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Study of Energy Performance in Malaysian Public Hospital using Power Query

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Abstract: In 2016, the Ministry of Health (MOH), Malaysia, initiated a sustainable program that includes activities for sustainable energy management at all 145 buildings under the MOH. The focus of the sustainable energy management program is to target these buildings to reduce their annual energy consumption by 10% by 2018. The target implementation of a sustainable energy management program includes achieving 3-star EMGS certification within 5 years. By December 2022, 135 have achieved two-star certification with the requirement to achieve at least 5% energy consumption savings. By 2019, the 118 buildings that embarked on EMGS certification had achieved 22.62% energy consumption savings. District and specialist hospitals achieved 23%–24% savings in 2019. The largest energy consumption in MOH buildings is for room cooling, which is contributed by air conditioning and mechanical ventilation (ACMV) equipment. The implementation of a sustainable energy management program has contributed to energy cost savings of RM21 million per year to MOH energy bills in 2019.

Keywords: *ETL, Power Query, BEI, and Sustainable Energy Management program.*

1. Introduction and Background

Energy, by definition, is a product of burning fuel or renewable sources (Ong et al., 2011). Energy consumption causes severe environmental damage, which is understood mainly through climate change (Schaeffer et al., 2012). Energy consumption is one of the main contributors to global warming from carbon dioxide gas emissions into the atmosphere. In 2015, 190 countries pledged to the Paris Agreement for a Global Framework to limit global warming to well below 2 degrees centigrade (European Union, 2016). With the agreement, Malaysia has committed to reducing carbon dioxide emissions to 45% by 2030 relative to 2005 (Ministry of International Trade and Industry, 2017).

Global energy consumption growth slowed down in 2019 at 0.6% compared with an average of 2% per year over the 2000–2018 period, in the context of slower economic growth. In 2019, global electricity consumption grew at a much slower pace than that recently at 0.7%, compared to an average of 3%/year over the 2000–2018 period, due to a slowdown in economic growth and milder temperatures in several large countries (Enerdata, 2020). Energy consumption has been linked to carbon dioxide (CO2) emissions that lead to global warming (Fulton et al., 2017). In Malaysia, the leading contributor of greenhouse gas (GHG) is the use of fossil resources to generate electrical energy, with only 3.2% from renewable energy and 15.9% from hydro (Shaikh et al., 2017).

A study on energy consumption in Malaysia found that in 2008, the commercial sector consumed 8% of the total national energy consumption, and it is estimated that the Malaysia Public Hospital consumed approximately 19,311 MWh (Saidur et al., 2010). The Building Energy Index (BEI) of commercial buildings such as public hospitals is between 70 and 300 kWh/m2/year, which is 10 to 20 times that of residential buildings. In Thailand, the average BEI for hospitals is 148 kWh/m2/year (Saidur et al., 2010). With growing interest in sustainability management, hospitals have begun to design and build using sustainable technology, renewable resources, and energy efficiency to reduce energy consumption (Rina & Zakaria, 2014). In 2016, the Ministry of Health (MOH), in collaboration with MGTC, achieved an annual saving of 46 GWh or RM21 million from its EMGS certification program at 39 hospitals (MGTC, 2019).

2. Literature Review

Energy consumption leads to the burning of fossil fuels. It could lead to the emission of greenhouse gases and other air pollutants such as hydrocarbons, nitrogen oxide, and volatile organic compounds detrimental to the environment (Ong et al., 2011). Energy consumption also caused a significant rise in global carbon dioxide emissions from 19,380 million tons in 1980 to 31,577 million tons in 2008, and it was predicted that carbon dioxide emissions would increase to 40 billion tons by 2030 if no tremendous effort is made to control and reduce energy consumption (Moghimi et al., 2011). Malaysian energy generation is still heavily dependent on non-renewable energy fuels such as crude oil, natural gas, and coal, and with economic growth highly dependent on energy consumption, the increase in energy consumption is estimated to be in an uptrend of around 6–8% annually based on national economic growth (Ong et al., 2011). Malaysia has taken positive steps to address this issue by issuing a framework for energy development in terms of energy diversification and efficient utilization since 1979, known as NEP79. The objective is to promote energy efficiency and discourage wasteful and non-productive patterns of energy consumption (Chua & Oh, 2012).

