

ENERGY SAVING OPPORTUNITIES FOR MALAYSIAN HOSPITALS

KHAIRUL AZMY KAMALUDDIN



UMS

UNIVERSITI MALAYSIA SABAH

PERPUSTAKAAN
UNIVERSITI MALAYSIA SABAH

**FACULTY OF ENGINEERING
UNIVERSITY MALAYSIA SABAH
2017**

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS

Judul : **ENERGY SAVING OPPORTUNITIES FOR MALAYSIAN HOSPITALS**

Ijazah : **IJAZAH DOKTOR FALSAFAH**

Saya , sesi pengajian **2011-2012**; mengaku membenarkan tesis Ijazah Doktor Falsafah ini disimpan di perpustakaan Universiti Malaysia Sabah dengan syarat-syarat seperti berikut:-

1. Tesis ini adalah hak milik Universiti Malaysia Sabah
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tanda (/).

☐

SULIT (mengandungi maklumat yang berdarjah keselamatan atau kepentingan malaysia seperti yang termaktub di dalam AKTA RAHSIA 1972).

☐

TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi /badan dimana penyelidikan dijalankan).

☐

TIDAK TERHAD

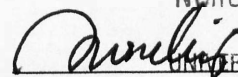
KHAIRUL AZMY KAMALUDDIN

Disahkan oleh,

NURULAIN BINTI ISMAIL

LIBRARIAN

UNIVERSITI MALAYSIA SABAH



Tandatangan Pustakawan

Tarikh: 09 MEI 2017

(Prof. Madya Ir. Dr. Yang Soo Siang)
Penyelia

ENERGY SAVING OPPORTUNITIES FOR MALAYSIAN HOSPITALS

KHAIRUL AZMY KAMALUDDIN



**THESIS SUBMITTED IN FULFILLMENT FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY**

**FACULTY OF ENGINEERING
UNIVERSITY MALAYSIA SABAH
2017**

DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excerpts, equations, summaries and references, which have been duly acknowledged.

25 April 2017

Khairul Azmy Kamaluddin
Pk20119127



UMS
UNIVERSITI MALAYSIA SABAH

CERTIFICATION

NAME : **KHAIRUL AZMY KAMALUDDIN**
MATRIC NO : **PK20119127**
TITLE : **ENERGY SAVING OPPORTUNITIES FOR
MALAYSIAN HOSPITALS**
DEGREE : **DOCTOR OF PHILOSOPHY
(ELECTRICAL AND ELECTRONIC ENGINEERING)**
VIVA DATE : **16 JANUARY 2017**

CERTIFIED BY ;

1. SUPERVISOR

Prof Madya. Ir. Dr. Yang Soo Siang

Signature



UMS
UNIVERSITI MALAYSIA SABAH.....

ACKNOWLEDGEMENT



First and foremost, I would like to express my deepest appreciation and my sincere gratitude to my supervisor Associate Professor Ir. Dr. Yang Soo Siang, for his direction and guidance. Without his guidance, assistance and persistency, this thesis would not have been possible. My sincere thanks to the Faculty of Engineering, University Malaysia Sabah for all the assistance provided. My appreciation also goes to the Ministry of Health, Malaysia for providing me the platform and support on the research subject. My special thanks to my good friends for their companion, support and encouragement that I always need going through the tough times trying to complete my work. To my beloved mother, brothers and sisters, many thanks for all the love, encouragement and support that have helped me so much. Lastly, but most important of all, I would like to express my never-ending love and appreciation to my beautiful wife Zurie, my daughters Nina and Aisyah, and my son Izzat for their patience and never-ending support during my journey in trying to complete my work.

