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Energy Measurement and Potential Energy Conservation Measures in Five Healthcare Buildings in Malaysia

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ABSTRACT

Concern is growing around the world as a result of the global economy's overall rise in carbon emissions and energy consumption. The healthcare facility is among the buildings in the world with the highest energy use. Thus, it is necessary to create energy-saving plans that evaluate the energy performance of buildings and put energy-saving measures into practice. Enhancing building energy efficiency is most commonly achieved through a comprehensive energy audit. The Building Energy Index is the current method used to analyses all forms of building energy performance. The operating hours of a healthcare facility are longer than those of a commercial building. The issue emerges when there is no clear criterion for establishing whether or not a healthcare facility is energy efficient, and the present norm may misread healthcare energy consumption. To determine the actual onsite energy use at the healthcare building, a full energy audit is performed. Five places are selected based on the sort of healthcare services offered. According to the on-site complete energy audit, cooling equipment consumes the most energy. The study's findings may be divided into two categories: Healthcare Building Energy Index from detailed energy audit results and derived directly from power bills for the years 2018 and 2019. In terms of Healthcare Building Energy Index, there is a contrast between utilizing detailed energy audit data and using utility bills directly. Nonetheless, a comparison of Healthcare Building Energy Index with existing Malaysian requirements reveals a significant discrepancy. Based on the audit and analysis results, several savings opportunities may be presented.

1. Introduction

Energy is essential for economic growth and can be divided into renewable and non-renewable sources. The trend of world energy consumption indicates that 73% is from non-renewable energy

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[1]. In Malaysia, almost 80% of electricity is generated by natural gas and coal, which cannot be replenished [2]. The depletion of non-renewable energy sources quite worrying the world to sustain the energy demand. Malaysia is an industrialised country with a market economy. Exports of petrol and oil make up over 40% of the nation's income. It should thus not be shocking that fossil fuels are the main source of electricity generation. The National Energy Balance 2010 states that natural gas produces 53% of the electricity, fossil fuels 40%, hydropower 5%, and coal 2% [3]. The increasing number of buildings in Malaysia will have an excessive impact on national development and demand high energy to supply. The biggest energy users in the world have been found to be buildings. Although the exact numbers differ by nation, buildings typically account for between 30% and 45% of the world's energy use [3]. The International Energy Outlook report shows that global energy demand will keep increasing by 56% between 2010 and 2040 [4]. Malaysia has committed to reducing its greenhouse gas emission intensity by 45% by 2030 and has launched a National Energy Efficiency Action Plan (NEEAP) [5]. It has also been shown that one of the main causes of carbon dioxide and greenhouse gas emissions is building energy use [6]. Healthcare buildings are known as complex and high-energy-demand buildings due to their long operation hours and need a lot of energy for lighting and air conditioning systems, medical and office equipment, and other devices [8]. A benchmark to measure energy efficiency is Building Energy Intensity (BEI) which is a measurement of the total annual energy used in a building in kilowatts hours divided by factors such as gross floor area [9]. According to MS1525, the optimum BEI standard is 135 kWh/m^2/year which is implemented in all types of buildings. But most Malaysian structures don't adhere to this requirement [10]. Malaysia has several types of healthcare facilities, such as major hospitals and district hospitals, utilizing a current BEI will result in an inaccurate assessment of energy performance [11]. The healthcare building has long operation hours than a commercial building. It is quite challenging for the healthcare building to achieve BEI standard according to MS1525 standard. The problem arises when the current standard might misinterpret the energy usage in healthcare building. The objective of this research project is to enhance the facility's energy efficiency, suggest cost savings, and establish a new standard for measuring the building's energy performance. The following are the objectives for this research, identify the building characteristic and energy consumption to operate a healthcare building, propose a potential Energy Conservation Measure (ECM) and analyse the economic benefits of the potential of ECM and identify Healthcare Building Energy Index (HBEI) to measure energy usage for the healthcare building.