In 2018, the total energy consumption was 64,658 ktoe (kilo tonne of oil equivalent), an increase of 3.5% from the previous year. All sectors showed an upward trend in 2018, except for the transport, residential, and commercial sectors. The transport sector's energy consumption declined by 2.0% to settle at 23,555 ktoe, while the residential and commercial sectors dropped to 7,773 ktoe. Figure 1 Energy consumption by sector and Figure 2 Energy consumption by sector (Malaysia Energy Commission, 2018) shows that electricity consumption by sector is % in the commercial sector, which is the second biggest consumption behind the industrial sector, and the trend is increasing year on year (Malaysia Energy Commission, 2018).

Figure 1: Energy Consumption by Sector

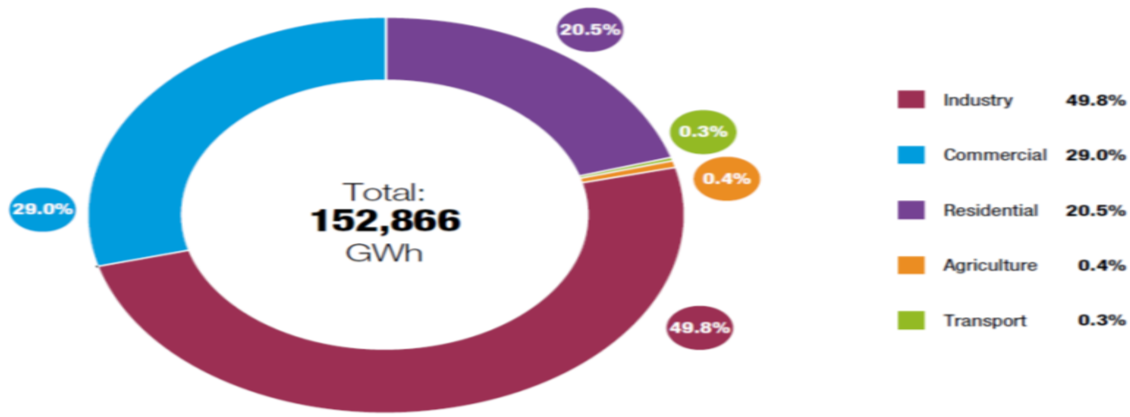
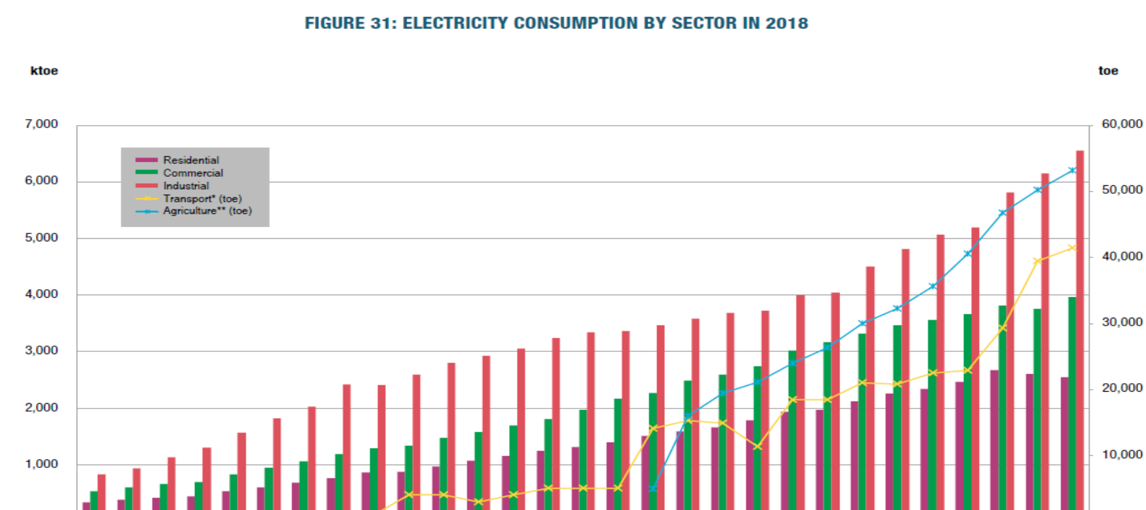