Khairul Azmy Kamaluddin

16th January 2017



UMS
UNIVERSITI MALAYSIA SABAH

ABSTRACT

There has been a growing interest in the Malaysian government on the issue of energy efficiency and the environment. While much information is already available insofar as technology and building engineering systems are concerned, what is lacking is the local energy performance information. Continuous monitoring and managing of performance will provide the health sector a realistic local and regional energy performance benchmarks in line with any changes in local and regional energy policies and regulations. This thesis presents the investigation and analysis of electrical energy performance characteristics of hospital buildings in Malaysia. A generic questionnaire was developed to collect energy data of hospital buildings and to acquire comprehensive knowledge on energy performance characteristics for developing a generic hospital-base energy benchmarks for a hot and humid climate. Calculated electrical consumption indices and representative benchmarks introduced in this study can be practically used in whole building energy-use comparison between hospitals. Information gathered from the survey was used to construct a typical Base-case hospital building model. Using building simulation method with local weather data, areas of energy savings opportunities and its cost effectiveness are investigated. The study highlighted the diversity of electrical energy consumption across hospitals, the lacking of energy conscious design, and the opportunity to save energy consumption through building and systems retrofit. Simulation using selected cost effective energy savings measures suggests that the Annual Electrical Energy Use Index (EUI) of the typical Base-case hospital building model can be significantly reduced. The study suggest applicable energy efficiency guideline for retrofitting existing hospital building in Malaysia, focusing on the importance of computer simulation program, assessment, measurement and verification of site energy data, improvement of building envelope, cooling and ventilation system, lighting system, operation and maintenance, and the importance of implementing energy management policy in the health building sector.

ABSTRAK

PELUANG PENJIMATAN TENAGA BAGI HOSPITAL-HOSPITAL DI MALAYSIA

Perihal berkaitan dengan kecekapan tenaga dan persekitaran telah mendapat perhatian yang semakin meningkat oleh kerajaan Malaysia. Walaupun maklumat mengenai teknologi dan kejuruteraan bangunan mudah didapati tetapi maklumat mengenai prestasi penggunaan tenaga masih lagi jarang ditemui. Pemantauan dan pengurusan tenaga secara berterusan boleh memberikan tanda aras prestasi tenaga di sektor kesihatan seiring dengan perubahan polisi atau peraturan di peringkat setempat dan negara. Tesis ini memberikan maklumat mengenai kajian dan analisis prestasi penggunaan tenaga elektrik di bangunan hospital di Malaysia. Suatu borang kaji selidik telah disediakan bagi mengumpul maklumat tenaga elektrik hospital untuk mendapat pengetahuan mendalam mengenai ciri penggunaan tenaga bagi tujuan membentuk tanda aras tenaga secara umum bagi bangunan hospital di dalam iklim panas dan lembab. Index dan tanda aras yang diperkenalkan di dalam kajian ini boleh digunakan bagi membuat perbandingan penggunaan tenaga antara hospital-hospital. Maklumat daripada borang kaji selidik tersebut juga digunakan bagi membina model bangunan hospital rujukan. Dengan menggunakan kaedah simulasi dan data iklim tempatan, peluang untuk penjimatan tenaga dan kos dapat dikaji. Kajian ini juga mengutarakan julat penggunaan tenaga elektrik antara hospital-hospital, rekabentuk bangunan yang tidak peka kepada penjimatan tenaga termasuklah mencari peluang-peluang yang ada untuk menjimatkan tenaga elektrik melalui penambahbaikan ke atas bangunan dan sistem. Langkah penjimatan tenaga yang dinilai melalui simulasi komputer ini menunjukkan index penggunaan tenaga elektrik tahunan oleh model bangunan rujukan tersebut boleh dikurangkan secara berkesan. Kajian ini mengetengahkan juga garis panduan kecekapan tenaga untuk penambahbaikan bangunan hospital yang sedia ada di Malaysia, dengan memberikan fokus kepada kepentingan penggunaan simulasi komputer, penilaian, pengukuran dan pengesahan data tenaga, penambahbaikan kepada aspek luaran bangunan, sistem hawa dingin dan pengudaraan, sistem pencahayaan, operasi dan senggara di samping implementasi polisi pengurusan tenaga bangunan di dalam sektor kesihatan negara.

TABLE OF CONTENTS

	Page
TITLE	i
DECLARATION	ii
CERTIFICATION	iii
ACKNOWLEDGEMENT	iv
ABSTRACT	v
<i>ABSTRAK</i>	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	xi
LIST OF FIGURES	xiv
LIST OF ABBREVIATIONS	xvii
LIST OF APPENDIX	xix
 CHAPTER 1: INTRODUCTION	
1.1 Research Background	1
1.2 Aim and Objectives	2
1.3 Scope of Research	2
1.4 Method and Approach	3
1.5 Thesis Contribution	5
1.6 Thesis Organization	6
1.7 Limitation of Study	8
 CHAPTER 2: LITERATURE REVIEW	
2.1 Introduction	9