A healthcare building is designed to operate for long working hours and has unique and intensive energy use requirements [12]. It is important to identify and evaluate the energy consumption of a healthcare building to enhance energy effectiveness. The electricity consumption usually depends upon the scope and complexity of equipment and services provided in the healthcare building [13]. These conditions have affected the demand for electrical energy. Energy issues are less to be prioritized by Malaysians nowadays due to a lack of awareness. This research project will act as an educational platform for raising awareness of the necessity of energy-saving measures in the community. It is substantial to raise their awareness regarding the consequences of extensive electricity usage to nature. Hence it is crucial to identify and evaluate the energy consumption of a healthcare building. The significance of this research in enhancing energy effectiveness of healthcare buildings. Furthermore, developers and design teams such as architects or consultants involved in creating energy-efficient building design projects and preventing mistakes from occurring in future development by using any useful information provided in this research study on current building performance are encouraged to participate. Finally, this research project will act as an educational platform for raising awareness of the necessity of energy-saving measures in the community. Malaysia, being a developing country and a member of the ASEAN, is exploring inexhaustible and repeatable alternative energy sources such as biomass, solar, micro-hydro and wind. Malaysia is also physically located in a tropical and humid environment, making it simple to utilize a variety of renewable energy sources. Malaysia's government has created a renewable energy programme to encourage enterprises and people to employ renewable energy systems in electricity applications.

2. Literature Review

2.1 Energy Act and Policy

Energy Commissioning plays an important role in energy management, as it has the authority to regulate and enforce energy supply operations and legislation in Malaysia under the Energy Commission Act 2001. One of the functions and powers of the Energy Commissioning is providing advice to the Minister on all matters concerning the national policy objectives for energy supply activities. It also put energy supply rules into effect and enforcing them. Energy Commissioning also can control all aspects of the electricity supply sector and to safeguard everyone from the dangers of electricity generation, production, transmission, distribution, supply, and consumption as set out in the energy supply legislation. Malaysian Standard 1525 or known as MS1525 is a Malaysia energy-efficient building design standard, focusing on air conditioning, lighting, electrical power, architectural and passive design, and control management. The main goal for MS1525 is to encourage the design, construction and maintenance of new and existing buildings in ways that minimize energy consumption while preserving originality in design, building function and occupant comfort and productivity. It also deals effectively with economic issues. In addition, establish criteria and minimum energy efficiency requirements for new construction and retrofitting existing structures, as well as means for evaluating conformity with these criteria and minimum standards. Similarly, ISO 50001 International Energy Management Standard (EnMS) was released in June 2011 to enable companies to improve their energy performance through a systematic strategy. Furthermore, National Energy Efficiency Action Plan (NEEAP) 2016- 2025 aims to reduce Malaysia's power usage by 8% by 2025. NEEAP emphasizes for better efficiency in the utilisation of electrical energy [14]. It is primarily targeted at industrial and commercial customers, who account for the majority of the country's electrical energy demand. As a result, Ministry of Energy, Science, Technology, Environment, and Climate Change (MESTECC) established the national BEI initiative for government buildings in 2018 to encourage building owners to optimize energy consumption. The ratio between yearly building energy consumption and the net floor area of the building is used to calculate a bench marking tool that evaluates a building's energy performance based on energy consumed per square meter per year. BEI theory states that any building with a good energy performance will receive more stars. In additional to, Energy Management Gold Standard (EMGS) is a certification system based on energy management excellence offered by the (AEMAS). It offers businesses a Sustainable Energy Management System (SEMS) that not only achieves but also maintains and improves cost reductions. Companies will also receive extensive training for their energy managers to achieve their company's Energy Efficiency goals. Moreover, Green Building Index (GBI) is one the initiative which is a green grading system created in 2009 by the Malaysian Institute of Architects and the Association of Consulting Engineers Malaysia to raise awareness about green buildings and establish sustainability and BEI criteria. A building has to fulfil a certain set of key criteria to be recognized as a green building under the green rating system. Quality of the indoor environment, innovative design, and sustainable site planning, materials and resources, and water efficiency are the evaluation criteria used in GBI [15].