Figure 2: Energy Consumption by Sector (Malaysia Energy Commission, 2018)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Residential	345	385	422	447	532	604	681	770	874	885	975	1,081	1,161	1,248	1,319
Commercial	540	603	659	700	833	945	1,066	1,191	1,291	1,335	1,478	1,579	1,698	1,818	1,979
Industrial	830	937	1,137	1,303	1,567	1,826	2,029	2,422	2,411	2,591	2,805	2,930	3,059	3,242	3,340
Transport* (toe)	-	-	-	-	-	-	-	1,000	1,000	4,000	4,000	3,000	4,000	5,000	5,000
Agriculture** (toe)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Residential	1,395	1,515	1,598	1,668	1,792	1,937	1,974	2,126	2,262	2,346	2,471	2,679	2,610	2,553
Commercial	2,172	2,277	2,496	2,598	2,743	3,020	3,172	3,325	3,466	3,566	3,663	3,817	3,762	3,958
Industrial	3,371	3,475	3,587	3,687	3,719	3,994	4,045	4,509	4,818	5,072	5,200	5,822	6,145	6,547
Transport* (toe)	5,000	14,117	15,295	14,862	11,358	18,439	18,428	21,027	20,774	22,443	22,901	29,291	39,451	41,439
Agriculture** (toe)	-	4,886	15,991	19,393	21,080	23,920	26,312	30,014	32,240	35,578	40,526	46,747	50,228	53,113

Source: TNB, SEB, SESB, Co-Generators and Land Public Transport Agency
Note (*) : From 2006 until 2018 data were collected directly from train operators
(**) : Effective from 1 June 2006, TNB has introduced Specific Agriculture Tariff; previously Agriculture was under the Commercial Tariff

A recent study on Spanish hospitals reveals taht consumption of electricity by the commercial sector reaches 24.2% of the total energy consumption (González et al., 2018). The average annual energy consumption in Spanish hospitals reaches 20% of the total national energy consumption (Gangolells et al., 2016). To meet hospital operating standards in terms of temperature and humidity, hospitals consume a significant amount of energy (Moghimi et al., 2011). In the US, the healthcare industry consumes a high level of energy, which contributes to more than 8% of the national harmful greenhouse gas (GHG) emissions (Chung, 2011). In addition, several studies have observed that implementing energy efficiency and engineering retrofitting could reduce energy consumption in hospitals. Commercial buildings such as hospitals, because of their 24-hour operation, are recommended to implement energy efficiency activities, especially for the heating, ventilation and air-conditioning (HVAC) system, the building envelope, the building management system, and the compressed air system.

From the perspective of Malaysia in 2008, the commercial sector consumed 8% of the total energy consumption, and an estimated MWh of electricity was consumed by public hospitals (Saidur et al., 2010). The Building Energy Index (BEI) of a commercial building in which public hospitals fall under this category is between 70 and 300 kWh/m2/year, which is 10 to 20 times that of residential buildings. In Thailand, the average BEI for hospitals is 148 kWh/m2/year (Saidur et al., 2010). There are also correlations between the average energy consumption in hospitals and the number of workers, the number of available beds, and the built surface area (González et al., 2018).

It is essential now that hospitals embark on energy-saving measures where they must interfere with daily operations (González et al., 2018). Implementing energy-saving measures in hospitals should not compromise the health, safety, or care effectiveness of patients (Shepley et al., 2009). That is, many hospitals have less interest in green building certification compared to other industries (Wang et al., 2016). Recently, there has been a growing interest in sustainability development where a new trend is to design and build hospitals using sustainable technology, renewable resources, and systems designed to reduce energy consumption ((Rina & Zakaria, 2014).

3. Research Methodology

The research method is based on quantitative research, which involves data collection, data extraction, and data analysis. Data collection was conducted based on the Energy Management Gold Standard (EMGS) certification application by Malaysian public hospitals to Malaysia Green Technology and Climate Change (MGTC). The information obtained includes energy consumption amount in kWh and RM, hospital building profile such as gross floor area (GFA) in m2, hospital operational categories such as state hospital, specialist and district hospital, and hospital operating location.

Extraction, transform, and load (ETL) are used to extract data from data form applications submitted by hospitals to MGTC. ETL is one of the most powerful tools in data analysis, which helps to discover anomalies such as missing data and null values (Rodzi et al., 2016). ETL is commonly used in tasks dealing with data warehouse homogeneity, cleaning, and loading problems, and it is a cost-effective solution. ETL is also a fundamental step in the process of implementing a decision-making system through the design and implementation of a data warehouse. In this process, data from various sources are first extracted, cleaned, and eventually standardized before being stored in the data warehouse (Diouf et al., 2018).

