh per month for six consequences month based on the Efficient Management of Electrical Energy Regulation 2008 (EMEER 2008) enforced by the Energy Commission [Suruhanjaya Tenaga (Malaysia Energy Commission), 2008] . The hospital operates 24 hours a day (24/7) and consumes large amounts of electricity. The hospital's bills showed that the hospital consumed 4,000,000 kWh per month of electricity and spent about RM 1.5 million per month (from 2015 to 2017) on electricity. The electricity usage of the hospital was assessed through a preliminary energy audit in this study. This study highlighted the electricity saving potential that can be obtained from the use of electrical equipment in various departments of the hospital. The research framework design, which includes the research objectives, data collection methodology, data analysis and research outcomes, is shown in Figure 1. Moreover, this section also describes the flow of data collection through a walk-through energy audit, which is the process of energy audit and formulation used to calculate electricity consumption.

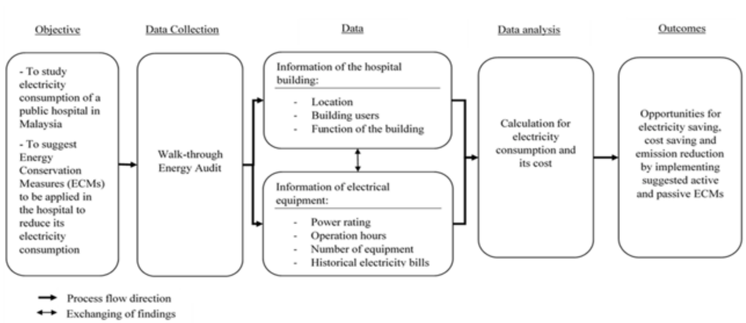

Figure 1 : Research Framework Design

2.1 Data Collection: Walk-through Energy Audit

Based on the 'Electrical Energy Audit Guideline for Buildings' by the Energy Commission of Malaysia (Energy Commission, 2016), an energy audit was conducted to collect information on the equipment used in the hospital. Figure 2 shows the flowchart of the audit.

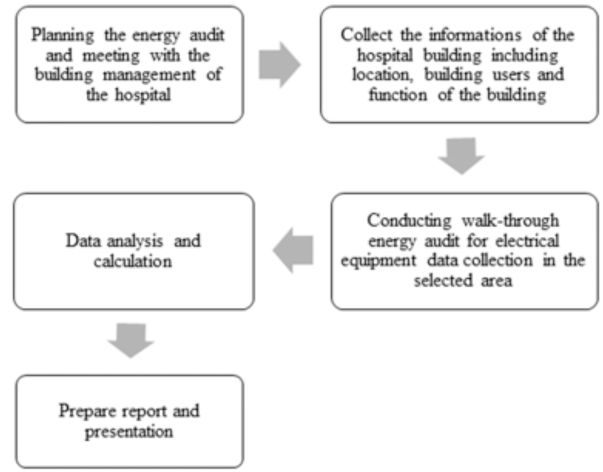

Figure 2 : Walk-through energy audit flowchart

2.2 Electricity Consumption Formulation

To analyse the collected data, the formulation for electricity consumption was calculated. Suitable energy conservation measures were developed from the results.

The measurement of total electricity consumption was performed by using build load data collected through desktop and field collection methods. It is the summation of the electricity consumption of all equipment, which are assumed to operate in full capacity. Equation [1] shows the calculation of electricity consumption for each type of equipment (Saidur, Hasanuzzaman, Yogeswaran, Mohammed, and Hossain, 2010). In the equation, E is electricity consumption (kWh), P is the power rating of the equipment, M is operation hour and Neq is number of equipment. Moreover, the reading only covered weekdays, and we assumed that the total daily electricity consumption was similar throughout a year with only 260 days (52 weeks × 5 days).

$$E=P\times M\times N_{eq} \quad [1]$$

3. RESULTS AND DISCUSSION

3.1 Electricity Consumption

The equipment that were audited in the walk-through audit were categorised into five groups: office equipment, medical equipment, electrical appliances, refrigerator/chillers and kitchen utensils. Overall, the total number of active and operating appliances (assets and non-assets) in the hospital was 3422 units.