2.2 Previous Research

There have been references to a few earlier studies that are pertinent to this research. The prior studies' selections are predicated on studies on building energy consumption and possible energy-saving techniques that may be used in structures. Hasan Al Fakhri researched the energy indexing for different type of hospital buildings in Malaysia. The research focus on creating an energy indexing system that enables benchmarking of various hospital facilities in Malaysia according to their specifications and needs. If the right variables are monitored and controlled, energy indexing may be reduced. Additionally, effective energy-saving techniques can lower the price of electrical energy [16]. The quantification of energy indexing for each hospital category reveals that the mean predicted energy indexing for Major Specialist Hospital is as high as 191.00, followed by General Hospital at 185.72, Minor Specialist Hospital at 173.24, and Non-Specialist Hospital at 147.81. Meanwhile, M.H Amlus study about evalution on innovation approaches on performance from Malaysian perspective: A study on Malaysian Building energy saving. The main idea of this research is to find a strategy for matching individual energy use with the equipment is called a load apportionment technique. This work aims to tackle the most fundamental innovation task—energy audit, a load-apportionment method. This technique reschedules utilisation hours and balances equipment utilisation with fully utilised space. The information gathered enables the determination of each load's present utilisation, and the loads are then grouped according to the same portion and time of utilisation. The outcome shows the energy usage for each day in vivid detail and indicates the highest and lowest peaks. The results reveal that electrical energy use changes from one weekday to the next, but is practically constant on weekends. To begin the campaign to minimise energy consumption, it is necessary to modify customers' behaviour and habits about the proper and efficient usage of appliances and equipment [17].

2.3 General Operation of Healthcare Building in Malaysia

Healthcare building especially hospitals are highly energy-intensive structures, with their own set of design standards, equipment, occupancy rates, and operation schedules. According to American Society of Heating, Refrigerating and Air Conditioning Engineer (ASHRAE) the average hospital uses 2.5 times more energy than a commercial building [12]. Despite the increase in energy demand, awareness of energy-efficient opportunities and approaches is still low [18]. Malaysia's healthcare system is made up of universal services supported by taxes and managed by the government, as well as a burgeoning private sector. There are five categories of healthcare buildings in Malaysia: general hospital, district hospitals, teaching hospitals, clinics or medical centre, laboratories. The most well-known form of hospital is the general hospital, which is designed to treat a wide range of diseases and injuries and usually includes an emergency room. A district hospital is smaller than a general hospital and only accepts patients from the same district or community. Teaching hospitals are hospitals that relate to universities for medical research and the training of medical professionals. Clinics are medical institutions that are smaller than a hospital and are operated by a government body for health care or a private partnership of physicians. Healthcare buildings come in a variety of shapes and sizes, and it is important to research each one's unique characteristics to compare electrical energy. The purpose of selecting these five healthcare buildings is that they share certain similarities owing to the fact that they are all government healthcare building and receive government funding. However, it has different variables that cause the energy evaluation to deviate. The various variables such as net floor space, operating hours, and the equipment used in each facility. Besides that, each building represents the category of healthcare building as discussed earlier.

3. Research Methodology

The data collected during this study was divided into two phases which is the first phase by gathering all the general information. The general information about each healthcare building will be collected using the desktop audit method and meeting with the building owner. During this stage, the selection of healthcare buildings is decided. The healthcare building will be labeled as A, B, C, D, and E. The second phase gathering information about equipment. The information about equipment will be gathered during detailed energy audit on site. Additionally, the number of electrical appliances in each healthcare building should be noted in more detail as they have different types and energy power. Each healthcare building represents the category of healthcare building and features equipment similar to those seen in healthcare. The government manages the public hospital and provides financing, and all of the buildings adhere to the same environmental sustainability strategy.