The functionality of ETL can be summarized as follows:
a) Identification of relevant information at the source
b) Extraction of information
c) Customization and integration of the information
d) Cleaning the dataset
e) Propagation of the data to the data warehouse.
(Simitsis et al., 2005) and (El-Sappagh et al., 2011).

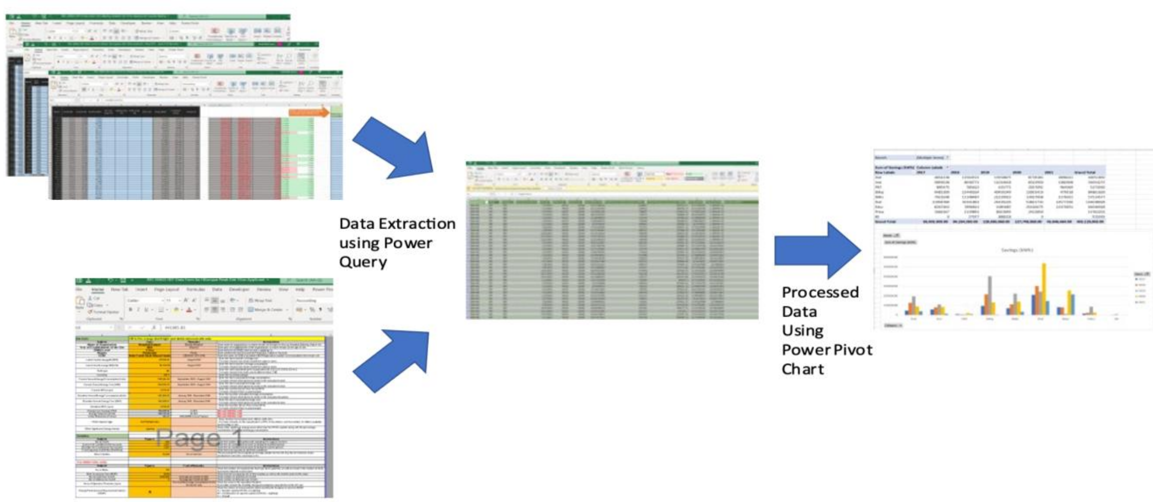
Power Query is a data transformation and data preparation engine. Power Query comes with a graphical interface for obtaining data from sources and a Power Query Editor for applying transformations. Because the engine is available in many products and services, the destination where the data will be stored depends on where Power Query was used. Using Power Query, you can perform extract, transform, and load (ETL) processing of data (Becker & Gould, 2019). The Excel 2010 and 2013 versions provide a customized way for the user to view the perspective and insights of the data. The collection assessment team began using these advanced Excel options to support a more robust program of data analysis, visualization and transparency. This will provide the opportunity to build a dashboard, interactive reports, and even geospatial maps with pivot tables, pivot charts, and slicers.

In Excel, Power query serves as ETL in BI applications (Valdez et al., 2017) with intuitive and consistent experience to discover, combine, and refine data from a wide variety of sources. In addition, power queries are commonly used to access data from multiple running Excel workbooks or files (Becker & Gould, 2019). In Microsoft Office, using Power queries for BI solutions is often accompanied by Power Pivot, Power View, Power Map, and Power BI (Erik Kajáti, 2017). In addition, Excel, as described by Wu (2010), is one of the most used BI tools and is commonly accompanied by power tools such as power queries for data extraction, transformation, loading, and analytics. Using Power Query, data can be extracted from different sources such as a file, online data warehouse, web, and databases (Leonard et al., 2021). Power Query is a self-service ETL tool that runs on Excel and can accept data from various sources, manipulate data into a form, and load it into Excel (Gowthami & Kumar, 2017).

4. Data Collection and Analysis

The data are based on energy information for 120 hospitals and buildings under the MOH, which includes all hospital categories for the state, specialist, district, and mental institutions. The raw data were obtained from the AEMAS EMGS application submitted by an organization interested in obtaining EMGS certification. The application data were submitted to the Malaysia Green Technology and Climate Change Corporation. The application for certification was submitted using an Excel file that comprises organizational energy consumption information and other organizational information. The data extraction process can be summarized as per Figure 3-Data Flow Diagram.

