A COMPARATIVE STUDY OF ENERGY CONSUMPTION BETWEEN VARIOUS HOSPITALS IN MALAYSIA

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A COMPARATIVE STUDY OF ENERGY CONSUMPTION BETWEEN VARIOUS HOSPITALS IN MALAYSIA

ABSTRACT

The buildings' sector consumes about 15% of the total energy consumption in Malaysia. Of the biggest contributors to this figure are hospitals, which usually use energy above average due to their operation hours, occupants, and complex services. A survey study was conducted during various energy management system audits to Malaysian hospitals where important data for energy, load apportioning, and significant energy users are collected and comparatively analyzed. The data spans the period of three years from 2015 up till 2017 and the hospitals are categorized by their number of resident specialties and subspecialties. From the study, it was estimated that in 2015, district hospitals consume in average 2,237,776 kWh having a BEI of 148.92 kWh/m^2.year; minor specialist hospitals consume in average 6,155,092 kWh having a BEI of 216.62 kWh/m^2.year; major specialist hospitals consume in average 17,848,413 kWh having a BEI of 241.89 kWh/m^2.year; general hospitals consume in average 28,224,856 kWh having a BEI of 240.96 kWh/m^2.year. The load apportioning for 5 different hospitals were also analyzed and it was found that HVAC contributes to about 69% of the total load in hospitals. The study also found in 2016 that, the impacts of El Niño Southern Oscillation event to hospitals' energy consumption increased the energy consumption up to 13.6% depending on the types of hospitals. The study concluded with ways that could improve energy performance in hospitals from various angles that include technical, management and system improvement.

SATU KAJIAN PERBANDINGAN KEPENGGUNAAN TENAGA ANTARA HOSPITAL-HOSPITAL DI MALAYSIA

ABSTRAK

Sektor bangunan menggunakan dalam 15 peratus daripada jumlah keseluruhan kepenggunaan tenaga di Malaysia. Antara penyumbang terbesar kepada nilai ini adalah hospital, di mana pada kebiasaannya hospital menggunakan tenaga lebih dari purata; disebabkan waktu operasi hospital (yang panjang), penghuni (yang ramai), dan pelbagai perkhidmatan yang kompleks. Satu kajian tinjauan telah dilaksana semasa audit sistem pengurusan tenaga di mana data penting untuk kepenggunaan tenaga, pembahagian beban akhir dan pengguna utama tenaga dikumpulkan dan dianalisa secara perbandingan antara satu sama lain. Maklumat tersebut bermula dari tahun 2015 hingga 2017, selama tempoh tiga tahun. Hospital-hospital dalam kajian juga dikategorikan berdasarkan kepada jumlah kepakaran dan sub-kepakaran yang bertempat di hospital tersebut. Daripada kajian ini, dianggarkan pada tahun 2015 hospital-hospital daerah menggunakan tenaga elektrik secara purata sebanyak 2,237,776 kWh dengan nilai BEI berjumlah 148.92 kWh/m2.tahun; hospital-hospital berpakar minor pula menggunakan tenaga elektrik secara purata sebanyak 6,155,092 kWh dengan nilai BEI berjumlah 216.62 kWh/m2.tahun; hospital-hospital berpakar major pula menggunakan tenaga elektrik secara purata sebanyak 17,848,413 kWh dengan nilai BEI berjumlah 241.89 kWh/m2.tahun; hospital-hospital umum pula menggunakan tenaga elektrik secara purata sebanyak 28,224,856 kWh dengan nilai BEI berjumlah 240.96 kWh/m2.tahun. Pembahagian akhir beban untuk 5 hospital yang berbeza juga telah dianalisa dan didapati bahawasanya sistem HVAC menyumbang peratusan terbesar, sebanyak 69% daripada jumlah penggunaan tenaga di hospital. Kajian ini juga mendapati pada tahun 2016, kesan 'Ayunan Selatan El Niño' kepada kepenggunaan tenaga di hospital, meningkatkan penggunaan tenaga sebanyak 13.6%, bergantung kepada jenis hospital.

Kajian ini dirumuskan dengan cara-cara untuk meningkatkan prestasi tenaga hospital daripada pelbagai sudut, melibatkan penambahbaikan daripada segi aspek teknikal, pengurusan dan sistem.

ACKNOWLEDGEMENTS

First and foremost, I am grateful to Allah, the most compassionate and the most merciful that I finally completed my research report as planned and on time. I personally thank my supervisor, Associate Professor Dr. Kazi Md. Salim Newaz for his guidance and assistance along the journey of my report preparation. I also expressed full gratitude for the full support from my family particularly my parents: Dr. Faridah Basaruddin and Prof. Dr. Ahmad Ainuddin Nuruddin that always believe in me even in the worst of time. I am thankful for my Islamic circle mates: Fauzi, Khairul, Nu’man, Mawardi, Ali, Ikmal, Amirul and Khairuzzaman that though I have been skipping our weekly gatherings due to my hectic schedule that involved outstation on-site postings during weekdays and master’s classes in weekend, still have faith in me, pushing me to deliver my best in what I do. Last but not least, I am personally indebted to my wife that stands by my side along my journey of gaining knowledge (and a lot of staying up burning the midnight oil as well as data crunching); with the hope that what I struggled through will benefit mankind.

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LIST OF SYMBOLS AND ABBREVIATIONS

For examples:

AHU	:	Air Handling Unit
BEI	:	Building Energy index
BOR	:	Bed Occupancy Rate
CDD	:	Cooling Degree Days
CO_2e	:	Carbon Dioxide equivalent
CSSU	:	Centralized Sterile Supply Unit
EEI	:	Energy Efficiency Index
EnMS	:	Energy Management System
GDP	:	Gross Domestic Products
NFA	:	Net Floor Area
HVAC	:	Heating, Ventilation and Air-Conditioning
MOH	:	Ministry of Health
NDC	:	Nationally Determined Contributions
OT	:	Operation Theatre
VSD	:	Variable Speed Drive

LIST OF APPENDICES

CHAPTER 1: GENERAL INTRODUCTION

Climate change is becoming more common and prevalent in many parts of the world. The countries that are most affected by climate change are the third world countries or the global south as they are not well equipped and prepared to adapt to the effects of climate change (Franco, Shaker, Kalubi, & Hostettler, 2017). Malaysia specifically is among the developing countries that are fast becoming one of the developed nations (Zhang et al., 2017). Though small in land size and population, Malaysian carbon emissions are becoming larger in amount day by day (Suruhanjaya Tenaga (Energy Commission), 2016). Among all the end-use sectors, the buildings' sector contributes to about 30-35% of the final energy end-use in the world ("The IEA Energy Efficiency Indicators Database," n.d.) while in Malaysia the contributing percentage from buildings' sector is 14.3% (Suruhanjaya Tenaga, 2016). Generally, the buildings sector end use is defined as any end use of energy by buildings that are employed for residential and commercial use. The same definition also applies in Malaysia (Suruhanjaya Tenaga, 2016).

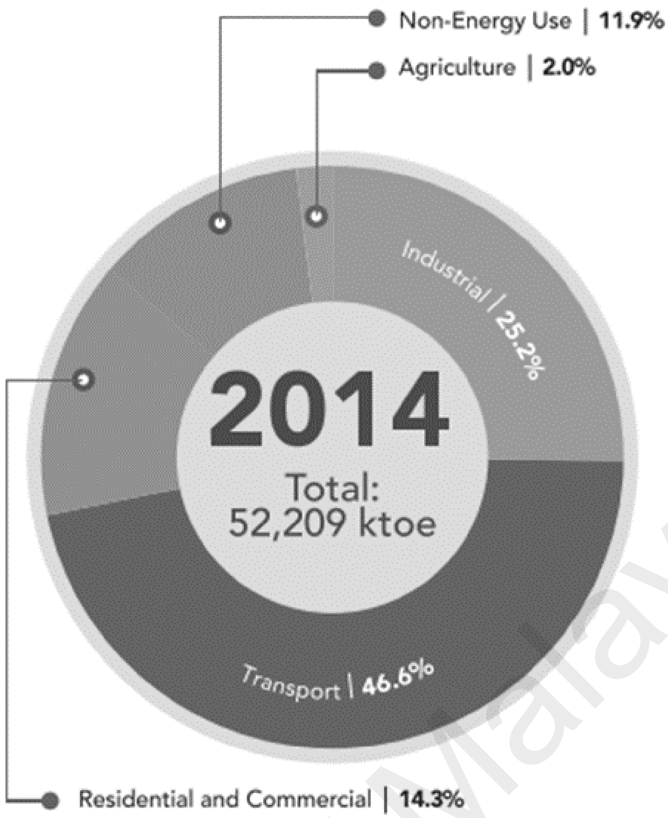

Figure 1.1: Final Energy Consumption by Sector in Malaysia

During the last seminal conference of parties in Paris dubbed the Paris Agreement (PA) back in 2015, Malaysia ratified their target of achieving 45% CO_2e emissions reduction by GDP intensity by 2030 compared to the baseline year (2005) (Ministry of International Trade and Industry, 2017). To be able to reach the target and tackle climate change will lead to actions to improve upon the buildings sector's energy performance. Among all types of buildings, hospitals relatively are among the biggest contributors to greenhouse gases emissions when compared to other commercial buildings (Morgenstern, Li, Raslan, Ruyssevelt, & Wright, 2016). Hospitals are also of the most complicated buildings to deal with as it involves many stakeholders and many users as well as various services and sophisticated equipment that operated 24 hours a day and 7 days a week (Thinate, Wongsapai, & Damrongsak, 2017). In this research report, the author will discuss various angles pertaining to the topic of energy consumption specific to Malaysian hospitals. The report will try to answer questions regarding the framework of hospital benchmarking and how well Malaysian hospitals are performing relative to each other, investigation of the impact of heating, ventilation and air-conditioning (HVAC) system size and climate change to the hospital's energy consumption; as well as the methods and technique to improve energy consumption in hospitals. As a summary, three main objectives will be tackled through this research:

1. To investigate and benchmark the energy performance of various hospitals in Malaysia.
2. To study on the HVAC system effects to the energy consumption of Malaysian hospitals.
3. To explore methods and technique to assist in the reduction of energy consumption in hospitals.

CHAPTER 2: LITERATURE REVIEW

There are numerous existing literatures that discuss in detail about specific topics of energy usage in hospital and general buildings. Literatures on energy consumption for hospitals can be found in various articles along the topic of energy management, building management system, combined heat and power, waste heat recovery, HVAC, building envelope, energy efficiency, facilities management, thermal comfort and sustainable buildings. However, the articles that discussed in detail about hospitals' energy performance and the impact of climate related events were very limited and cannot be simply applied in a tropical context such as in Malaysia. Most of the literatures are limited to studies on the energy performance for hospitals that are located in European countries or United States of America. Roughly, only 1 out of 20 of the articles cited in this research are directly related to the topic of energy consumption in Malaysian hospitals.

It was found that hospital's average annual energy consumption to correlate to the built surface area, number of workers, number of available beds with the factors having correlations of more than 90%. The geographic location particularly total degree has direct link to the energy consumption though not for type of management, GDP nor climate conditions (González González, García-Sanz-Calcedo, & Salgado, 2018).

A 2016 article by Morgenstern et al. studied on energy performances and targets of hospitals in the UK and Germany; comparing their current consumption, breaking them down to electricity and heat, and different hospital categories according to number of beds, and types of hospitals (acute, general or clinical and research).

Table 2.1: Overview of hospital energy performance figures and targets

Source	Country	Year of data	Category	# data points	Current consumption kWh(m2.yr)		Target kWh(m2.yr)	
					Electricity	Heat	Electricity	Heat
Industry Guidance								
[29]	UK	Pre 1996	Acute Hospital	Unclear	108	510	74	422
[12]	UK	2006	General Acute Hospital	Unclear, likely about 150	143	373	122	317
[31]	Germany	1999	Hospital with up to 250 beds	102	53	289	32	170
			Hospital with 251 to 450 beds	76	67	243	45	172
			Hospital with 451-650 beds	46	77	314	48	204
			Hospitals with 651 - 1000 beds	27	78	308	36	230
			Hospital with more than 1000 beds	31	164	446	47	270
Mandatory Disclosure								
[24]	UK (DEC)	?	Hospital (Clinical and Research)	Unclear	90	420		
[32]	Germany (Energie-ausweis)	2007	Hospital with up to 250 beds	111	120	205	84	145
			Hospital with 251 to 1000 beds	104	115	250	80	175
			Hospital with more than 1000 beds	33	115	285	80	200

(Morgenstern et al., 2016)

Morgenstern et al. also compared between the various units in a hospital and compared them with the average energy consumption. Operation theatres and laboratories have almost thrice the average energy intensity of the hospital. They also discussed the energy consumption impacts of hospital having more beds for the hospitals in Germany while in the UK, they compared the energy consumption between acute hospitals and general acute hospitals which are larger in size. The contribution of energy from heat consumption in the samples is significantly higher than electricity by a factor of up to 5 explaining the need for heat due to the low temperature of the areas as well as the European climate.