2.1.1	Building Energy Standard Development and Status	10
2.1.2	Building Energy Standards in ASEAN Region	13
2.1.3	Potential for Energy Efficiency Improvement	18
2.2	Energy Efficiency Program	19
2.2.1	Electricity Consumption Growth in Malaysia	19
2.2.2	Malaysian Energy Efficiency Initiatives	21
2.2.3	Energy Efficiency Effort in Hospitals	23
2.3	Energy Benchmarking for Hospital Buildings	31
2.3.1	Performance Benchmarks	31
2.3.2	Energy Assessment Methods and Building Energy Standards	33
2.3.3	Benchmarking methods	39
2.4	Modeling of Energy Performance in Buildings	40
2.4.1	Building Energy Simulation Method	40
2.4.2	Regression Technique for Simplified Energy Assessment	41
CHAPTER 3: METHODOLOGY AND ANALYSIS		
3.1.	Data Collection	44
3.1.1	Hospital Energy Assessment Survey	44
3.1.2	Survey Objectives and Scope	46
3.1.3	Survey Methodology and Procedures	47
3.1.4	Compilation of Energy Consumption Indicators	49
3.2	Data analysis	51
3.2.1	Development Of A Representative Distributional Energy Benchmarking For Malaysian Hospitals	51
3.2.2	Description of Hospital Buildings	52
3.2.3	Electrical Energy Analysis	53
3.2.4	Significance of Collected Data	61
3.2.5	Apportionment of Major Energy End-users	62

3.2.6	Developing Distributional Benchmark	66
3.3	Application Of Multiple Regression Technique To Develop A Simplified Energy Use Model For Hospital Buildings Using Surveyed Data	71
3.3.1	Statistical Analysis Benchmarking	71
3.3.2	Regression-based Techniques in Energy Modeling	73
3.3.3	Model Construction	76
3.4	Investigation Of Base-Case Hospital Building Energy Characteristics Using Simulation Modeling	84
3.4.1	EnergyPlus Simulation Software	85
3.4.2	Hospital Building Design Information	87
3.5	Simulation Analysis of the Base-case Hospital Building Model	99
3.5.1	Calibration of simulation	100
3.5.2	Comparing Base-Case Parameters to Others	103
3.5.3	Building Model Heat Gain Analysis	105
CHAPTER 4: RESULTS AND DISCUSSION		
4.1	Results	120
4.2	Discussion	128
4.2.1	Strategies In Retrofits Energy Efficiency And Saving Measures	128
4.2.2	Energy Savings Options	131
4.2.3	Need of Better Dehumidification Control and Energy Recovery System	144
4.2.4	Cost Effectiveness Analysis of Energy Conservation Measures	145
4.2.5	Building Energy Performance through Overall Improvement	148
4.2.6	A General Guideline for Improved Energy Usage in Malaysian Hospital	149

**CHAPTER 5 : CONCLUSION AND RECOMMENDATION FOR
FURTHER WORK**

5.1 Conclusion	153
5.2 Recommendation for Further Work	156
References	
Appendix A	172
Hospital Building Energy Assessment Questionnaire	
Table A1 Energy assessment survey time plan	
Appendix B	188
HBEAQ Parameters	
Table B1 Regression Statistics	
Table B2 Year 2014 Monthly Electrical Energy Consumption collected from Utility Bills for the 28 hospitals	
Table B3 Mean daily temperature in Degrees Celsius and mean daily solar radiation in MJ/m2 at 20 selected Weather Station, Malaysia.	
Table B4 Tabulation of Energy Breakdown Estimates	
Appendix C	202
Table C1 Values of Pair-wise Correlation Coefficient of Determination (R2)	
Appendix D	204
Table D1: Extract of Kuala Lumpur, Malaysia weather data	
Table D2 – D12: Results of Base-case Model Simulation	
Extract of EnergyPlus Input File : BasecaseTypHospital.idf (in text format)	