4. Result and Discussion

During data collection, four aspects are considered: identification, location, building user trends, and building characteristics. Real energy cost is obtained from the electrical provider's bill. The location refers to a specific place or area on the planet's surface. It may be described using absolute location, which plots the building's longitude and latitude using a Cartesian coordinate grid. The relevance of knowing the location of a structure is to be able to predict the weather in the area. The weather in all case study locations is normally hot, oppressive and rainy. The average temperature is around 26^{o}Celsius – 35^{o}Celsius. The operating hours of each department in the healthcare building are referred to as the user trend. Throughout the year, the healthcare building is recognized for operating at overlong hours. However, certain departments keep regular working hours. Building characteristics are linked to energy management as a passive feature [19]. The ultimate objective of passive design is to ensure consistent occupant comfort while doing dealing with the requirement for active mechanical systems and the associated fossil fuel-based energy consumption. Heating, ventilation, cooling, and natural lighting are just a few examples of passive elements.

Conducting an onsite audit is the most effective approach to learn about each piece of equipment. There are three types of data collection methods; walk through assessment, Energy survey and analysis and Detailed Energy Audit [20]. Significant energy user or known as SEU can help the owner building tackle the sector that use a lot of energy. The SEU that has largest percentage must be focused and come up with the solution to reduce the energy usage. The typical hospital architecture comprises of huge structures, which need careful temperature management on the inside and external cooling and heating. For example, a standby electric generator is also required by the hospital to provide a constant supply of electricity during emergencies and vital procedures. Estimation of electric energy consumption is calculated based on the number equipment that existed in each building, the operation hour with their power rate. The significant energy user which is lighting and air conditioning systems consume the bulk of energy in a building. On the contrary, the other equipment least using energy. The other equipment is usually related to the work nature of the building. The air conditioning system accounts for 75% of energy costs, while lighting and other basic equipment account for 18% [21].

Table 1 shows the general information regarding healthcare building in this study. For similarity of each building is all the premise is healthcare building managed by Ministry of Health Malaysia with different type of healthcare building. Type of healthcare building include of clinic, general hospital, district hospital, specialist hospital and laboratory.

Table 1
General Information Regarding Healthcare Building

Healthcare Building	A	B	C	D	E
Location	Johor	Putrajaya	Selangor	Johor	Kuala Lumpur
Year of Operation	21 Years	23 Years	32 Years	9 Years	31 Years
Type of Healthcare Building	University Health Clinic	General Hospital	District Hospital	State Mental Hospital	National Laboratory
Operation Hour	8.30 am to 7.30 pm (Office working days)	8 am to 5 pm, 24 hours, 7 days/week.	8 am to 5 pm 24 hours, 7 days/week.	8 am to 5 pm for 24 hours, 7 days/week.	8.30 am to 7.30 pm (Office working days)
Net Floor Area	2,739 m^2	40,575 m^2	16,167 m^2	102,310 m^2	49,225 m^2
Number of Staff	49	2,800	1,375	897	700
Electrical Tariff	C1	C1	B	C1	C1
Cooling Equipment	ACSU	Chiller, AHU, ACSU, ACPU	Chiller, AHU, ACSU, ACPU, FCU	ACSU, AHU, ACPU	Chiller, AHU, FCU
Lighting Equipment	Fluorescent	Fluorescent, LED, Metal Halide, CFL	Fluorescent, LED, Metal Halide, CFL	Fluorescent, LED, Metal Halide, CFL, PLC	Fluorescent, LED, HPSV, CFL
Other Equipment	Office & Biomedical	Office & Biomedical	Office & Biomedical	Office, Biomedical & Laboratory	Office & Biomedical
Lift	Not Available	1	5	1	Not Available

Table 2 demonstrates the significant energy user in the building. The significant energy user can be divided into three aspect which is cooling, lighting and other equipment. The biggest energy consumer in each building is cooling equipment, which accounts for the highest percentage of energy demand. Because the temperature and humidity in the healthcare building must be maintained, the cooling system must perform ideally to meet demand. As it is the greatest user of energy, the cooling system must be priority in order to decrease energy consumption.