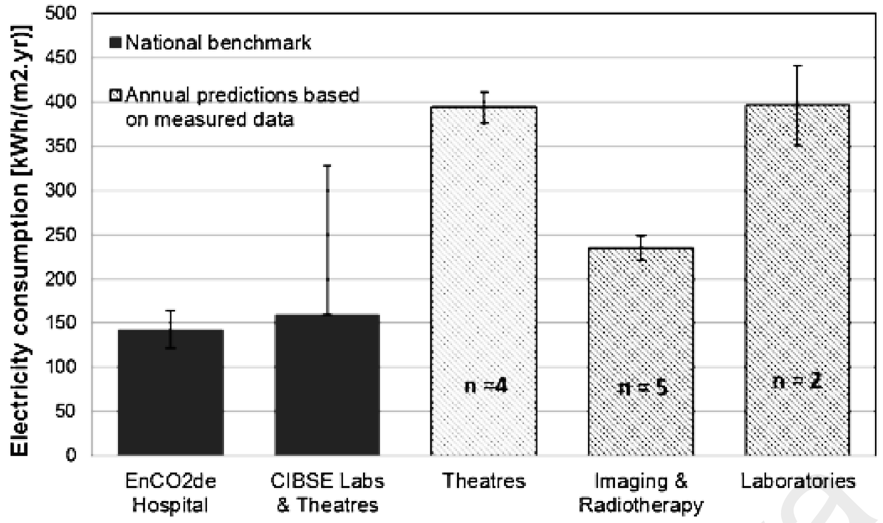

Figure 2.1: Electricity intensity of various hospital departments in relation to established benchmarks
(Morgenstern et al., 2016)

Morgenstern et al. also suggested that composite benchmarks that consider differing energy intensities between various departments is developed; as to accommodate large heterogeneity between hospitals, and set better specific departmental targets to reduce energy consumption (Morgenstern et al., 2016). In another recent article, Burpee (2017) discussed and compared the energy use between hospitals in the US, Norway and Denmark. It was found that the US hospitals consume almost twice the energy of an average Norway or Denmark hospital (Burpee, 2017).

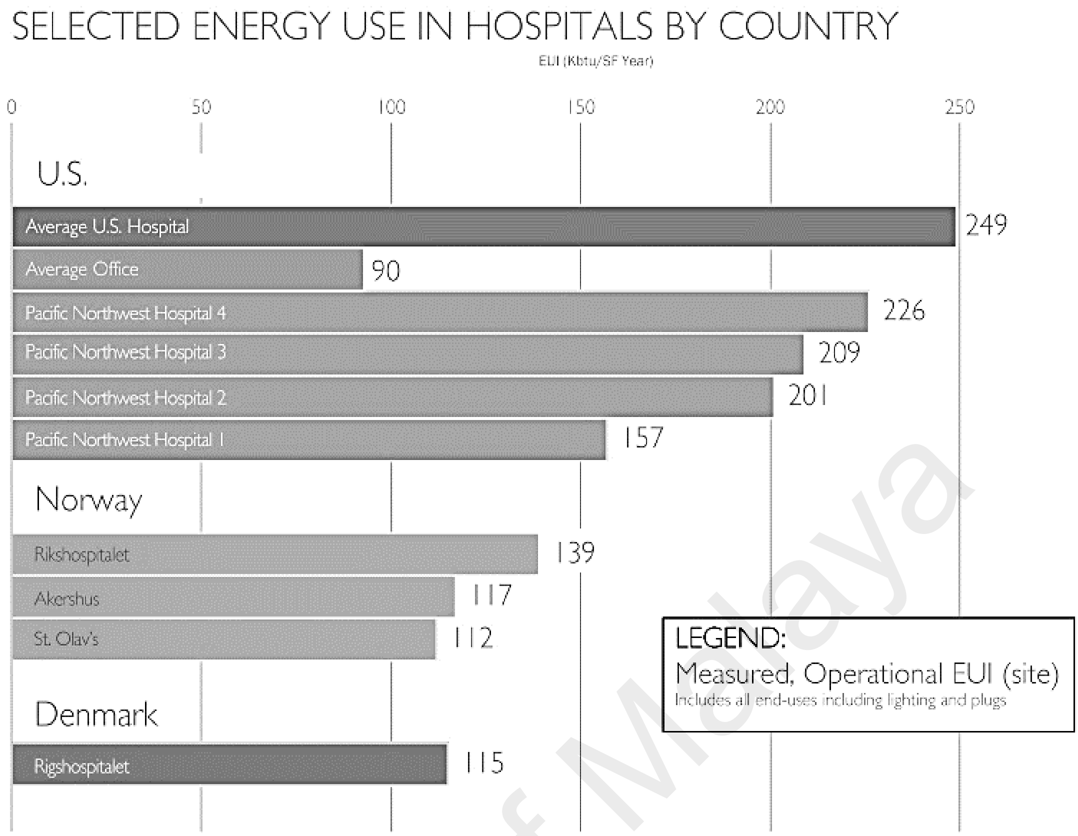

Figure 2.2: Hospital energy use in the US vs. Norway and Denmark
(Burpee, 2017)

In another study in Thailand by Thinate et al. (2017), they discussed the energy performance of Thai hospital buildings, collecting data from 45 large hospitals. They also managed to develop the average load apportioning or final energy end use of Thai hospital buildings. It was found that most of the electricity is consumed by the HVAC component specifically the chiller system (Thinate, Wongsapai, & Damrongsak, 2017).

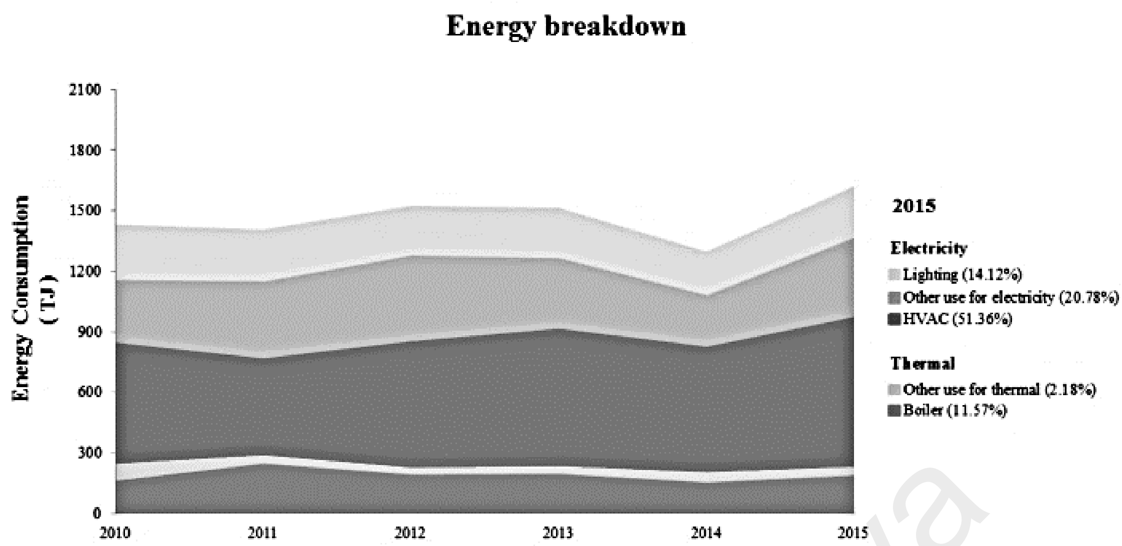

Figure 2.3: Energy breakdown in large Thai hospital
(Thinate et al., 2017)

Saidur et al. (2010 & 2011) studied in two different case studies, the energy use of a Malaysian public hospital, and a public university building. The two studies were contradictory that the final energy end-use for that specific hospital in the case study was contributed mostly by lighting while the public university energy consumption was mostly contributed by the chillers, consuming about 40% of the total energy; even though the system in the two case studies are not significantly different. They also discussed in both literatures, the possibility of installing high efficient motors and VSDs in both the hospital and university building, and compared the energy savings from the retrofit between various motor loadings (Saidur, Hasanuzzaman, Yogeswaran, Mohammed, & Hossain, 2010) (Saidur, Hasanuzzaman, Mahlia, Rahim, & Mohammed, 2011). Yau & Chew in another study, discussed on Malaysian hospitals as well but was more focused on the topic of thermal comfort of hospital workers and how the HVAC was not operated according to the ASHRAE Standard 55. Less than half of the examined locations met the standard requirements and 51% of the occupants were unsatisfied with the room temperature (and humidity) of the hospital (Yau & Chew, 2009).

There were no existing literatures that discussed in great details the energy consumption of hospitals specific to Malaysia and compare them between each other. Some of the literatures were also found not to be helpful in benchmarking the hospitals while providing little to no solutions whatsoever on how to move forward and improve the condition of the hospitals. The existing literature that discussed the load apportioning for Malaysian hospital was also found not to be that accurate, with contradictory values from other literatures. The literatures specific to Malaysia or even the Southeast Asia region, were limited and only a handful were present during time of writing. In the context of the last El Niño event in Malaysia (January to May 2016), there were also no literatures that discussed the impact of the increased surrounding temperature to the energy consumption of hospitals; specific to the humid climate and high CDD that Malaysia have. Most of the studies of El Niño were more concerned of the impacts of drought that will mostly impact food production and water reserves. All these gaps will try to be filled by the author in this study.

CHAPTER 3: METHODOLOGY

The data for the study was collected over a period of one year in 2017, in different months; covering the energy consumption from the year 2015 up till 2017. The data is then verified and carefully selected that only hospitals' data with complete details are used for analysis. The complete data for the benchmarking study must consist of the annual energy data for the year 2015, 2016, partial data for 2017, the net floor area (NFA)[1] and energy baseline[2] period. The data for other energy consumption such as from liquefied petroleum gas, natural gas and diesel were not taken as to focus on electricity alone as the data for the other fuel sources are limited and differed from hospital to another hospital. From the annual energy consumption and net floor area, a specific energy performance indicator, the building energy index (BEI) is calculated.

$$\textbf{Building Energy Index (BEI)} = \frac{Energy\ Consumption\ in\ a\ year\ (kWh)}{Net\ Floor\ Area\ (m^2\ )}$$

As the data for the year 2017 was partially collected during specific time of the year, for example in July 2017, the energy consumption data are only available up till the month prior to the collection, the data which in this case is Jun 2017. The energy consumption for remaining months of the year must be estimated and projected as to create the annual energy consumption value as well as the BEI for 2017. This is done by calculating the correcting factor (CF) and multiplying it with the previous year's energy data value for the remaining months.

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[1] The net floor area is measured in square meter and only considers the enclosed space of the building, where open spaces and corridors are not included in the measurement

[2] Baseline is a set of data or information used as a basis for benchmarking and comparison

Correcting Factor (CF)

$$= \frac{\text{Sum of the known values for the energy consumption of 2017}}{\text{Sum of corresponding values for the energy consumption of 2016}}$$

$$Example: \frac{Sum\ of\ monthly\ energy\ usage\ from\ January\ to\ June\ 2017}{Sum\ of\ monthly\ energy\ usage\ from\ January\ to\ June\ 2016}$$

Projected 2017 Energy Consumption

$$= \text{Sum of the known values for the energy consumption of 2017}$$

$$+ (\text{CF x Sum of the completing values from 2016})$$

$$Example: Sum\ of\ monthly\ energy\ usage\ from\ January\ to\ June\ 2017$$

$$+ (CF \times Sum\ of\ the\ monthly\ energy\ use\ from\ July\ to\ Dec\ 2016)$$

For the benchmarking study as well, the author defines the categories of hospitals and divides them based on the categorization given by Malaysian MOH in their specialty and subspecialty framework handbook (Ministry of Health Malaysia, 2016). The hospitals are divided into general (or state), major specialist, minor specialist, specialized, district and private specialist hospitals. District hospitals do not have resident specialties; specialized hospitals/institutions only have specific resident specialties; minor specialist hospitals have up to 10 resident specialties; major specialist hospitals have up to 20 resident specialties/sub-specialties; while general hospitals have greater resident specialties/sub-specialties than 20. For private specialist hospital, it is defined by not being administered by Malaysian MOH.