LIST OF TABLES

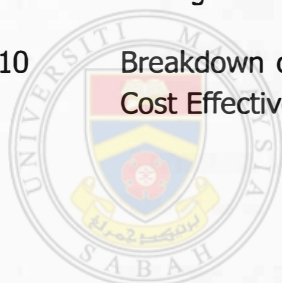
	Page
Table 2.1 Comparison of OTTV Based Design Standards in ASEAN Countries	15
Table 2.2 UK Good and Typical Practice Benchmarks for Delivered Energy Consumption of Hospitals (GJ/100m ³ heated volume)(DETR/BRESCU,1996).	32
Table 2.3 Performance Benchmark of a Large Acute Hospital (kWh/100m ³ per year) Based on EEO Guide	33
Table 2.4 Brief Comparison of Widely Used Energy Assessment Methodologies and Standards for Building	34
Table 2.5 Applications of Selected Energy Standards, Codes and Guidelines	37
Table 2.6 Comparison of Typical Malaysian Whole Building Energy Performance Standard to UK Standard in Annual kWh/m ²	39
Table 3.1 Parameters Collected from HBEAQ Survey Questionnaire	50
Table 3.2 EEUI (kWh/m ² /yr) to Gross Floor Area(GFA) and Mechanically Conditioned Area(MCA) According to Hospital Types	56
Table 3.3 Measured Average Values of EEUI in kWh/m ² /yr for Malaysian Hospital and Comparison to Other Building Standard Values in Similar Climate	57
Table 3.4 Average of Percentage Values of Annual Energy Consumption Breakdown Based on Hospital Categories	65
Table 3.5 Representative Apportionment Benchmarks in kWh/m ² /yr based on Estimates	68
Table 3.6 Comparison of the 990-bed Hospital Actual Annual	69

Consumption to Set Target

Table 3.7	Values of Pair-wise Correlation Coefficient of Determination (R^2)	80
Table 3.8	Precision comparison of alternative variables/indicators	83
Table 3.9	Hospital Building Construction Elements and Properties	92
Table 3.10	Construction Thermal, Solar and Visible Absorption Properties	93
Table 3.11	Base-case Occupancy Activity and Temperature Set-points	95
Table 3.12	Base-case Building Occupancy Schedule (in fractions) for Ground Floor Zones	97
Table 3.13	Characteristics of Malaysian Reference Base-case Hospital Building	98
Table 3.14	Breakdown of Annual Energy Consumption for Base-case Building Model	100
Table 3.15	Acceptable tolerances for monthly and yearly ERR	102
Table 3.16	Comparison of Typical Malaysian Hospital Building and Energy Use Characteristics to Other Country Typical Hospital Building	104
Table 3.17	Comparison of Selected Roofing Properties and its Annual Energy Consumption Reduction to Base-case Building	115
Table 3.18	Summary of Base-case Simulated Design Cooling Requirement	118
table 4.1	Simulation Input Changes for Potential Reduction in Energy Consumption	130
Table 4.2	Comparison of Properties of Selected Glazing Retrofits	132
Table 4.3	Comparison of Peak Daily Solar Heat Gains through	133

Glazing

Table 4.4	Comparison of Annual Energy and Energy Cost Savings from Glazing	134
Table 4.5	Comparison of Cooling Capacity, Maximum Daily Heat Gains and Heat Output of Selected Lighting Retrofits	136
Table 4.6	Comparison of Annual Energy Usage and Cooling Requirement from Lighting Changes	138
Table 4.7	Generic Parameters of Cooling and Ventilation Systems in Simulation	140
Table 4.8	Comparing Simulation Model of a CAV System, Improved chiller COP, VAV System and Fan Coil System Annual Energy Consumption	143
Table 4.9	Cost Effectiveness Analysis from the Selected Energy Saving Measures (ESM)	146
Table 4.10	Breakdown of Annual Energy Consumption of Selected Cost Effective ESM in Comparison to Base-case Building	148



UMS
UNIVERSITI MALAYSIA SABAH

LIST OF FIGURE

		Page
Figure 2.1	Conventional Approaches for Compliance in Building Energy Standards (CEC 2013)	12
Figure 2.2	Electrical Energy Use in Malaysia. a)Annual Electricity Use from 1980 to 2010, b) Breakdown Comparison of Electricity Use among Major Sectors	20
Figure 3.1	Monthly Consumption Trends of the 28 Malaysian Hospitals (legends shows hospital codes)	54
Figure 3.2	Mean Daily Temperatures for 2010 to 2014	54
Figure 3.3	Past 5 year climatic data of absolute maximum and minimum dry bulb temperature recorded at KLIA Airport weather station	55
Figure 3.4	Correlation of Annual Energy Consumption to Floor Area Mechanically Conditioned	59
Figure 3.5	Relation of Installed Chiller Capacity to Annual Energy Consumption	60
Figure 3.6	Annual Energy Intensity Normalized to Area Mechanically Conditioned	61
Figure 3.7	Frequency and Cumulative Distribution EEUI of 28 hospitals	62
Figure 3.8	All hospitals End-use Energy Breakdown	65
Figure 3.9	Comparison of Energy Breakdown for Hospital and Office Building. (MECM, 2001) for Typical Office Building	66
Figure 3.10	Ranking of Hospital Energy Use Intensity (GFA)	68
Figure 3.11	Prediction of annual energy consumption of Malaysian hospital with 90% confidence interval.	83