Figure 3: Data Flow Diagram



The application also consists of raw data comprising monthly energy consumption as follows:

A) Energy consumption information:
- Energy consumption in kWh
- Energy consumption in the RM
- Monthly Building Energy Index

B) Organization basic information:

- Building name
- Building location – State, District
- Building category
- Building Gross Floor Area

The raw data comprise applications from 120 MOH buildings for EMGS 2-Star and 3-Star certifications. The Excel files comprise several worksheets. The energy consumption data are extracted from the energy bills worksheet. The energy consumption data were extracted based on the monthly consumption data. The monthly consumption data were collected based on the organization's available data from 2015 to 2021. The monthly savings in RM and kW are based on the differences between the current and previous months. The monthly energy index is based on monthly consumption divided by gross floor area (GFA). The annualized savings in kWh and percentage are based on the current annual consumption against the annual baseline as set by the organization. From the Fact worksheet, data on hospital information and variables were extracted. Using a power query, the extracted data are then compiled into another Excel file for compilation and analysis into the compilation worksheet. The data were organized and transformed into more readable data for analysis. The data will then be combined between the worksheets to show the relationship between the energy consumption data and organization data. The data were then organized and grouped in an Excel sheet to be easily interpreted for analysis.

Data Source: Data collection activities include the compilation of hospital applications for EMGS certification. The certification requirement includes the presentation of energy data and hospital technical information compiled from 118 MOH buildings in Malaysia. The categorization of the hospital data collected is shown in Table 1. Number of MOH buildings by category. The categorization of buildings is based on the MOH identification of building facilities. Under the hospitals, the categories are District, Minor Specialist, Major Specialist, and State. The MOH institution includes mental institutions, laboratories, research institutions, and specialized institutions.

Table 1: Number of MOH Buildings by Category

Hospital Categories	Quantity
Institution	14
District	57
Major Specialist	16
Minor Specialist	19
State	12
Total	**118**

The data for energy consumption in terms of kWh and RM for all MOH buildings are complete from 2016 to 2019. For the years 2020 and 2021, the energy consumption data are still incomplete, primarily because of COVID-19. There are also energy consumption data for the year earlier than 2016, but the data are not complete for the MOH buildings. These data were also excluded from the analysis. Energy consumption has recorded a reduction from 2018 onwards with the introduction of an energy management program under the sustainable program in 2017. This can be seen in Figure 4. Energy consumption trend (2016 to 2019) Energy reduction has grown year on year from 1.53% in 2016 to 22.62% in 2019. The increasing energy trend is shown in Figure 5 (Annual monthly average energy saving (%) trend (2016-2019)).

Figure 4: Energy Consumption Trend (2016 to 2019)