The categorization is being made on the basis of comparing between all of the hospitals in the same category; to identify the average, minimum and maximum value as to recognize hospitals in the respective category that require corrective and improvement actions if their average energy consumption value is higher than the average in their respective category as well as for overall hospitals. However, a cumulative figure was also provided as to show the difference between the average value of the different categories. The categorization also made clear of the graphs for the energy consumption value from the year of 2015 to 2017; as to display the trend for the 3-year period. The trends cannot be directly seen in the cumulative figure.

To maintain confidentiality of the data, the hospitals are not named and only labeled by their categories and randomly numbered 1, 2, 3 and so on. The samples for the benchmarking study involved 27 samples: from 8 district hospitals, 6 minor specialist hospitals, 7 major specialist hospitals, and 6 general hospitals, covering both peninsular and east Malaysia though the sample is more weighted to peninsular Malaysia by a factor of 4.4 to 1.

For the specific study of the impact of HVAC system size to energy consumption, the load apportioning for 5 samples are collected, consisting of 2 district hospitals, 1 specialized institute, 1 major specialist hospital and 1 general hospital. The mean, max, mean and median percentage value for each end-energy-use namely HVAC, lighting and others are automatically calculated using excel functions.

Next, for the 2016 El Niño's impact study on Malaysian hospitals' energy consumption, the most important data collected for analysis were monthly energy use from January 2015 to the latest month prior to data collection (example: August 2017). The sample for the study was taken from 10 hospitals: 4 district, 2 minor, 2 major and 2 general, with all the hospitals located in peninsular Malaysia. The profiling for the energy consumption is however constructed not by month-to-month basis but rather in an annualized form; to clearly depict the trend and pattern of consumption and to neglect the difference of the monthly energy usage due to number of days. The annualized energy consumption can be calculated using the following equation.

$$\textbf{Annualized Energy Consumption}$$
$$= \text{Sum of the monthly energy usage for 12 months (starting from any month)}$$
$$Example: Sum\ of\ monthly\ energy\ usage\ from\ July\ 2016\ to\ June\ 2017$$

For the calculation of CO_2e mitigation through energy management system implementation and certification, the samples were taken from 35 hospitals, from all over Malaysia. Out of the 35 samples, 34.3% are district hospitals, 8.6% are minor specialist, 31.4% major specialist, 2.8% private specialist, 8.6% specialized hospitals/institutes, and 14.3% general hospitals. The emission factors were taken from the Malaysian energy commission energy statistics handbook where the latest figure from the year 2014 was used.

Table 3.1: Carbon emission factors for Malaysia per MWh of electricity

Regions	***Carbon Emissions (tCO_2/MWh)***				
	2010	**2011**	**2012**	**2013**	**2014**
Peninsular	0.76	0.747	0.741	0.742	0.694
Sabah	0.574	0.531	0.546	0.533	0.536
Sarawak	0.847	0.841	0.872	0.724	0.699

(Suruhanjaya Tenaga, 2016)

The energy cost savings calculation was estimated using a value of RM0.35 per kWh due to lack of information on each hospital's electricity tariff subscription; taking a conservative approach though most of the hospitals in the study will most likely use the TNB[3] 'B' and 'C1' electricity tariff. The rate for B Tariff is RM0.435 for the first 200

[3] TNB or Tenaga Nasional Berhad is the national electric utility company of Malaysia, which started first as the central electricity board (Lembaga Letrik Pusat). It was renamed as Lembaga Letrik Negara (National Electricity Board) after Malaya's independence and before privatization of the board took place in 1990.

kWh and RM0.509 for 201 kWh onwards while the rate for C1 tariff is RM0.365 per kWh (Appendix B). The value for the maximum demand is not measured and collected as that would be another case study to be conducted in the future.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Benchmarking of energy consumption in Malaysian hospitals

Subchapter 4.1 describes the discussion and results from the benchmarking study of various hospitals in Malaysia. From 35 samples, the minimum, maximum, mean and median were calculated and identified for each categories of hospitals. It was found that the most minimum value of annual electricity consumption of all the hospitals to be 848,101.04 kWh, which is the annual electricity consumption of one district hospital in the samples. District hospital in Malaysia is known to be small, having an area of not more than 24,000 m^2 (with most district hospitals having NFA of around 11,000 -12,000 m^2); with no resident specialties (only visiting specialists) hence less needs for complicated medical equipment; and standard operating conditions requirement due to lack of operating theatres, intensive care units, and other units or rooms that require rigorous control parameters to maintain certain specifications such as: minimum air change, relative humidity, temperature, and pressure (positive for OT, negative for isolation room). Most of the district hospitals studied also do not have large HVAC system such as a water-cooled chiller system. Most of them utilized split air-conditioning units not more than 4 hp, and air-cooled package units for their minor OT and labs. The smallest BEI of the samples are 73.73 kWh/m^2.year which do not necessarily correspond to the district hospital with the lowest annual electricity consumption but hospital with the lowest energy consumption for a given area. It was found in average that the air-conditioned area for districts hospitals is around 44.1% of the NFA, this should explain why the average BEI of district hospitals in the study is significantly lower than any other types of hospitals.

The highest annual electricity consumption is 65,898,831.55 kWh, which corresponds to the largest general hospital in the sample. General hospital is the largest hospital in any given Malaysian state, and the main referral center for all hospitals for a state even from the private sector. They are large in size, usually having a NFA of around 110,000 m^2; have various resident specialties and sub-specialties which cover many disciplines (more than 20); consists of large units and departments which require strict operating conditions; employing large number of staff, with minimum not more than 3000; and utilizes highly consuming chiller system and sophisticated medical equipment. It was found in average that the air-conditioned area for general hospitals is around 56.4% of the net floor area. As for the highest BEI of all the hospitals in the sample, it is found to be 374.32 kWh/m^2.year which belongs to a major specialist hospital located in Sarawak. The specific hospital was also found to have the highest percentage of air-conditioned area among all the sample studied, having a value of 74.0% of the NFA. Generally, hospital in Sarawak are smaller in NFA even for major specialist hospitals that have up to 20 resident specialties/sub-specialties. They relatively consume more than the hospitals in peninsular (of the same area) due to the cheap electricity tariff compared to peninsular Malaysia (provided not by TNB but rather Sarawak Energy). As for the NFA, the largest value among all hospitals is 248,216.7 m^2, twice bigger than the next general hospital in the sample.

In terms of energy consumption and BEI, the value for 2016 tends to be the highest for majority of the hospitals in the sample. This is due to the fact that in the year 2016, from the period of January to May, the effects of El Niño took place, driving higher the electricity consumption for cooling. The energy consumption for 2017 tends to be the lowest between the three years and can be reflected in the correction factor of lower than one. The energy management system set-up and certification program were started mid-2016 and is slowly showing its impact and becoming more prevalent in 2017.

Table 4.1: Data for hospitals

Categories	*Values*	*Energy Consumption (2015) (kWh)*	*Energy Consumption (2016) (kWh)*	*Energy Consumption (2017) – Projected (kWh)*	*Correcting Factor for 2017 Projection*	*Baseline (kWh)*	*Current Consumption (kWh)*	*NFA (m^2)*	*BEI (2015) ($kWh/m^2.year$)*	*BEI (2016) ($kWh/m^2.year$)*	*BEI (2017) ($kWh/m^2.year$)*
District	Min	874,182.00	949,719.00	848,101.04	0.86	874,182.00	888,491.72	6,006.12	76.00	82.56	73.73
	Max	3,680,541.00	3,740,862.00	3,412,090.85	0.98	3,680,541.00	3,571,837.36	23,799.07	194.39	207.36	191.62
	Median	2,167,108.48	2,064,791.72	1,883,806.57	0.92	2,070,616.22	1,934,743.50	15,227.80	147.67	148.99	135.86
	Average	2,237,776.21	2,240,405.06	2,062,935.41	0.92	2,124,314.93	2,049,717.12	15,159.15	148.92	149.83	137.14
Minor Specialist	Min	1,298,709.00	1,387,984.00	1,248,358.50	0.87	1,343,347.00	1,341,172.00	12,193.40	106.51	113.83	102.38
	Max	9,080,729.00	9,375,548.00	8,950,968.00	0.94	9,080,729.00	9,375,548.00	48,768.97	319.30	302.66	285.53
	Median	6,548,992.00	6,591,603.00	6,190,093.51	0.90	6,560,992.00	6,407,822.45	23,543.91	233.66	238.42	213.04
	Average	6,155,092.00	6,277,077.33	5,719,925.55	0.90	6,156,172.42	6,125,060.05	28,455.10	216.62	220.62	200.94
Major Specialist	Min	5,389,252.00	5,561,574.00	5,502,363.19	0.85	5,389,252.00	5,541,867.00	19,264.39	178.82	179.80	167.62
	Max	30,412,669.96	30,228,296.24	31,338,181.22	1.04	30,412,669.96	31,064,723.36	131,055.69	374.32	372.31	370.31
	Median	18,763,875.00	18,125,453.00	15,496,550.18	0.99	18,436,742.00	16,767,707.00	92,451.00	212.94	210.35	216.74
	Average	17,848,412.88	17,752,857.72	17,461,784.72	0.98	17,759,893.06	17,593,948.55	79,896.54	241.89	241.43	237.23
General	Min	16,908,396.00	19,183,604.00	18,874,972.51	0.92	19,183,604.00	19,030,676.00	62,362.37	190.81	198.88	182.67
	Max	62,563,847.00	65,898,831.55	62,326,546.65	1.00	65,898,831.55	64,390,136.00	248,216.70	313.78	352.94	340.00
	Median	22,223,430.22	23,281,966.06	21,899,967.20	0.95	23,499,028.06	22,491,767.10	109,546.87	233.76	239.50	227.03
	Average	28,224,856.06	29,678,339.64	28,240,445.35	0.96	29,680,201.33	28,987,420.48	119,432.91	240.96	256.92	246.12