Table 2
Significant Energy User

Healthcare Building	A	B	C	D	E
Cooling Equipment	65%	73%	87%	45%	77%
Lighting Equipment	19%	6%	7%	40%	3%
Other Equipment	16%	21%	6%	15%	20%

Aside from that, cooling equipment is frequently obsolete and inefficient in terms of energy use. Older technology needs a lot more energy to run when compared to modern technology. Second, other equipment ranks second in terms of energy use. Biomedical equipment, office equipment, a lift, and other items make up the rest of the equipment. The only approach to decrease energy usage for other equipment is to ensure that it is turned off when not in use. The user's or worker's energy awareness is critical. Finally, the lighting system in a healthcare facility consumes the least amount of energy. The majority of healthcare facility owners have already switched from non-energy-saving to energy-saving lamps. LEDs are the most energy-efficient form of bulb now in use in most buildings. The low cost and ease of acquisition have sparked a shift to this kind. The lamps don't use any more energy, but they still need to be managed to avoid any energy waste [17].

4.1 Development on Healthcare Building Energy Index

BEI is used as a benchmark to measure energy efficiency in all type building in the industrial and commercial sectors, but there is no unique instrument or method for determining the efficiency of energy use in healthcare facilities. Nevertheless, Healthcare Building Energy Index (HBEI) is a ratio of a healthcare facility's total annual energy usage to its net floor area. Total energy consumption is measured in kWh per year and is defined as the total amount of electricity or equivalent utilized by the building. Net floor area is divided into three types: gross floor area, net floor area and air conditioned area. Healthcare buildings must meet specific standards that set them apart from other structures or building. The exclusive factor that healthcare building have is the healthcare building is recognized for being a building that runs nonstop all year. Normally, during peak seasons, such as during the holiday season, the number of patients admitted will increase. Secondly, the equipment used in healthcare building especially biomedical equipment for laboratory usage, such as X-ray machines, MRI machines, ultrasound machines, and pathology machines consumes a lot of energy. Lastly, the typical hospital architecture comprises of huge structures, which need careful temperature management on the inside. Internally, the inhabitants and running equipment create a significant quantity of heat. Depending on the external weather conditions, effective cooling and heating. The ventilation technology, in combination with the hospital's well-insulated. Walls will help to decrease the hospital's susceptibility to the weather. A standby electric generator is also required by the hospital to provide a constant supply of electricity during emergencies and vital procedures.

Figure 1 shows the comparison total energy consumption (kWh) with healthcare building energy index (kWh/year/meter square).