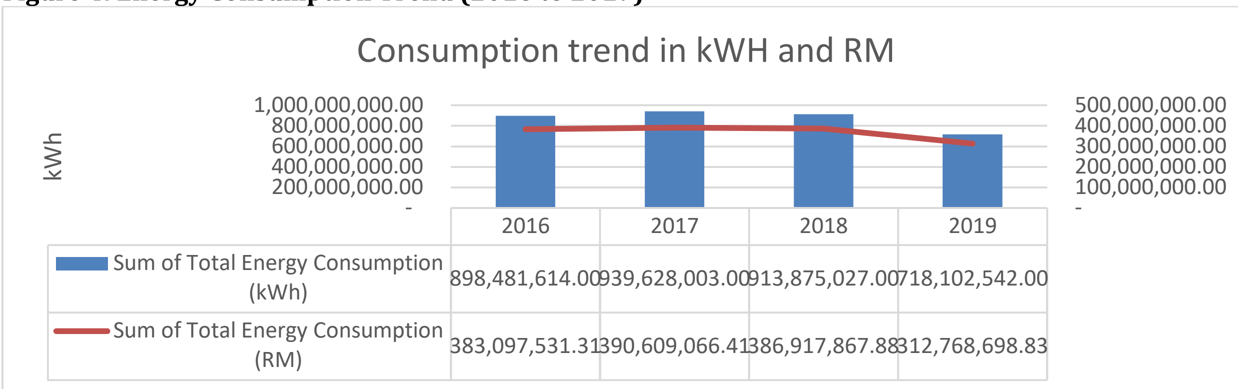
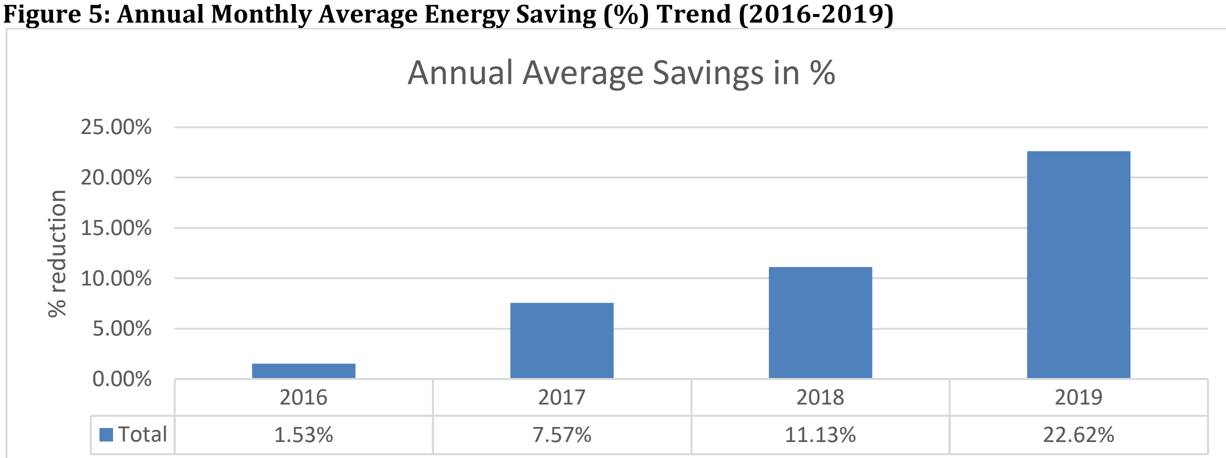
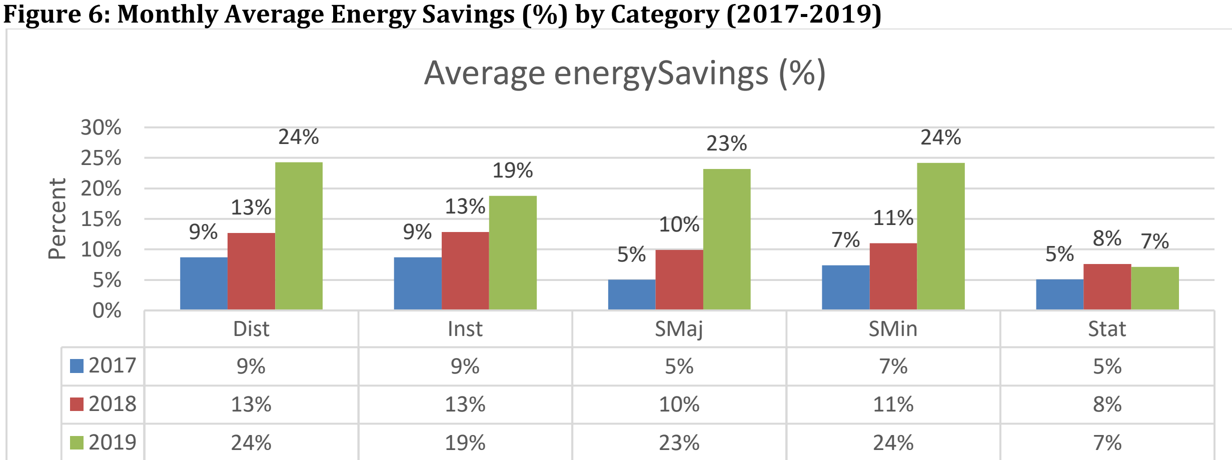


Figure 5: Annual Monthly Average Energy Saving (%) Trend (2016-2019)