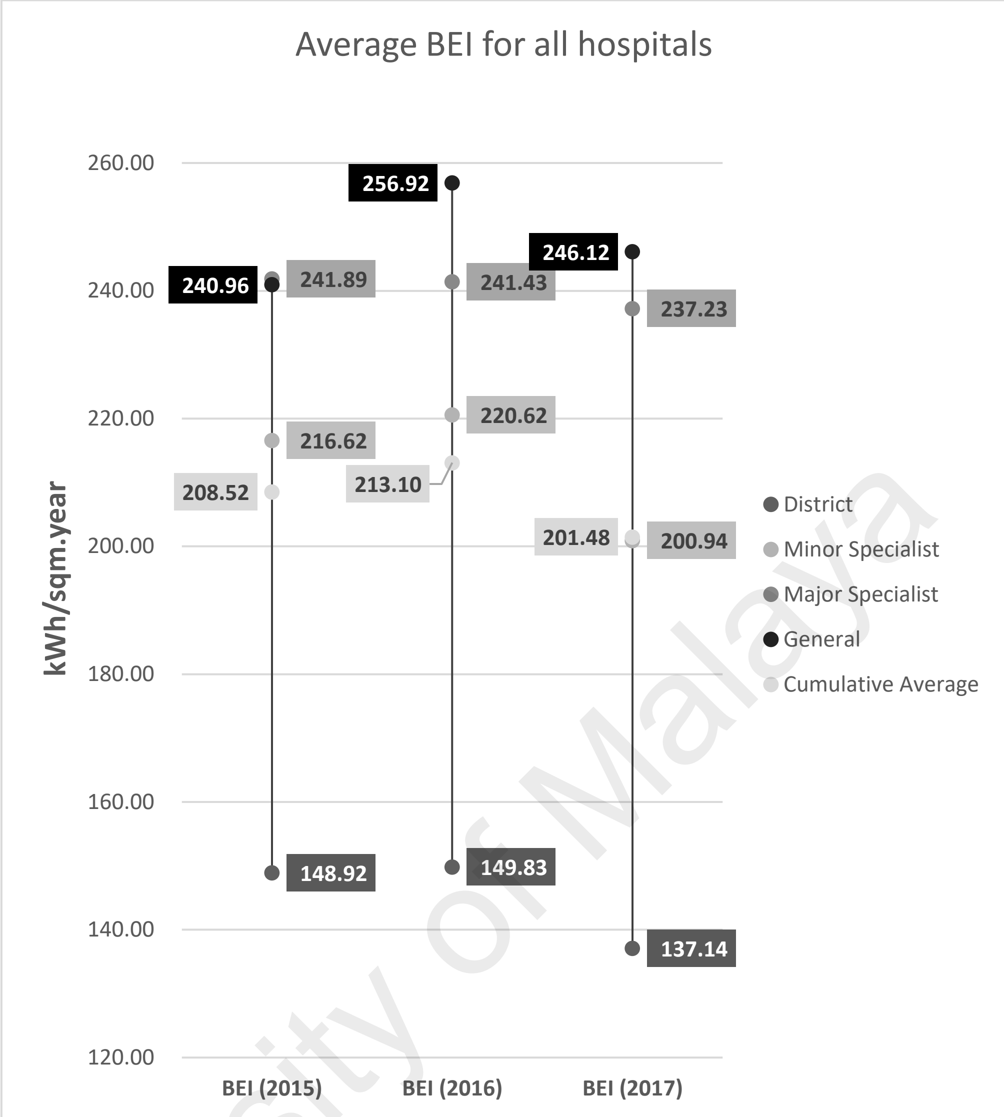

Figure 4.1: Average BEI for all hospitals

The average BEI for all hospitals in the study are 208.52 kWh/m^2.year in 2015, 213.10 kWh/m^2.year in 2016, and 201.48 kWh/m^2.year in 2017. District hospitals have in average around 60 kWh/m^2.year less than the average BEI values. As for the general and major specialist hospitals sample in the study, they have relatively almost the same BEI in average, this can be due to some hospitals consuming significantly higher than the average. The anomalous cases are explained later in the successive paragraphs for the related hospital categories.

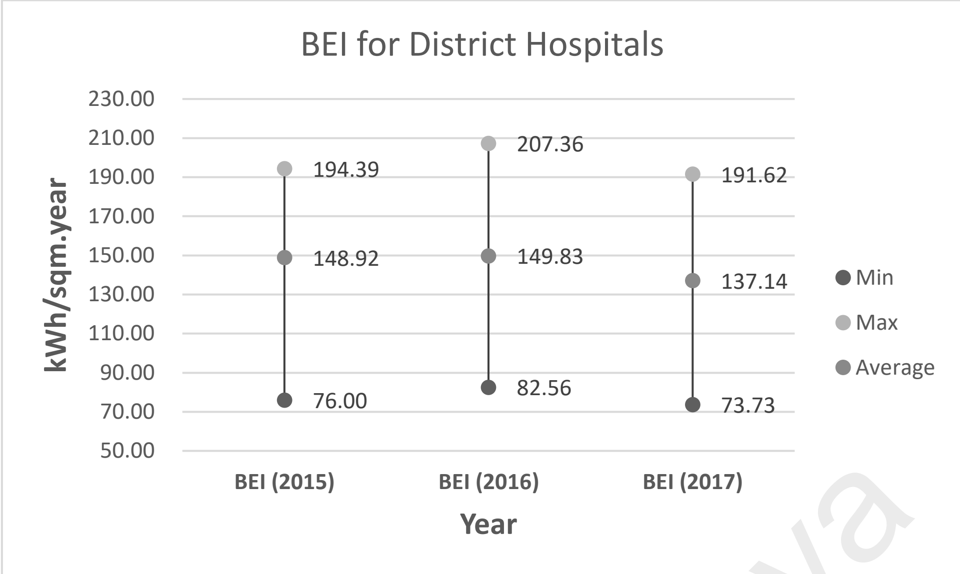

Figure 4.2: BEI for district hospitals

The average district hospitals' BEI in Malaysia for 2015 is around 150 kWh/m^2.year, slightly lower than 2016 and significantly higher than 2017. BEI for the year 2017 is the lowest with most hospitals under the care of private facilities management companies (privatized concession companies)[4] pursuing the mandatory energy management certifications, the Energy Management Gold Standard (EMGS)[5] under the ASEAN Energy Management Scheme (AEMAS)[6]. Through EMGS as well, they initiated to reduce energy through no-cost and low-cost measures. Some of the no-cost measures include awareness training to end users and staff, setting up the equipment according to specified control parameters, and de-lamping excess lightings but still adhering to Illuminating Engineering Society (IES) standard as well as the Malaysian Standard (MS

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[4] Concession companies are the 5 hospital health services companies in Malaysia under the long 10-year concession agreement with the Malaysian ministry of health. They are: Edgenta Mediserve (Northern region), Radicare (Central region and east coast), Medivest (Southern region), One Medicare (Sarawak) and Sedafiat (Sabah).

[5] Energy Management Gold Standard (EMGS) is an energy management system certification program for end-users/organizations under the ASEAN Energy Management Scheme.

[6] ASEAN Energy Management Scheme (AEMAS) is a regional program to promote best practices in energy management in the ASEAN region. It was launched officially in 2011 and implemented in 8 ASEAN countries by respective country chapters.

1525:2014). The low-cost measures that required little cost were also implemented such as installation of timers on certain AHUs, and replacement of limited numbers of 4-feet T8 fluorescent to LED lightings which is about 57% more efficient, which is operated 24 hours a day[7].

The range of min and max for the year 2015, 2016 and 2017 from the average value is very large, clearly depicting the wide range of BEI for the district hospitals in the sample. Some hospitals have larger NFA while being efficient, having a BEI of about 80 kWh/m^2.year, some hospitals still have not completely implemented energy management system, having BEI greater than 200 kWh/m^2.year. Most of the district hospitals in Malaysia are fan-powered, with split unit air-conditioners available in certain staff's rooms, and air-cooled packaged units (ACPU) for certain departments (such as CSSU and OT). The coverage of air-conditioning and cooling in average for district hospitals is around 44.1% of the NFA.

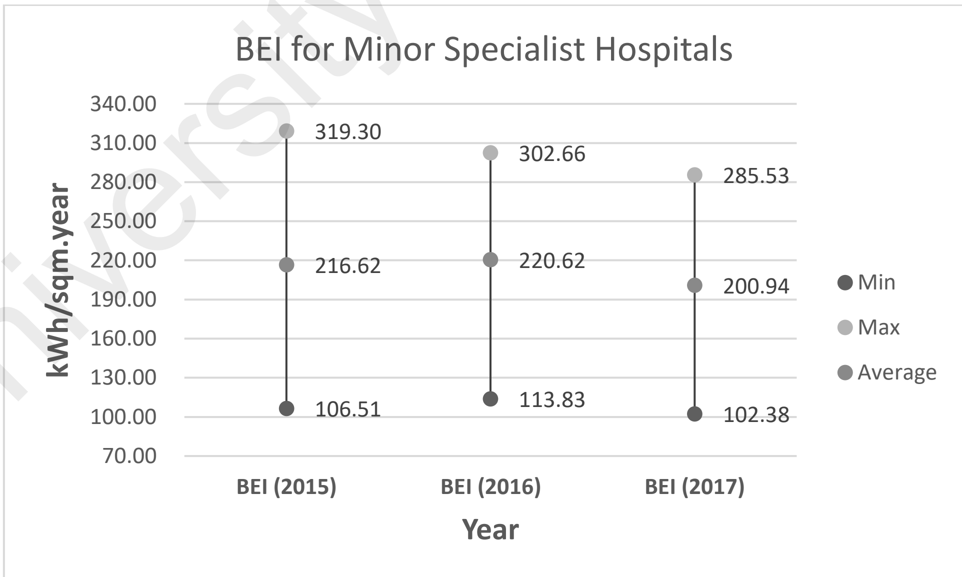

Figure 4.3: BEI for minor specialist hospitals

[7] General replacement of T8 fluorescent lighting (36 W + 6 W Ballast) to LED (18 W)

The average minor specialist hospitals' BEI in Malaysia for 2015 is around 215 kWh/m^2.year, slightly lower than 2016 and higher 2017. BEI for the year 2016 is the highest due to the El Niño effect, which impacted hospitals the most in January to March. The BEI value is higher than BEI for district hospitals as minor specialist hospitals are generally bigger, have more air-conditioning load, and houses more activities and patients. The coverage of air-conditioning and cooling in average for minor specialist hospitals is around 50.3% of the NFA, about 6% higher than district hospitals. The ranges of min and max for the year 2015, 2016 and 2017 from the average value are very large, clearly depicting the wide range of BEI for the minor specialist hospitals in the sample with the max going up to about 315 kWh/m^2.year and the lowest being about 75 kWh/m^2.year. The hospital with the largest BEI of about 315 kWh/m^2.year has bigger air-conditioning demand but have the same NFA as the median value.

As for the lowest minor specialist hospitals' BEI which is about 110 kWh/m^2.year, this is due to one anomalous hospital in the sample being categorized as a minor specialist hospital only as it has sufficient number of resident specialists. The hospital is located in Sarawak, where it has almost the same capacity as a district hospital, being small and less energy-demanding but due to Sarawak being a large state with hospitals far apart from each other, it is necessary to have such minor specialist hospital at that particular location, as to accommodate the citizens nearby.

Figure 4.4: BEI for major specialist hospitals

The average major specialist hospitals' BEI in Malaysia for 2015 is around 240 kWh/m^2.year, almost the same as 2016 and slightly higher than 2017. The BEI value for major specialist hospitals are higher than BEI for minor specialist hospitals by a value of 25 kWh/m^2.year in average. Major specialist hospitals have more air-conditioning load, a more complicated HVAC system sometimes with built-in building automation system and more specialized equipment and department. The coverage of air-conditioning and cooling for major specialist hospitals is in the range of 49.1 to 74.0 percent of the NFA, way more varied compared to minor and district hospitals.

The ranges of BEI min and max for the year 2015, 2016 and 2017 from the average value are very large, with wide gap of BEI for major specialist hospitals especially from the average to the max. The maximum BEI goes up to about 370 kWh/m^2.year and the lowest is about 170 kWh/m^2.year. The hospital with the largest BEI of about 370 kWh/m^2.year is another anomalous case where it has great energy demand for such small NFA, almost twice than the hospital of the same size. It is located in one of the main cities of Sarawak where it is the main referral center for other far located district hospitals.

As for the lowest major specialist hospitals' BEI which is about 180 kWh/m^2.year, the hospital has initially a BEI of 200 kWh/m^2.year but since the implementation of energy management system, has reduced its BEI to about 170 kWh/m^2.year (for 2017).

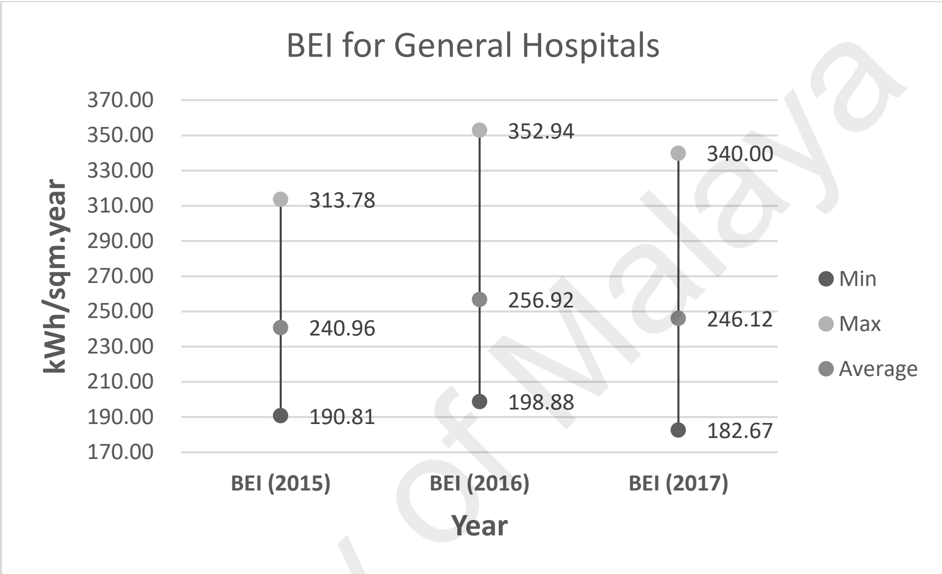

Figure 4.5: BEI for general hospitals

Finally, for general hospitals, the average BEI in Malaysia for 2015 is around 250 kWh/m^2.year. The BEI value for general hospitals are higher than BEI for major specialist hospitals by a value of 10 kWh/m^2.year in average. General hospitals have more operation rooms that require very specific humidity, temperature and pressure (air change) to run and maintain, while being bigger, house more patients, with larger number of wards and beds, as well as bed occupancy rate. The coverage of air-conditioning and cooling in general hospitals ranges from 37.6 to 69.8 percent of the NFA, differing according to the hospitals' size and number of beds.