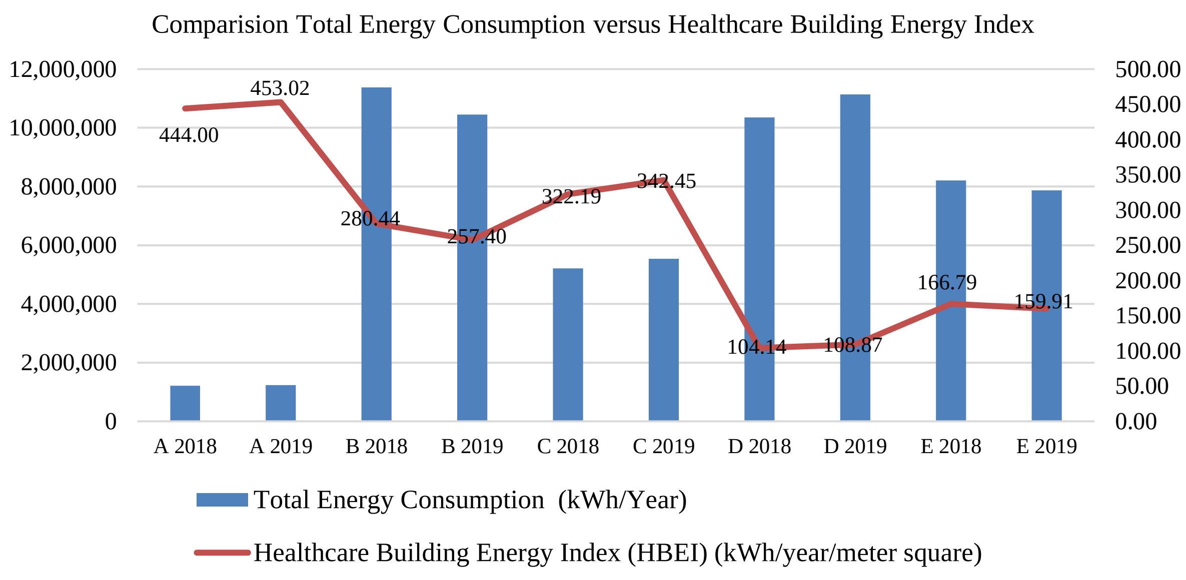

Fig. 1. Comparison total energy consumption versus Healthcare Building Energy Index

HBEI from DEA results and HBEI obtained directly from electric bills for the years 2018 and 2019. In terms of HBEI, there is a distinction between utilizing DEA results and directly using utility bills. Building A has the greatest HBEI among the other buildings, although having the lowest NFA of roughly 2,739.79 m^2. When utilizing data from an energy bill, the HBEI for building A is roughly 400 kWh/m^2/year. Building A has the lowest energy usage when compared to other healthcare buildings, yet the key factor determining the HBEI is the size of the facility or for this research refer to net floor area of the premise. Furthermore, the use of ineffective equipment and instruments has a significant impact on the energy consumption at the building. While utilizing DEA data, the HBEI is just 119.98 kWh/m^2/year. The distinction is because the utility cost for Building A includes all departments, not only the university health clinic. The HBEI using utility bills for building B is roughly 300 kWh/m^2/year, whereas the HBEI using DEA data is 270 kWh/m^2/year. The HBEI for building C in both conditions is roughly 200 kWh/m^2/year. The HBEI from electricity bills and DEA data for building D is essentially identical, with a range of 100 kWh/m^2/year. Last but not least, there is a disparity in HBEI between the DEA and the electricity bill for Building E. The DEA HBEI is 98.01 kWh/m^2/year, but the HBEI from utility bill is roughly 100 kWh/m^2/year.

There are a few buildings in Malaysia that may be used as examples of energy efficiency, such as the Green Energy Office (GEO) building which has a BEI of 65 kWh/m^2/year. Furthermore, the diamond building refers to the Energy Commissioning Building in Putrajaya. The BEI for diamond construction is 85 kWh/m^2/year. In addition to Low Energy Office or LEO buildings, the suggested BEI must be less than 100 kWh/m^2/year. Finally, MS1525 is the most commonly used reference standard in terms of BEI. The ideal BEI, according to MS1525, is 135 kWh/m^2/year. Figure 2 depicts a significant disparity between HBEI of healthcare buildings and present Malaysian norms. The use of commercial buildings, which are regular office buildings that function 10 hours per day, is common to all standards, whereas healthcare buildings operate with high energy and a lengthy operating period. This makes it unfair for healthcare facilities to compete with regular structures, thus they must have their own standard.