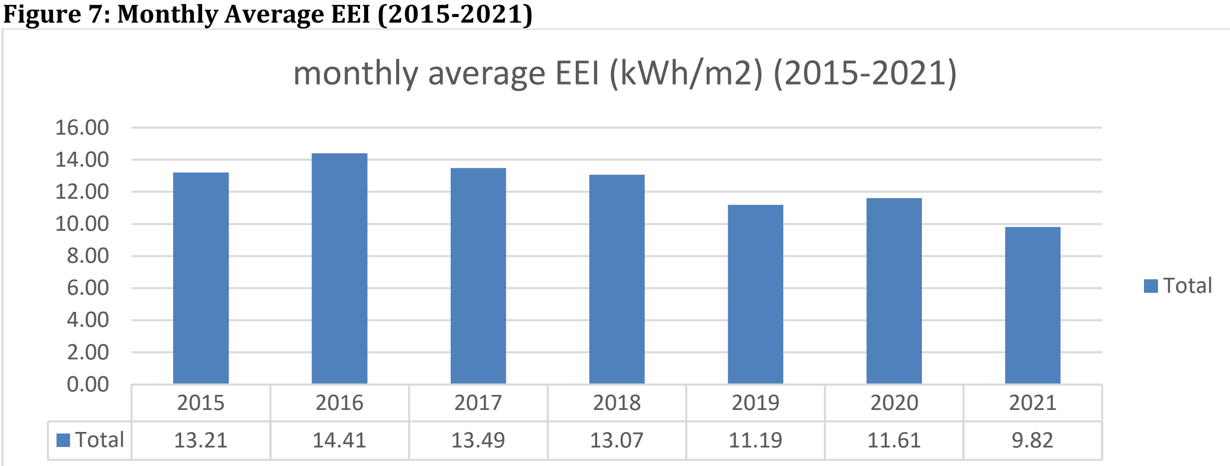
When analyzing the energy consumption savings by category, there are significant savings in the year 2019 for the district, minor specialist and major specialist hospital buildings, which achieved 23%–24%. The energy consumption savings for institution buildings are slightly lower at 19%. However, for state hospital buildings, the energy consumption reduction is the least with only 7% (Figure 6, monthly average energy savings (%) by category (2017-2019). Significant achievements for district, minor, and major specialist hospital buildings mainly contribute to energy-saving measures in lighting and cooling systems. The lighting energy-saving measures are from the replacement of fluorescent lights with LED lights. The cooling system energy saving measures are mainly due to the replacement of split unit air-conditioning with inverter-type air conditioning and the replacement of conventional chiller systems with magnetic drive chiller systems.

Figure 6: Monthly Average Energy Savings (%) by Category (2017-2019)



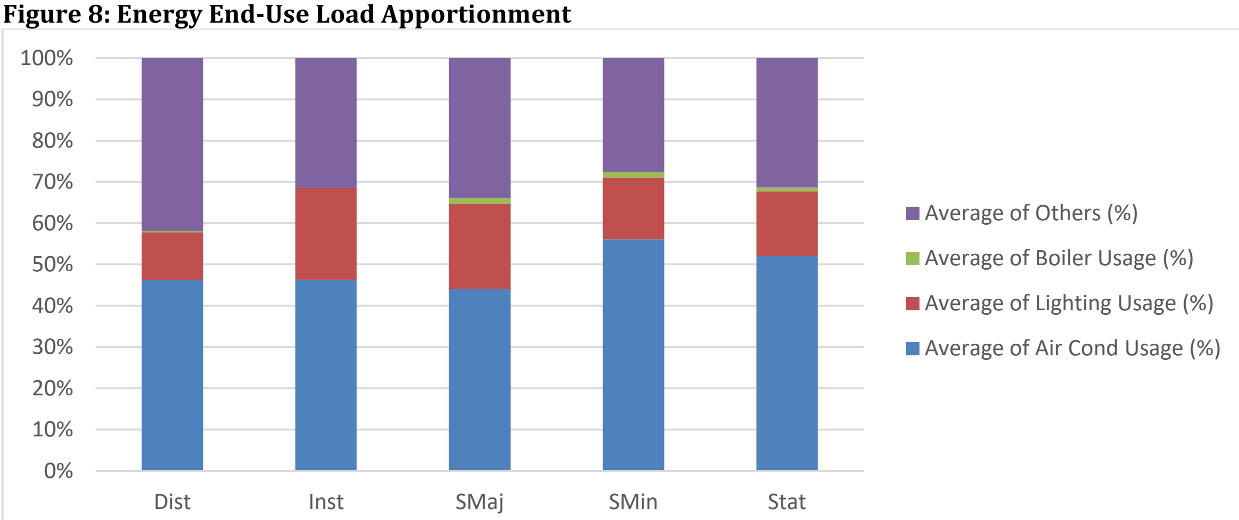
The average monthly energy efficiency index (EEI) in kWh/m2 for MOH buildings shows a downward trend from 2016; please refer to Figure 7 (Monthly average EEI (2015-2021)). This shows that there is a significant improvement in terms of energy efficiency year after year. This improvement in energy efficiency is mainly due to the reduction in energy consumption, and there is no significant variation in the floor area. The overall average EEI for 2021 is 9.82 kWh/m2 per month. If it is translated into the building energy index (BEI) annual energy consumption per year, the BEI will be approximately 117 kWh/m2. The 117 kWh/m2 compared to the commercial building standard is much lower than the 135 kWh/m2 set by MS 1525 as an energy-efficient building (Dwaikat & Ali, 2016).