The ranges of BEI min and max for the year 2015, 2016 and 2017 from the average value are very large especially from the average BEI value to the max. The maximum

BEI goes up to about 350 kWh/m^2.year and the lowest is around 180 kWh/m^2.year. The hospital with the largest BEI of about 350 kWh/m^2.year is a packed and busy general hospital located in Selangor, of the states in Malaysia with the highest economic output and growth. The hospital is the main referral center for all hospitals in Selangor.

4.2 Impact of HVAC system size to energy consumption

Table 4.2: Load apportioning of 5 Malaysian hospitals

Type	*HVAC*	*Lighting*	*Others*
District A	71.0%	22.0%	7.0%
District B	74.0%	20.0%	6.0%
General A	72.0%	20.0%	8.0%
Specialized A	66.0%	23.0%	11.0%
Major Specialist A	63.0%	34.0%	3.0%
Min	**63.0%**	**20.0%**	**3.0%**
Max	**74.0%**	**34.0%**	**11.0%**
Median	**71.0%**	**22.0%**	**7.0%**
Mean	**66.5%**	**24.3%**	**5.8%**

The table shows the load apportioning of 5 Malaysian hospitals according to their type and 3 different end loads which are: HVAC, lighting and others. ‘Others’ are considered energy usage other than for the use for HVAC and lighting. It was found that the largest load to be HVAC and others to be the smallest load. HVAC consumes about 63 to 74 percent of energy of the system. Lighting’s load is more or less a third of the energy consumed by HVAC, contributing about 20 to 34 percent. Others contributed about 3 to 11 percent of the energy consumption. Among all types of hospital, district and general has almost the same value. Specialized and major specialist hospital has almost the same value for HVAC but very distinct value for lighting and others.

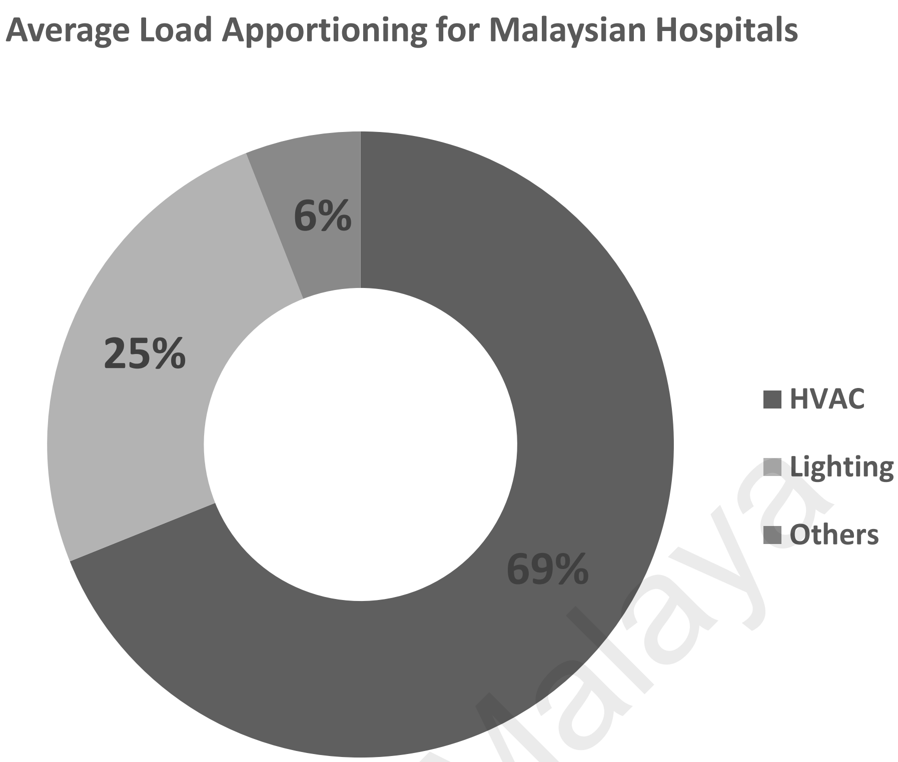

Figure 4.6: The average end-use apportioning for Malaysian hospitals

From table 4.2 and the 5 samples taken, an average load apportioning pie chart for Malaysian hospitals are constructed, HVAC in general consumes about 69% of the energy in a given hospital. This may be different according to the hospital's size and occupancy rate. As for lighting, it is expected to consume about 25% of the energy while others contribute the remaining percentage which is about 6%.

4.3 Impact of El Niño to the energy consumption of Malaysian hospitals

El Niño is a name given to a phenomenon where an annual week warm ocean current that moves southward across Peru's coast and Ecuador around Christmas time. Niño is the Spanish word for the word of 'boy Christ-child'. It was only recently becoming more known and linked with the abnormal large warmings that took place every few years, that caused the change in the regional and local environment.

The impact of El Niño generally is divided to two: coastal warming, and atmospheric warming. The coastal warming is related to a more extensive anomalous ocean warming and it is this Pacific basin wide phenomenon that forms connection with the anomalous global climate patterns. The atmospheric warming linked to El Niño is termed the ‘Southern Oscillation’, whereby scientists frequently call the phenomenon where the atmosphere and ocean warming took place simultaneously as ENSO, shorten from El Niño–Southern Oscillation. El Niño event corresponds to the warm phase of ENSO. The opposite of El Niño is what we called as the ‘La Niña’ (‘the girl’ in Spanish) phase which consists of a basin wide cooling of the tropical Pacific, representing the cold phase of ENSO. However, the masses know the term for the whole phenomenon as ‘El Niño’ (Trenberth, 1997).

The worst El Niño event that have struck Malaysia in the past few decades took place during the year 1998 and 2016. The Malaysian Academy of Sciences published a report stating the 1997-1998 El Niño impacts to Malaysia, which described the adverse event of drought, which in turn could affect not only the agricultural landscape but also energy. They stated in subchapter 3.5 that the 1998 El Niño event has delivered detrimental impact on the supply side of energy, affecting hydropower’s dam and power stations that relied on certain level of water. During ENSO as well, due to the lack of clouds, solar irradiance over Malaysia increases, thus increasing the heat flux that will drive higher surface air temperature, making the energy demand for cooling larger (Academy of Sciences Malaysia, 2016). This is especially true for hospitals and will be explained later in the following paragraphs, as well as through simple charts.

An official statement from the Malaysian ministry of health in 2016, described that the ENSO event in 2016 as being on par with the severity of the ENSO event in 1997/1998. The impact of the 2016 El Niño is said to cause an increase of temperature of about 0.5°C to 2.0°C, from the period of mid-January to mid-April. It was also expected during that time that the most effected regions in Malaysia, would be that state of Sabah (that is known to be among the states that received highest value of solar irradiation), northern region of Sarawak, northern region and east coast of the Malaysian peninsular. Haze could also arise if there is uncontrolled open burning. It was also reported that during the El Niño period, there is increasing number of reported cases of heat strokes, as the ambient temperature got as high as 38°C or higher than 35°C for five days in a row (Kementerian Kesihatan Malaysia, 2016).

In this subchapter, the impact of the 2016 El Niño event to Malaysian hospitals are studied. There are 10 samples in the study however only 4 samples are used to display the corresponding impacts of El Niño to their energy consumption; as only these 4 hospitals have the complete cycle of energy consumption that is needed to accurately depict the El Niño impact as well as the trending patterns. It was found that as the hospitals have more resident specialists on site, the energy consumption gets higher and the correlation is almost perfect, with value of 97.34%.

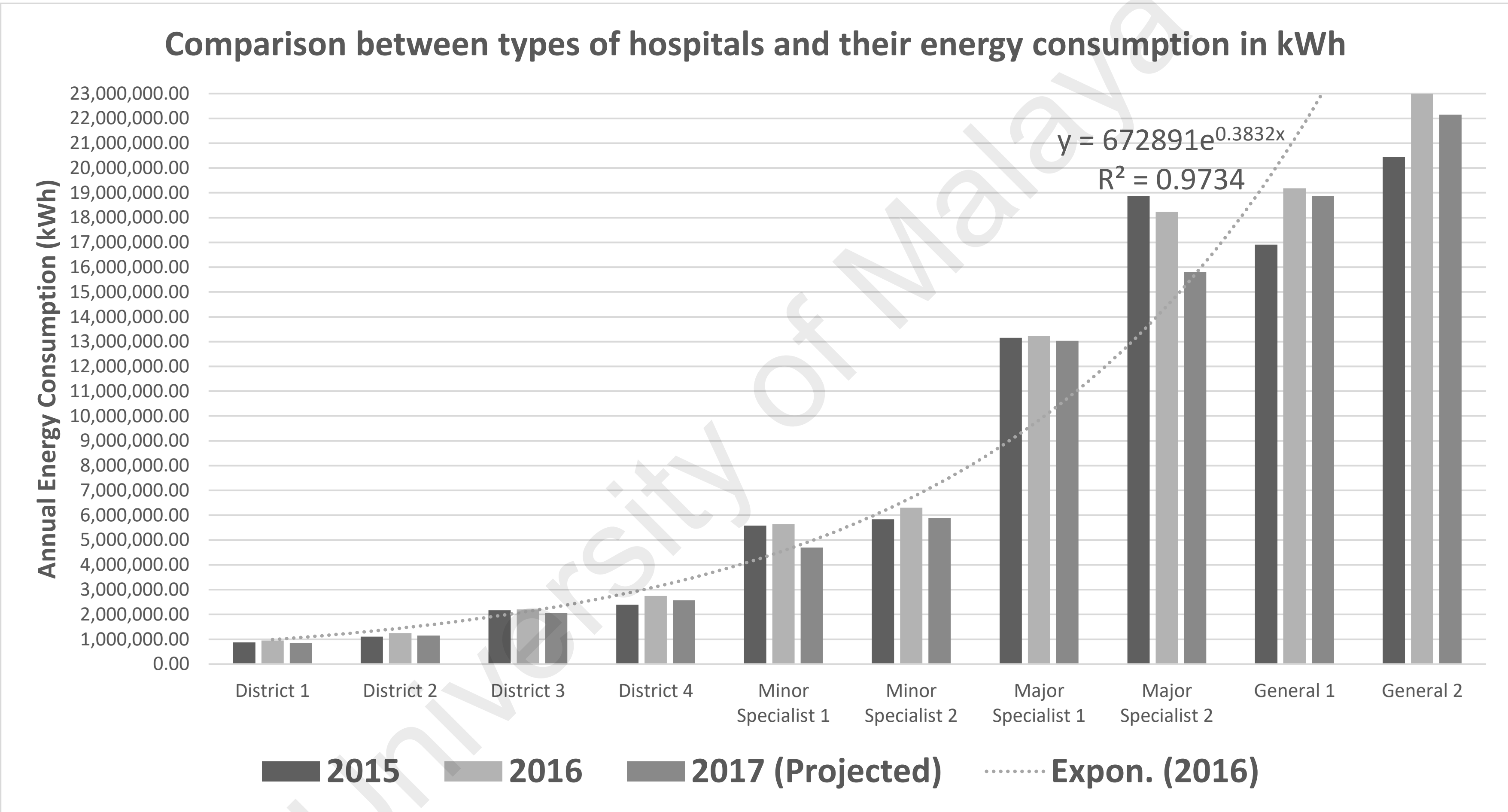

Figure 4.7: Correlation between types of hospitals and their annual energy consumption