Medical equipment had the highest electricity consumption throughout the year; it accounted for 71.85% (Figure 3) of the hospital's total electricity consumption, which was 11,255,203.45 kWh/year.

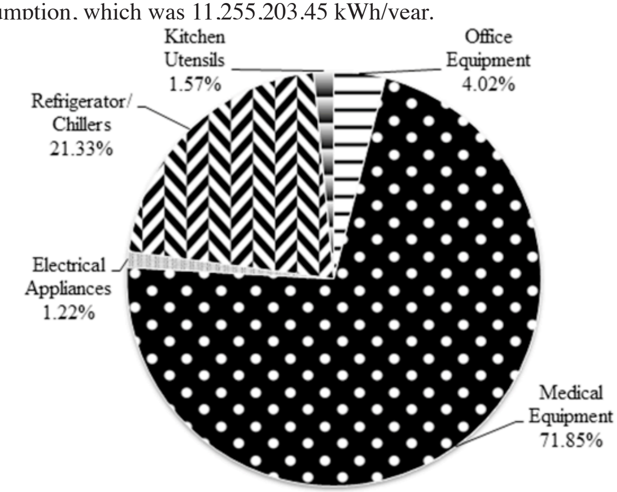

Figure 3 : Percentage of electricity consumption by categories

Most of the audited floors showed similar result patterns. Medical equipment on the basement, ground and second floors contributed 75.72%, 49.08% and 90.6% to the electricity consumption, respectively. The first floor had the highest electricity consumption primarily because of the office (34.12%) and medical (30.02%) equipment on it.

A study conducted in another public hospital in Malaysia showed that lighting consumes the highest electricity usage among electrical appliances, followed by biomedical and office equipment (Saidur et al., 2010). Other studies that aimed to reduce the electricity consumption of electrical equipment in radiology departments (Burke and Stowe, 2014; McCarthy et al., 2014; Prasanna, Siegel, and Kunce, 2011) found that these departments consume large amounts of electricity. They discovered that energy use in these departments can be reduced by turning off computers and other office appliances when not in use. Similarly, the present study discovered that the radiology department consumed the largest amount of electricity on the ground floor of the hospital. Meanwhile, the radiotherapy and oncology department, psychiatry and labour area and operation theatre complex consumed the largest amount of electricity on the basement floor, first floor and second floor, respectively.

3.2 Electricity Cost

The electricity usage was calculated based on the utility bills by Tenaga National Berhad (TNB) Tariff C2–medium voltage peak/off-peak commercial tariff (Commercial tariffs, 2018). All kWh during peak and off-peak periods were calculated regardless the fact that each kW of maximum demand per month during the peak period should be considered. The cost of electricity was calculated by multiplying the total electricity consumption with the rate of electricity. The total electricity cost for all electrical equipment in the hospital was determined to be RM 3,900,467.64/year. The electricity cost depended heavily on the electricity usage of the building.

4. ENERGY CONSERVATION MEASURES

The audit team came 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 (ECMs) and can be categorised as active and passive actions. Active actions entail costs, whereas passive actions do not need costs or are low cost.

4.1 ECM #1: Unplugging/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 focuses on the cost savings and environmental issues associated with energy use. Information can be disseminated through websites or newsletters. This measure focuses on lighting and computer systems because these are often 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 habits, such as leaving computers on during idle hours and leaving other appliances (microwave, electric kettle and water heater) on standby mode most of the time. Phantom power is constantly being drawn when appliances are turned off but still plugged to power outlets (Beth Brindle, 2011). Therefore, it is strongly recommended to connect office equipment, such as computers, printers and copiers, to a single power strip so that they can be switched off all together.

According to the Standby Power Summary Table (2018), a computer in off mode draws about 2.84 Wh of energy on the average. If an unplugging campaign is implemented, 2.84 Wh of energy can be saved by a single computer for an hour. For example, the first floor of the studied hospital had the most computers (about 318) among all floors. Therefore, unplugging for an hour can save about 903.12 Wh of energy per day and 234.81 kWh of energy per year. In terms of cost, RM 85.70/year can be saved based on the TNB tariff of 0.365 RM/kWh. If an unplugging campaign is applied to many appliances, then a high percentage of saved energy will be achieved. A study performed on a radiology department also found that turning off computers after working hours can save electricity usage by up to 25,040 kWh/year (McCarthy et al., 2014).