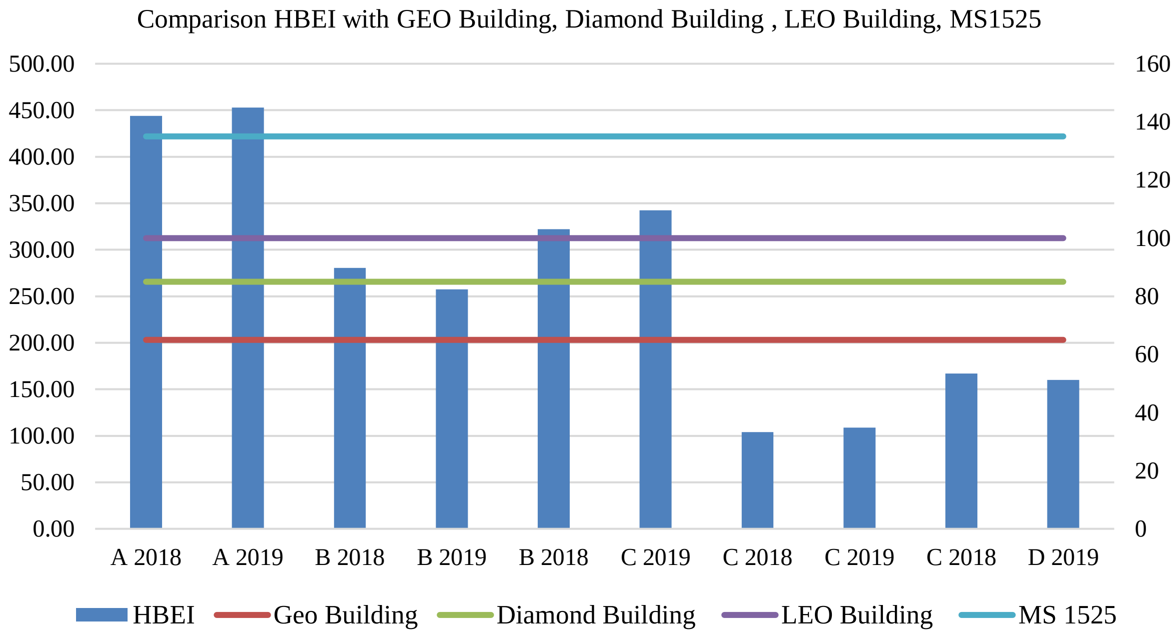

Fig. 2. Comparison HBEI with current standard

4.2 Potential Energy Conservation Measure

Potential Energy Conservation Measure (ECM) is the identification of possible energy saving strategies is based on the evaluation of site survey data and the analysis of monitoring data. Measurement and Verification plan is essential for appropriate savings calculation and verification. All data needed for appropriate savings determination will be accessible when the energy savings programme is implemented, within an acceptable budget, thanks to advanced preparation. Each of proposed ECMs will be analyse in term of economic analysis. The advantages of ECMs must be assessed in terms of energy and non-energy savings, as well as Carbon Dioxide reduction. The building owners will spend about 30% of their budget on energy, the economic impact study is one of the most critical concerns [22].

5. Conclusions

In a nutshell, for virtually all case studies, the cooling system is the largest energy consumer. The cooling system is critical for healthcare to maintain the necessary conditions and to function all day. Other systems are the second-largest energy consumer. Office equipment, pantry equipment, biomedical equipment, and other systems are examples of other systems. Last but not least, the lighting system consumes the least amount of energy because it is generally turned off when not in use. It will assist in lowering energy use. During 2018, building B had the greatest energy consumption compared to all four other healthcare buildings, while building A had the lowest energy consumption of all five healthcare buildings. Meanwhile for year 2019, the highest energy consumption recorded in building C while building A had the lowest energy consumption of all five building for this research. Malaysia's government has aggressively promoted energy saving principles and established a benchmarking tool that tracks a building's energy usage. In order to earn a high star rating, the building owner must continue to evaluate the facility's energy performance and take the lead in installing energy saving measures. For this research HBEI is develop as benchmarking tool to measure the energy consumption that specifically for healthcare sector only. Based on the research, building A has the highest HBEI value for both year 2018 and 2019. Meanwhile, for the same period, building D show the good value in term of HBEI. After implement energy conservation measure, each building has a chance to reduce energy consumption.

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