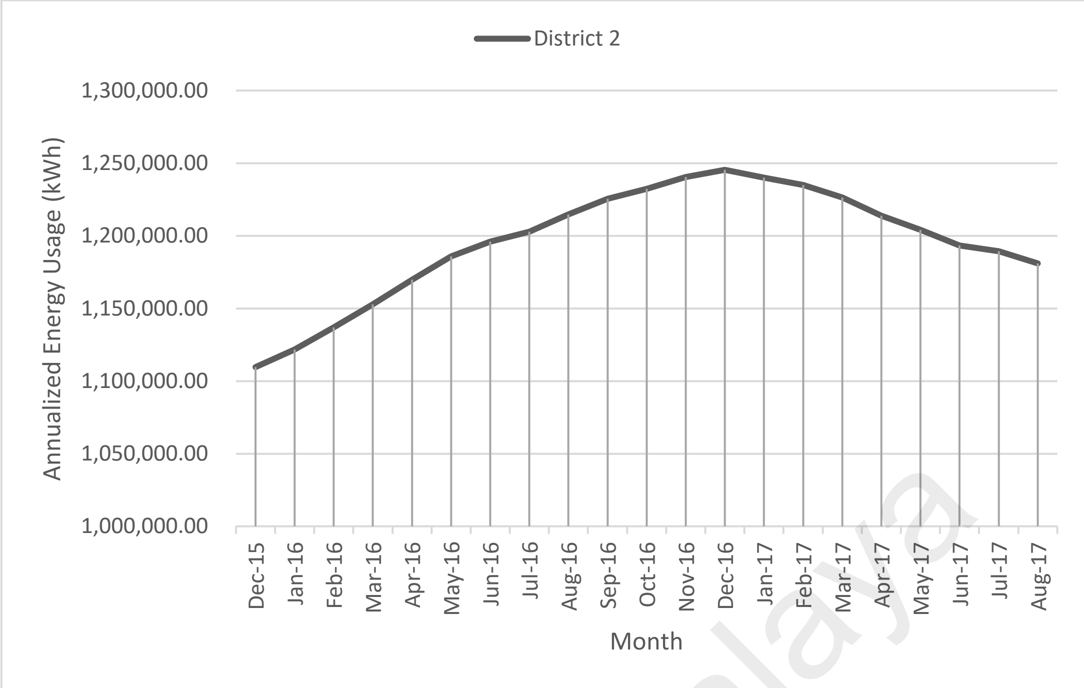

Figure 4.8: Annualized energy consumption for 'District 2' hospital

The peak of the annualized energy consumption chart for District 2 hospital is on December 2016, which means, the hospital consumes the most energy from the period of January 2016 to December 2016. As the one-year period consists of the 4 months where El Niño hits, the impacts of El Niño can be clearly seen; increasing the energy consumption by almost 150,000 kWh, a percentage hike of 13.6% from the energy consumption for the year 2015. After December 2016, the energy consumption can be seen to be decreasing steadily until August 2017, though not as small as the energy consumption in the year 2015.

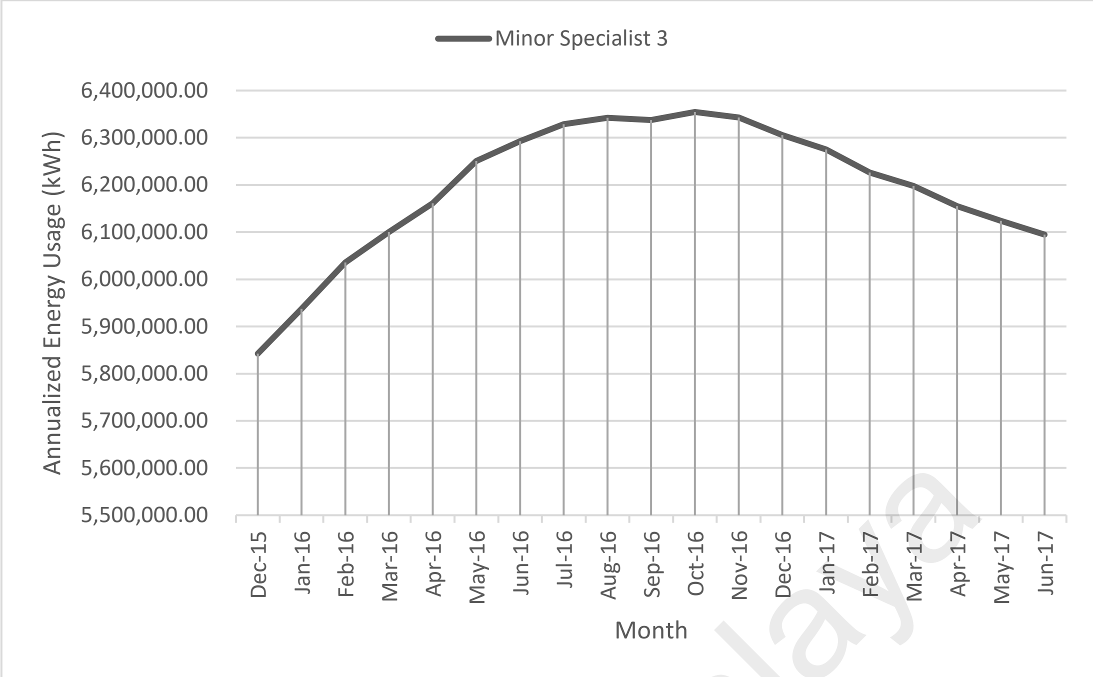

Figure 4.9: Annualized energy consumption for 'Minor Specialist 2' hospitals

The peak of the annualized energy consumption chart for Minor Specialist 2 hospital is during the month of October 2016, which means, the hospital consumes the most energy from the period of November 2015 to October 2016. As the one-year period consists of the 4 months where El Niño hits, the impacts of El Niño can be clearly seen, increasing the energy consumption by almost 500,000 kWh, a percentage hike of 8.6% from the energy consumption for the year 2015. After October 2016, the energy consumption can be seen to be decreasing steadily until June 2017.

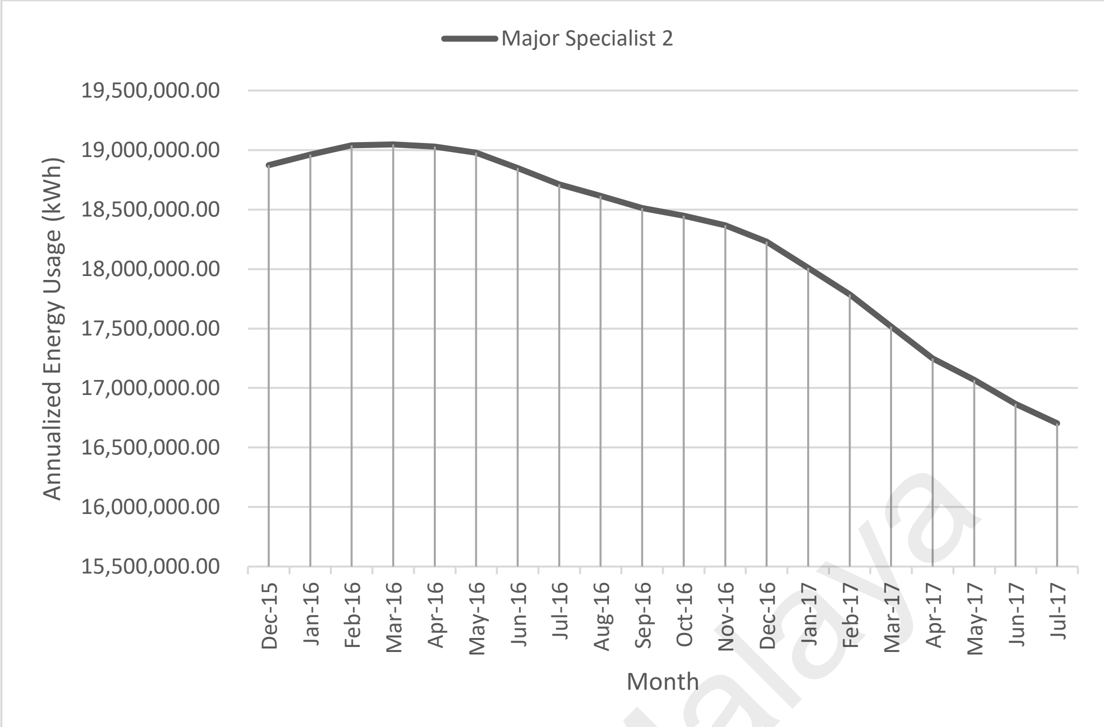

Figure 4.10: Annualized energy consumption for 'Major Specialist 2' hospital

The peak of the annualized energy consumption chart for Major Specialist 2 hospital is on February 2016, which means, the hospital consumes the most energy from the period of March 2015 to February 2016. As the one-year period consists of the 2 months where El Niño hits, the impacts of El Niño were not particularly significant here, specifically on the months of March and April where the energy consumption remains stagnant. The El Niño however still increased the energy consumption by almost 170,000 kWh, a percentage hike of almost 1% from the energy consumption for the year 2015. The small hike during El Niño period, is due to a great system implementation conducted by Major Specialist 2 hospital, reducing the great effects of El Niño. After February 2016, the energy consumption can be seen to be decreasing steadily until July 2017, to a value lower than the energy consumption in 2015; a decrease of about 2,100,000 kWh, or 11 %.

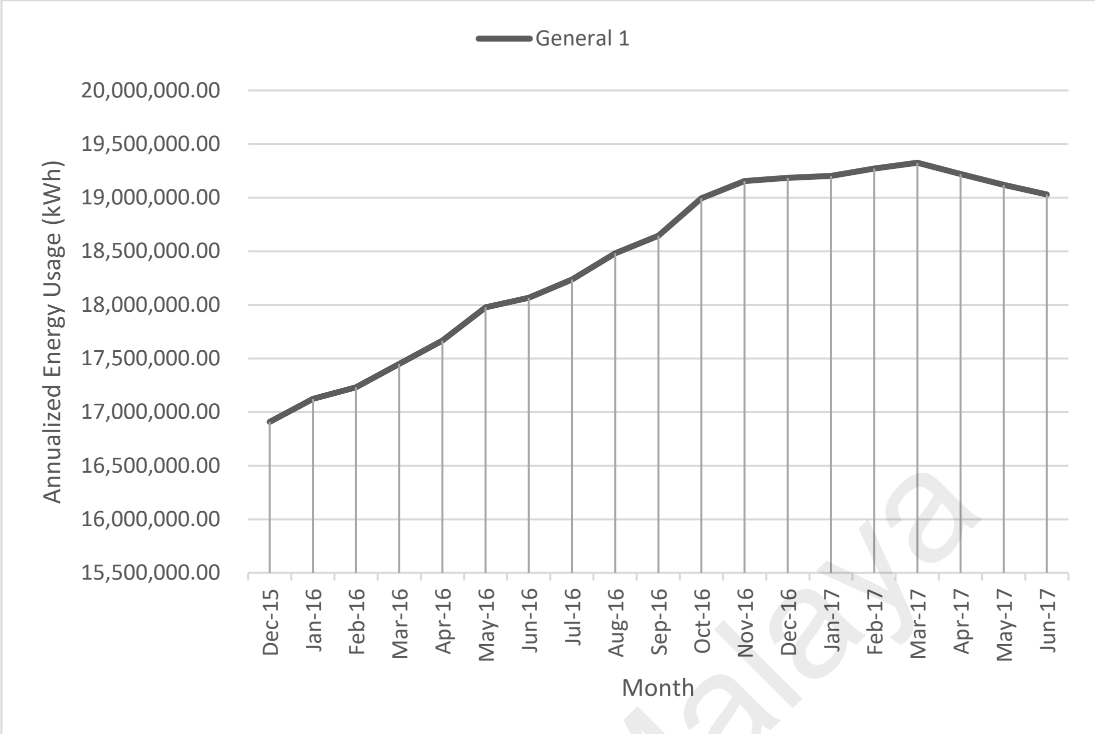

Figure 4.11: Annualized energy consumption for 'General 1' hospital

The peak of the annualized energy consumption chart for General 1 hospital is on March 2017, which means, the hospital consumes the most energy from the period of April 2016 to March 2017. As the one-year period consists only one of the 4 months where El Niño hits, the impacts of El Niño were not that significant to the hospital. This particular hospital is generally smaller than other general hospitals in Malaysia, and the services, occupancy rate, and number of outpatients and inpatients kept increasing day-by-day. The hospital has not also implemented a system-wide management of the energy performance, causing the increase of energy consumption by almost 2,100,000 kWh, a percentage hike of 11% from the energy consumption for the year 2015. After March 2017, the energy consumption can be seen to be decreasing steadily until June 2017.