4.2 ECM #2: Replacement of Existing Personal Computers with Laptops

We recommend an active ECM, i.e., replacing computers with laptops, under the assumption that the lifespan and investment/cost of renting computers and laptops are similar. A laptop can function even if it only uses its battery compared with personal computers that need continuous electrical supply. Given that laptops are battery operated, only the battery itself needs to be charged. For example, our calculation indicated that replacement with 318 laptops on first floor will consume about 14,892.32 kWh/year compared with the energy usage of existing personal computers, which is 138,860.8 kWh/year. This figure shows that 89% of electricity (123,968 kWh/year) can be saved from the replacement of existing personal computers by laptops. In terms of cost, RM 45,248.32 (1.16%) can be reduced annually from the total electricity cost of the hospital.

4.3 ECM #3: Regular Maintenance

The working conditions of equipment play a major role in their efficiency and energy consumption. Periodic maintenance of electrical equipment is important for these equipment to operate at the optimum level. Malfunctioning appliances pose hazards to building occupants and reduce system efficiency. Repair and maintenance of sub-par electrical equipment should be conducted immediately to minimise unnecessary losses. Energy savings can reach approximately 7% if preventive and corrective maintenance are conducted for appliances relative to not conducting such maintenance (Koo and Hoy, 2003). However, an additional maintenance cost will be incurred if this maintenance is conducted because this maintenance is an active ECM. We assume that 5% of the maintenance cost is from electrical consumption; hence, we can still achieve 2% cost saving each year. As a result, 22,104.069 kWh/year of electricity can be saved, which is equal to RM 82,162.99/year.

4.4 ECM #4: Refrigerator Replacement

During the walk-through energy audit, we found very old models of refrigerators without any energy-efficient star rating in various departments and clinics either for medical storage or general use (as in pantry) purposes. Sixty refrigerators were found on the ground floor, and they operate 24 hours a day for 365 days a year to ensure that items are kept fresh. These old models should be upgraded to five-star-rated energy-efficient refrigerators as an active ECM, and doing so could save up to 20% of energy (5-Star Energy Appliances: How Much Can You Roughly Save Annually?, 2016). Refrigerators that are still in good condition need not be replaced immediately. Replacing refrigerators once they malfunction is virtually a cost-free strategy. As a result, the electricity and cost savings would be 80,436.61 kWh/year and RM 24,630.55/year, respectively, with ~2 years of simple payback period.

5. ELECTRICITY SAVING, COST SAVING AND EMISSION REDUCTION

By applying these recommended ECMs, electricity saving, cost saving and reduction in carbon dioxide (CO_2) emission (emission factor: 0.69 kg/kWh; Mohamed et al., 2016) were calculated. Table 2 shows that 3.82% of electricity usage can be saved annually by implementing all of the ECMs. This percentage is equal to RM 152,127.57/year of cost saving and 296,522.94 kg/year of CO_2 reduction.

Table 2 : Electricity saving, cost saving and emission reduction by applying the recommended ECMs

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 in adopting energy-efficient aspects in this hospital is finance. Large funding is required to improve the efficiency of equipment with high power ratings or to replace them with improved ones. Therefore, we suggest implementing ECM #1 and ECM #2 first because they do not require an additional cost. Despite their small percentage of electricity saving, the cost saving from their implementation could be used to implement ECM #3 and ECM #4 later on.

6. CONCLUSION

Four ECMs were recommended based on the recognised energy-saving potential of a public hospital near Kuala Lumpur, Malaysia. The total electricity consumption of the hospital is 11,255,203.45 kWh/year. This value is expected to decrease by 3.82% per year (equal to RM 152,127.57/year of cost saving and 296,522.94 kg/year of CO^2 reduction) when all of the recommended ECMs are implemented. Thus, the hospital must implement the recommended ECMs to reduce its electricity consumption, electricity cost and CO_2 emission.

ACKNOWLEDGEMENT

We wish to acknowledge the financial support provided by Universiti Kebangsaan Malaysia (grant number TD-2016-011).

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