Figure 7: Monthly Average EEI (2015-2021)



In terms of end-use energy in hospital buildings, energy is primarily used for cooling. Refer to Figure 8. Energy end-use load apportionment, the cooling load apportionment contributed 45%–55% of the total energy consumption. The lighting apportionment contributed between 10% and 20% of the overall energy consumption. However, minor and major specialist and state hospital buildings use energy for water heating using a boiler system of less than 5%. Others contributed between 30% and 42% of the energy consumption normally used for biomedical and office equipment.

Figure 8: Energy End-Use Load Apportionment



Discussion: The energy consumption performance of MOH buildings improved with the introduction of a sustainable energy management program in 2016. In 2019, MOH buildings achieved 22.62%. With this achievement, the sustainable energy management program has assisted the MOH buildings in the introduction of energy efficiency activities especially for LED lighting retrofit, cooling system retrofit, and some renewable energy introduction. The renewable energies that have been commonly implemented in MOH buildings are solar photovoltaic and solar hot water systems for water heating and air conditioning. Apart from energy efficiency and renewable implementations, staff should be aware of energy consumption savings. This is prevalent where MOH buildings that do not implement any energy efficiency and renewable energy implementations still, manage to achieve more than 5% energy consumption savings through awareness in which these buildings achieve 2-star EMGS certification. The requirements to obtain 2-star EMGS certification are that the buildings must demonstrate that they have achieved at least 5% energy consumption savings. Based on Excel data, as of December 2019, 118 of 145 MOH buildings have achieved two-star certification.

The findings from data analysis show that efforts from the hospitals to achieve EMGS certifications have produced a positive result of 22.62% energy savings by the end of 2019. By that time, most high-energy-consuming hospitals, especially those that fall under state and specialist hospitals, had yet to achieve 3-star certification. The best period to study the overall performance of the hospital is from 2023 and above, as most hospitals will return to their normal operations by the middle of 2022. Further studies are recommended to observe the implication of COVID-19 disease on energy consumption, especially from the perspective of energy performance.

5. Managerial Implications and Recommendations

Obtaining EMGS certification requires compliance with seven criteria. The criteria for EMGS certification include the elements of performance. With the introduction of SEMS and EMGS certification, the energy management program at the hospitals has shown significant improvement in the organization's commitment to energy reduction. The commitment from the top management of the hospital has had a significant influence on the successful implementation of SEMS and EMGS certification. It is expected that by the end of 2024, all hospitals under the MOH will obtain three-star certification.

Conclusion: The MOH is the first ministry in Malaysia to have started a sustainable program for all its buildings since 2016. This initiative has resulted in RM21 million a year from energy consumption savings. Based on our analysis, the MOH could achieve annual energy savings of RM100 million a year through this energy management program. Thus, MOH has also contributed to the Malaysian initiative to reduce CO2 emissions by 45% by 2030 (Malaysia International Trade Investment, 2018). The successful implementation of energy reduction should be a leading example for all other ministries in the Malaysian Government and all Malaysians. Therefore, Malaysians could understand the impact of energy consumption and start saving on energy consumption. At the very least, Malaysians could learn how to reduce energy consumption and minimize energy wastage. For further studies, other sustainability initiatives have been implemented at Malaysian hospitals, such as the waste management program, Green Building Certification, and indoor air quality. All these programs including the sustainable energy management program are part of the MOH initiative under their Sustainable Program. These programs are worth studying for their impact on the environment.

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