4.4 Impact of energy management system development to Malaysian hospitals

Thirty-five samples were used for the calculation of the impact from the energy management system development at Malaysian hospitals. The hospitals in the sample have undergone the regional energy management system certification (EMGS), and implemented the necessary requirements as stipulated by the scheme. It covers the aspect of management, organization, process, information, financial, corporate responsibility, and achievement. The sample consists of various types and sizes of hospitals, as to represent as many hospitals as possible. The run-down figure for the study is that a total of 14,042,333.66 kWh of electricity is reduced through the energy management system development. The total kWh reduced is equivalent to 3.534% of the total energy consumption in average; contributing to an estimated cost savings value of RM4,914,816.78, and 9593.04 tonnes of CO_2 to be mitigated from the atmosphere annually. Net value in table 4.3 is the value inclusive of negative values, which does not truly reflect the energy management system performance of an organization.

Figure 4.11 shows the classic example of two hospitals where one hospital has implemented sustainable energy management system while the other still lacks and yet to have a sustainable energy management system in place. The major specialist 2 hospital's annual energy consumption is going to a downtrend continuously while the general 1 hospital continues to increase in energy consumption until a month where the energy demand is slightly less than the previous year's usage, that is because of El Niño.

Table 4.3: Impacts of energy management system development at 35 Malaysian hospitals and health institutes

	Electricity Reduced (kWh)	*CO_2 Mitigated (Tonnes)*
Net kWh	8,849,473.41	5,987.72
Total kWh	14,042,333.66	9,593.04
Cost Savings (RM)	4,914,816.78	

Table 4.4: CO_2e emissions' reduction through energy management system development at Malaysians hospitals

	Energy Reduction compared to Baseline (%)	*CO_2 (Tonnes)*
Min	0.04%	5.58
Max	32.79%	1643.57
Average	6.20%	383.72

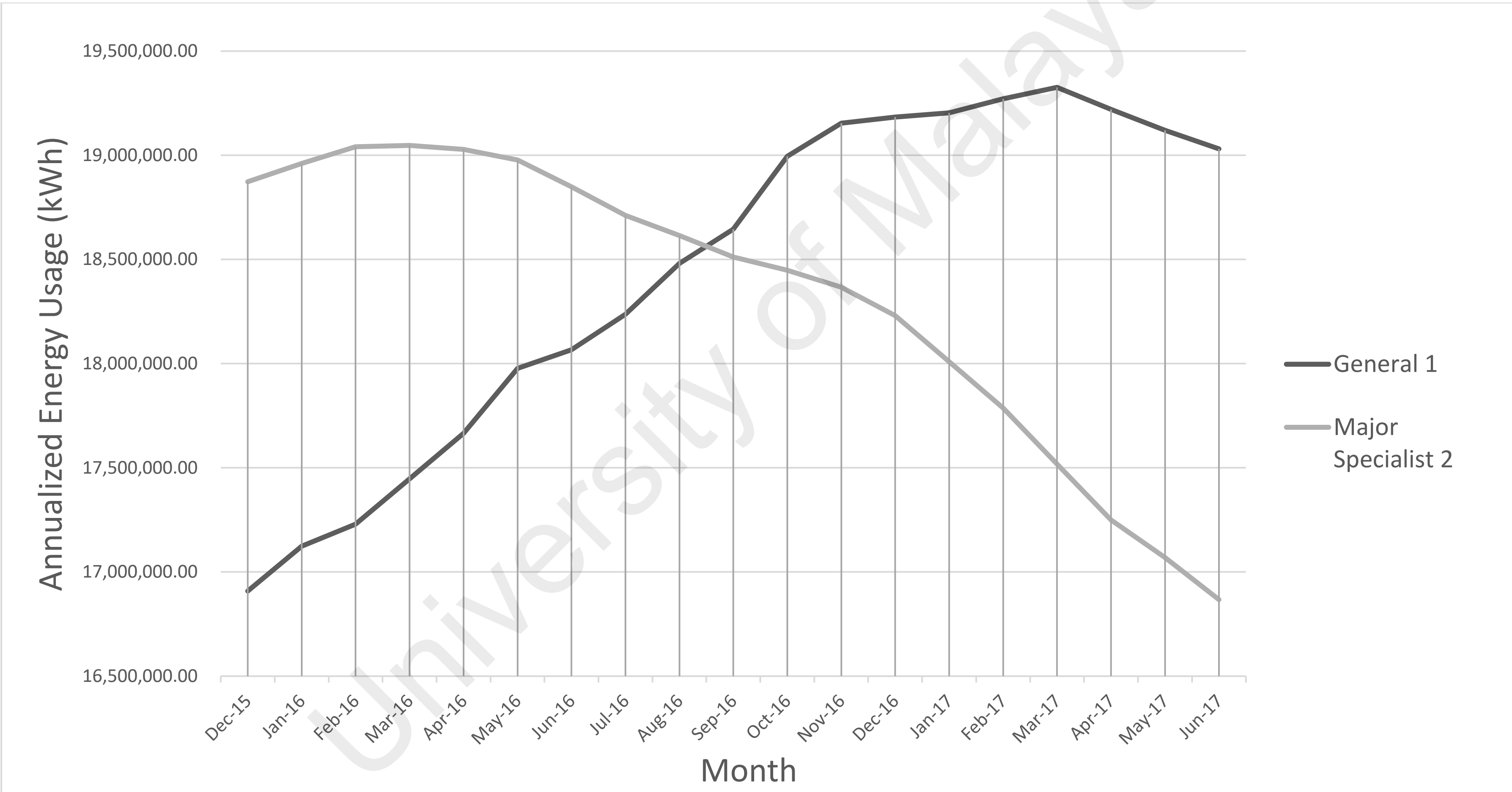

Figure 4.12: Comparison between two hospitals that has and has not implemented energy management system

4.5 Methods and technique to improve energy performance in hospitals

The previous subchapters discuss the expected baseline, energy consumption, load apportioning and BEI of Malaysian hospitals according to its categories. From there on, many methods and technique can be carried out as to improve the energy performance of hospitals, with the assistance of an established, strong and sustainable energy management system. This subchapter aims to fill the gap as to review literatures that explore the possibility of implementing various energy efficiency initiatives as to reduce the energy consumption of hospitals in Malaysia.

From the study by Saidur et al. (2010), energy reduction can be achieved through utilization of high efficiency motors (IE3, IE4) and variable speed drives on various equipment in hospitals. Chillers, chilled water pumps, condenser water pumps, exhaust fan, and fan motors can be retrofitted with variable speed drives as to reduce their energy consumption (Saidur et al., 2010) (Saidur et al., 2011). Teke and Timur (2014) also reiterated the need for VSD on motors and compressors, as well as to utilize heat exchangers to recover waste heat in the heating systems. It is expected that a pump system with VSD installed, could reduce power by 27% for 10% decrease of pump speed (Teke & Timur, 2014).

Another method to reduce energy consumption is to focus on building envelope and thermal insulation of a hospital building. Better insulation maintains and retains the required temperature for the building longer. Buonomano et al. (2014) discusses 4 different cases of energy efficiency retrofits, measuring their impact and concluded that significant amount of energy is lost due to the inefficiencies of the building envelope and the HVAC system and these should be the starting point for building retrofits (Buonomano, Calise, Ferruzzi, & Palombo, 2014). As hospitals are known to be very energy intensive due to the required precise microclimatic control, maintenance of necessary pressure and air changes, as well as strict requirement for temperature set points and relative humidity; it is of utmost importance to utilize techniques that involved building envelope and HVAC system manipulation. Various methods can be used to maintain and control the humidity of a respective unit. First is to use mechanical method, by means of overcooling and subsequent heating of the air, or the second method, by dehumidifying the air by means of adsorption, by using desiccants on a wheel (Ascione, Bianco, De Masi, & Vanoli, 2013). In Malaysia particularly, not many buildings employed the use of desiccant wheels to dehumidify the air before going into the room. Most of the buildings especially of older age in Malaysia employed the use of air-handler units that heat the sub-cooled air into desired temperature and relative humidity, and this wastes a lot of electricity in the form of heat. Figure 4.13 shows the difference between the use of desiccant wheels and mechanical method (sub-cooling and then heating) to achieve air temperature and humidity with the required specifications.

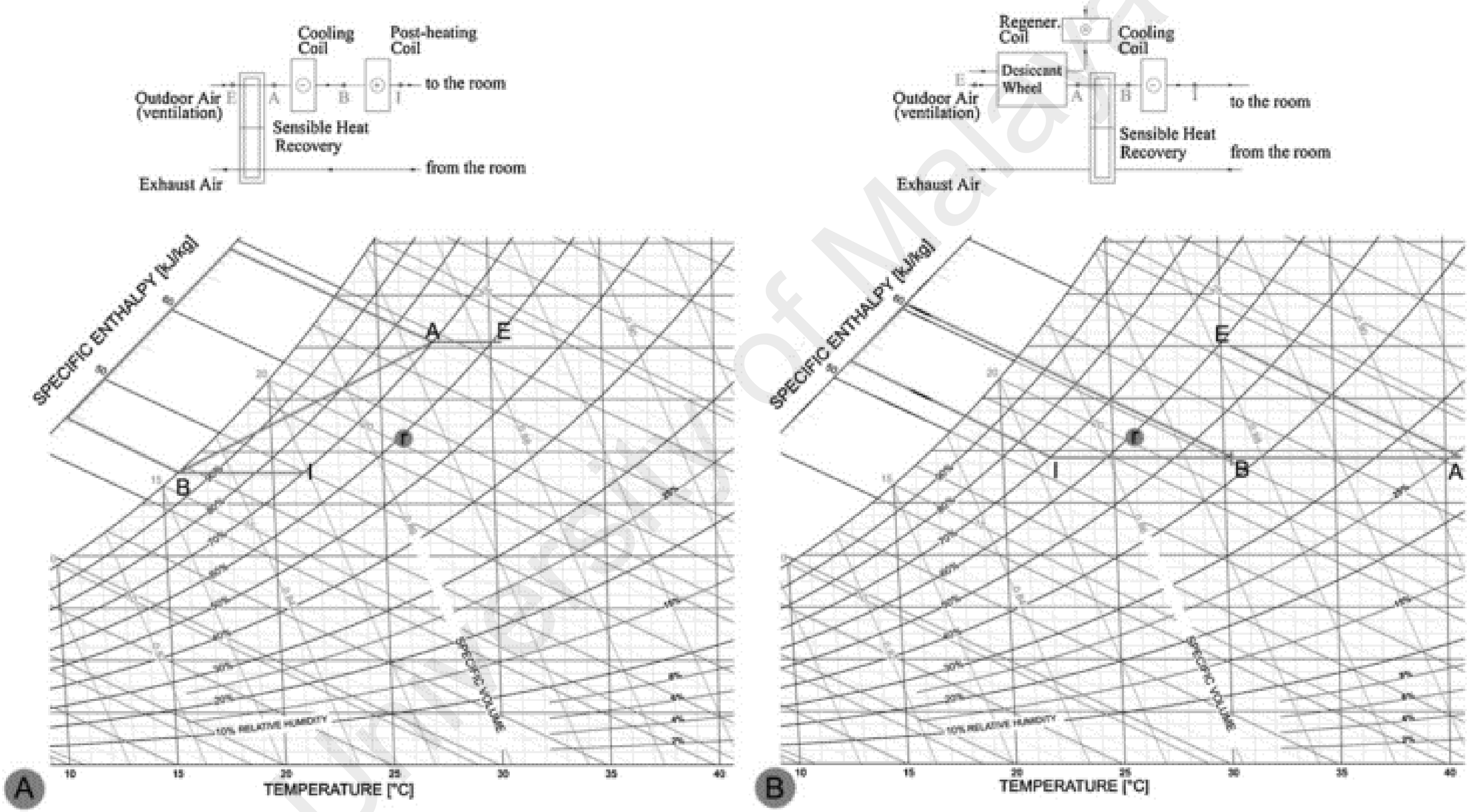

Figure 4.13: Air handled by HVAC system with mechanical (A) or dehumidification (B)
(Ascione et al., 2013)

HVAC's energy performance can be further improved by utilizing intelligent control, with the help of sensor controls for heating, cooling load, carbon dioxide concentration, humidity control, and VAV unit. Timer for the chillers as well as the air handling units can be set for certain operation hours, depending to what is required (Čongradac, Prebiračević, & Petrovački, 2014). In a study conducted by Bonnema et al. (2010), they studied the advantage of using heat pumps, high efficiency chillers and boilers, ventilation based on demand, more efficient pumps, tighter building envelope construction and building subsystems' integration (Bonnema, Studer, Parker, Pless, & Torcellini, 2010).