Figure 3.12	Schematic of EnergyPlus Simultaneous Solution Scheme	86
Figure 3.13	Base case Hospital Building Layout and Floor Plan	90
Figure 3.14	Comparing Base-case Model to State Hospital Annual Energy	101
Figure 3.15	Site Data for Base-case Hospital Building Simulation Modeling	106
Figure 3.16	Base-case Building Heat Gains through Building Components and Ventilation (refer Appendix D for tabulated detail)	106
Figure 3.17	Comparison of Zone Daily Solar Heat Gains through Glazing	108
Figure 3.18	Comparison of Zones Heat Gain (Ground Floor) through Mechanical Ventilation	108
Figure 3.19	Summer Design Daily Internal Heat Gains for Base-case Hospital	109
Figure 3.20	Annual Internal Heat Gains for Base-case Hospital	110
Figure 3.21	Internal Gains for Ground Floor East Zone	111
Figure 3.22	Internal Gains for Ground Floor West Zone	111
Figure 3.23	Internal Gains for First Floor East Zone	112
Figure 3.24	Internal Gains for Third Floor East Zone Naturally Ventilated	112
Figure 3.25	Summer Design-day Base-case Building Roof Zone Hourly Average Air Temperature Variation	113
Figure 3.26	Summer Design-day Hourly Temperature Profile for the Naturally Ventilated Third Class Wards below Roof	114
Figure 3.27	One Day Hourly Temperature Profile of the Naturally Ventilated Third Ward East Zone During the Cool Season	114
Figure 3.28	Annual Daily Air Temperature and Heat Gain Profile of	115

	Base-case Roof	
Figure 3.29	Roof Heat Gain of Base-case Building compared to Heat Gain with Added Insulation	116
Figure 3.30	Daily Roof Space Air Temperature Reductions Using Various Insulations	117
Figure 3.31	Comparison of Zones Cooling Load Requirement for Base-case Building	119
Figure 3.32	Monthly Electrical Energy Consumption of Base-case Building	119
Figure 4.1	Comparing Heat Gains through Different Glazing Materials	132
Figure 4.2	Comparison of Hourly Heat Gain from Selected Lighting Types	136
Figure 4.3	Variation of Building Average Daily Cooling Delivery due to Changes in Lighting Types	137
Figure 4.4	Annual Electricity (kWh) of Building using Selected Lightings	138
Figure 4.5	Schematic of a VAV system for the simulation	141
Figure 4.6	Schematic of a Fan Coil System for the Simulation	143
Figure 4.7	Comparisons of EEUI and Cooling Capacity Reduction from Selected ESM	149

LIST OF ABBREVIATIONS

AEC	Annual Electrical Energy Consumption in kWh
AHU	Air Handling Units
ASEAN	Association of Southeast Asian Nations American Society of Heating, Refrigeration and Air Conditioning
ASHRAE	Engineering
β	Regression Coefficient
BES	Building Energy Standard
BLAST	Building Loads Analysis and System Thermodynamics Modeling Engine
CAV	Constant Air Volume System
CIBSE	Chartered Institution of Building Services Engineers
COP	Coefficient of Performance
CV(RMSE_{Month})	Coefficient of Variation of the Root-Mean-Squared Monthly Errors
E	Error Component of a MLR
EEUI	Electrical Energy Utilization Index in kWh/m ² /yr
EIR	Energy Input to Cooling Output Ratio
ERR_{Month}	Monthly Error
FCU	Fan Coil Units
GFA	Gross Floor Area in m ²
HBEAQ	Hospital Building Energy Assessment Questionnaire
HVAC	Heating, Ventilation and Air-Conditioning
MCA	Mechanically Conditioned Area
MLR	Multiple Linear Regression
MTOE	millions tons of oil equivalent
MVAC	Mechanical Ventilation and Air Conditioning
N_{month}	The Number of Utility Bills in the Year
OTTV	Overall Thermal Transfer Value in W/m ²
R²	Coefficient of Determination
RMSE	Root-Mean-Squared Monthly Error