Other than HVAC and building envelope, hospital retrofits can be also done on lightings. Energy efficiency measures through lighting involve deployment of daylight or photo sensors; occupancy sensors where they are applicable; utilization of daylight and overhangs; reflective (albedo) and insulative surfaces; and energy efficient lighting such as LED. The expected savings could easily achieve more than 50% (Bonnema et al., 2010). Table 4.5 lists recommendations that could be implemented by building owner or facility manager to achieve 50 percent energy savings. The items that could be further improved and retrofitted are building envelope, lighting, and HVAC system components. The following items are then divided into various components that are given recommendation for improvements.

Table 4.5: Recommendations to achieve 50% energy savings

Item		Component	Recommendation
Envelope	Roofs	Insulation entirely above deck	R-25 c.i. to R-35 c.i., depending on climate zone
		SRI	Climate zone 1-3: 78, all other comply with Standard 90.1-2004
	Walls	Steel-framed	R-13 + R-7.5 c.i. to R-13 + R-21.6 c.i., depending on climate zone
	Slabs	Unheated	Comply with Standard 90.1
	Air Barrier	Infiltration	0.05 cfm/ft^2 of exterior wall and roof area
	Vertical fenestration	Total fenestration to gross wall area	40% max
		Thermal transmittance	U-0.20 to U-0.43, depending on climate zone
		SHGC – all types and orientations	SHGC-0.26 to SHGC-0.40, depending on climate zone
		Visible light transmittance	VLT-0.63 to VLT-0.69, depending on climate zone
		Exterior sun control (S, E, W only)	Projection factor of 0.5
Lighting	Interior lighting	Whole building interior LPD	0.88 W/ft^2
		Occupancy sensors	Installed in applicable zones
		Daylighting	400 lux continuous dimming in applicable perimeter zones
	Exterior lighting	Whole building exterior LPD	2.5 W/ft of exterior first floor façade perimeter
Operating Suite HVAC	Central air handling system	Water-cooled chiller	Variable speed, centrifugal, 7.0 COP, 44.0°F outlet temperature
		Cooling tower	Open tower, variable speed cooling tower fan
		Gas boiler	90% efficient condensing boiler, outdoor air temperature reset
		Pumps	Variable speed, 80% efficient
		Air-side economizer	Differential enthalpy controlled
HVAC	Water loop heat pump/dedicated outdoor air system	Water loop heat pump cooling efficiency	4.5 COP (15.4 EER) at 86°F
		Water loop heat pump heating efficiency	5.0 COP (17.1 EER) at 68°F
		Water loop heat pump fans	55% efficient, 0.30 in. w.c. pressure drop
		Condenser loop water-cooled chiller	Variable speed, centrifugal, 7.0 COP, 86.0°F outlet temperature
		Condenser loop cooling tower	Open tower, variable speed cooling tower fan
		Condenser loop gas boiler	90% efficient condensing boiler, 68.0°F outlet temperature
		Condenser loop economizer	Counterflow waterside economizer
		Condenser loop pumps	Variable speed, 80% efficient
		Dedicated outdoor air system fans	2.0 in. w.c. reduction over baseline central air handling system
		Dedicated outdoor air system boiler	90% efficient condensing boiler, outdoor air reset
		Dedicated outdoor air system chiller	Variable speed, centrifugal, 7.0 COP, 44.0°F outlet temperature
		Dedicated outdoor air system pumps	Variable speed, 80% efficient, 60 ft w.c.

(Bonnema et al., 2010)

Architectural strategies such as improved thermal envelope for example windows with natural ventilation, improved building massing, shading and daylighting strategy can also contribute to great energy reduction in hospitals. This can be seen from the case of Scandinavian hospitals being better than American hospitals (Burpee & McDade, 2014). The power demand for a given hospital must also be carefully monitored as peak demand shaving can contribute tremendously to cost savings and energy reduction (Chirarattananon, Chaiwiwatworakul, Hien, Rakkwamsuk, & Kubaha, 2010). In Malaysia, there is not enough actions being done to monitor and improve the maximum demand of major specialist and general hospitals that subscribed to C1 and C2 tariff (that requires the customer to pay for each unit of maximum demand in kW).

Next, to improve the system performance of hospital's energy consumption, it is necessary to have a good facilities management; regulating operational loads and managing extended operating hours. It is highlighted from a study by Min, Morgenstern, and Marjanovic-halburd (2016) where proactive operational control and rigorous maintenance regime are important to make sure optimal building's energy performance. It is important that integrated facilities management policies are developed to continuously improve the operation and maintenance of hospitals (Min et al., 2016).

The next vital method to improve hospital's energy performance is to establish an energy management system. Lee and Cheng (2016) reviewed various literatures on energy management system: from the years 1976 to 2014 in ranging topics. They concluded that energy management system can be broken down to 12 blocks where it could be further separated into 6 groups that are: EMS basic function, control function, analysis function, management function, advanced function and specific function groups. It is reported that the best energy management system is the one implemented for artificial lighting system with saving percentage up to 39.5% in average. As for HVAC and other equipment control, the savings are estimated at about 14 and 16 percent respectively (Lee & Cheng, 2016). Figure 4.14 explains the structure of an energy management system. A great EMS is one that includes basic functions, specific functions, management functions and control functions. From these functions, energy usage and system component performance can be monitored; scheduling, demand response and human comfort can be controlled; ISO based management and knowledge management can be implemented; and various specific functions that are tailored made for the buildings can be carried out.

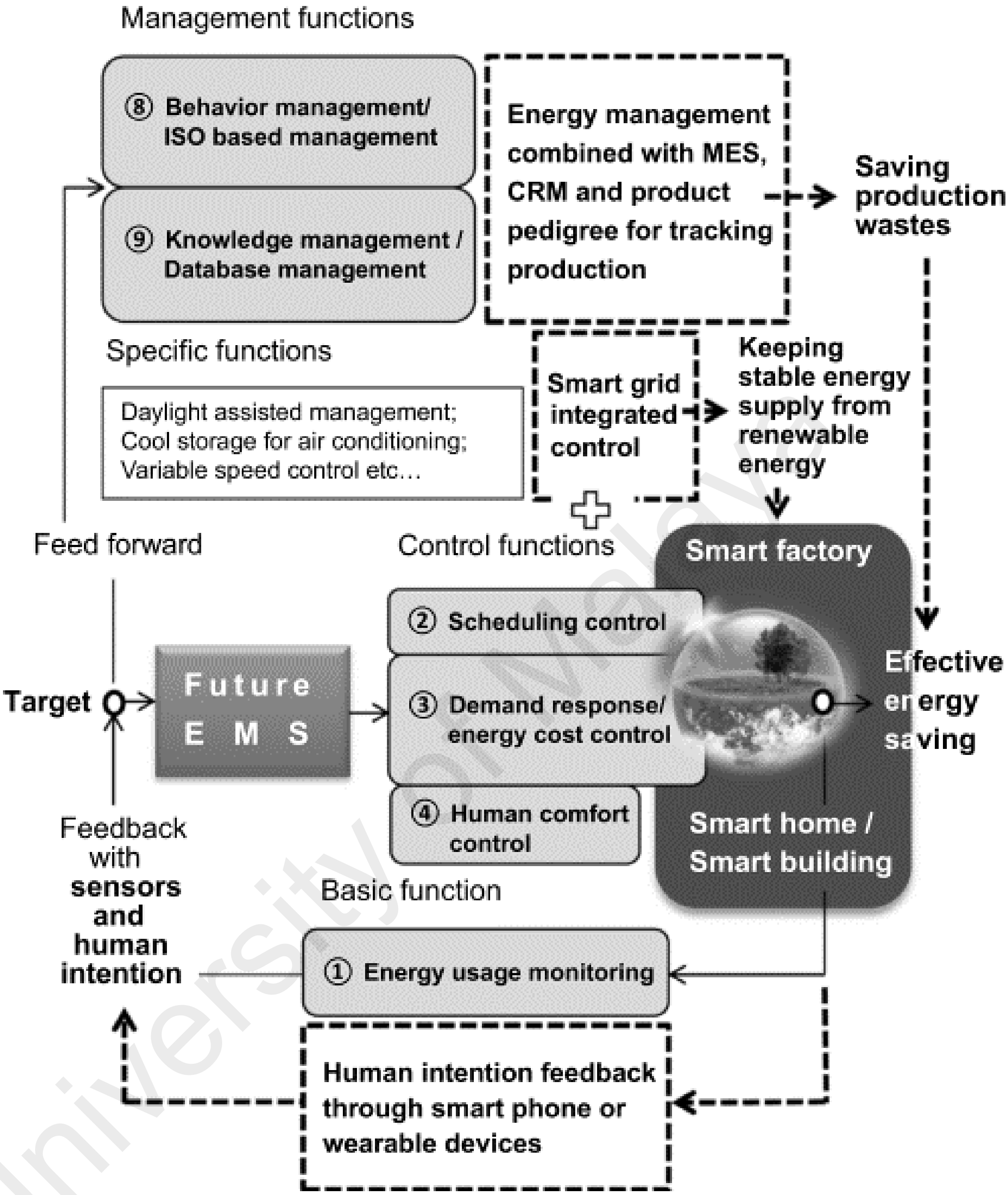

Figure 4.14: The structure of an energy management system
(Lee & Cheng, 2016)

The last but not least, of the methods to improve the energy performance in a hospital is to develop roadmaps, target and plan to improve energy efficiency while adhering to relevant standards. The energy performance roadmap must be comprehensive and be descriptive of what benchmark the organization needs to compare. The roadmap must consider the staff competency development and end-users awareness training (Singer & Tschudi, 2009). The hospital also must always check and review whether their equipment and building is operating according to the latest existing standards, for example MS1525:2014, MS:ISO50001 and Malaysian Society for Quality in Health (MSQH) standards. The barriers that hinder energy efficiency projects and programs from being implemented must be overcame and uplifted so that the program can sail smooth and sound. Of the barriers that must be considered are high investment costs during the earliest phase of the project that have long payback period which could take more than 3 years. As in the specific case of Malaysia, the electricity price is among the cheapest in the world and the energy costs represent only a small portion of the overall spending. Hence, the energy efficient measures do not significantly affect the core processes (Wang, Li, Liao, & Fang, 2016). In Malaysia as well, there are lack of incentives for energy conservation and emission reduction other than the energy audit conditional grant not to mention the lack of framework for energy performance contracting (EPC). There were also limited number of demonstrable success for energy efficiency projects and most of the projects are not publicly visible.

CHAPTER 5: CONCLUSION

It was apparent from the study that existing literatures that discussed energy consumption of hospitals and their benchmarking is of no to little significance on the specific case of Malaysia. Many of the studies are only relevant for European and American hospitals in which energy consumption comes predominantly from thermal sources such as gas or coal as opposed to electricity. Thus, the new benchmarking study provide a new set of data that other southeast Asian countries can refer to. The study also sets the minimum, maximum and the average value that Malaysian and ASEAN policymakers and practitioner can refer to as a guide for improvements in hospitals.

The BEI charts are general in nature as to be representative of all hospitals in their respective categories regardless of their locations and sizes, but this can be a disadvantage where specific benchmarking charts for energy demanding departments such as operation theatres, CSSU, or for hospital of equal specifications and services should be developed.

The load apportioning in the study provides a brief look of what the final end-use should be and where to improve, as to further improve from the study conducted by previous researchers. There are rooms for improvement as limited number of samples are used for this study and may not be representative of all hospitals in Malaysia.

The impacts of El Niño to Malaysian hospitals' energy consumption were also studied, and it could be a good reference point to anticipate the consumption hike that could arise from the event; to develop mitigation and adaptation response plan for such situation. From the El Niño study, it was found that the energy consumption could hike up to 13.6% from the baseline, projecting the increase of electricity usage cost in the respective period. Based on this, many measures can be taken to aid Malaysian hospitals respond to this phenomenon.

Finally, the report ended with a review of methods and techniques that can help hospitals reduce more energy and be more energy efficient from various perspectives, as to implement improvement measures that are holistic, economically feasible and technically proven. The study discusses the possibility to implement retrofits on chillers such as VSD; retrofits on building envelope, HVAC system components such as AHU, lighting and controls; as well as through the implementation of a sustainable energy management system, realistic energy performance target and roadmap development.

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