RTTV	Roof Thermal Transfer Value in W/m^2
SHGC	Solar Heat Gain Coefficient
TR	Tonnes of Refrigeration
U-value	Thermal Transmittance in $\text{W/m}^2\text{-K}$
VAV	Variable Air Volume System
WWR	Window to Wall Ratio
X	Independent Variable of a MLR
Y	Dependent Variable of a MLR



UMS
UNIVERSITI MALAYSIA SABAH

LIST OF APPENDIX

	Page
Appendix A Hospital Building Energy Assessment Questionnaire	172
Table A1 Energy assessment survey time plan	
Appendix B HBEAQ Parameters	188
Table B1:Regression Statistics	
Table B2:Year 2014 Monthly Electrical Energy Consumption collected from Utility Bills for the 28 hospitals	
Table B3:Mean daily temperature in Degrees Celsius and mean daily solar radiation in MJ/m2 at 20 selected Weather Station, Malaysia	
Table B4: Tabulation of Energy Breakdown Estimates	
Appendix C Values of Pair-wise Correlation Coefficient of Determination (R2)	202
Appendix D Extract of Kuala Lumpur, Malaysia weather data	204
Table D2 – D12: Results of Base-case Model Simulation	
Extract of EnergyPlus Input File : BasecaseTypHospital.idf (in text format)	

CHAPTER 1

INTRODUCTION

1.1 Research Background

The focus of this thesis is on the investigation and assessment of electrical energy usage characteristics and its implications on energy efficiency and energy saving efforts in the context of Malaysian hospital buildings. This chapter explains the aims and objectives, scope of research, research approach, and the relevant contributions of the research work to the body of knowledge in the area of energy efficient building. The chapter ends with a brief summary of the organisation and content of this thesis.

The continuous rapid economic and population growth in the last several decades has resulted in the planning and construction of many new hospitals in Malaysia. Apart from this, many existing large referral hospitals have been or in the process of major physical upgrading and refurbishment to meet the current and stringent medical standards, and to provide new facilities and services for new and expanding medical services. With a hot and humid climatic condition, plus the high expectation and requirement of medical and clinical standards, most hospitals have become very energy intensive. The Malaysian Code of Practice on Energy Efficiency and Use of Renewable Energy For Non Residential Building (MS 1525, 2014) aimed at promoting energy efficiency of buildings has been trying to encourage a general awareness in energy conscious design and operational practice. Lately, there has been a growing interest in the Malaysian government on the issue of energy efficiency and the environment. Malaysia National Green Technology Policy was launched in 2009 under KeTTHA, which promotes efficient use of energy that covers major area such as energy, building, transportation and water sector.

There is no doubt that a very significant increase in hospital operational costs is due to the increase in energy usage. In the current healthcare environment, where hospitals are generally recognised as the main energy users, operational cost

optimization is significant without compromising the quality of medical services provided to patients/clients.

1.2 Aim and Objectives

The aim of this research is to formulate or develop an approach to achieve energy efficiency that is applicable for hospital buildings in Malaysia. By acquiring comprehensive knowledge on energy performance characteristics of hospital buildings in Malaysia, energy saving opportunities can be objectively analysed. Investigation and analysis of energy performance characteristics of hospital buildings in Malaysia using appropriate assessment methodology and analytical tools is therefore important for the purpose of establishing areas of energy wastage and developing strategies in efficient energy usage. This is crucial in order to extract the maximum benefits out of a more efficient building system. While much information is already available insofar as technology and building engineering systems are concerned, there is lacking in the local performance information and benchmarking, and information on breakdown of energy consumption of hospital buildings, critical for the understanding of Malaysian hospital's energy profile and the many significant contributions it can provide. These objectives can be achieved through:

- Collecting and quantifying actual electrical energy consumption of hospital buildings using an appropriate assessment method.
- Developing specific Electrical Energy Utilization Index representative of Malaysian hospitals as a benchmarking
- Identifying usage trends on energy consumption associated with design and operation and to demonstrate opportunities on viable and cost effective energy improvement measures.
- Based on study outcome, to suggest applicable energy efficiency guideline for retrofitting existing hospital building in Malaysia

1.3 Scope of Research

The scope of this study will be on all existing government hospitals in Malaysia where, to date, no comprehensive research on its energy usage characteristics were

achieved. Information established in literatures on hospital energy profiles in developing countries with hot and humid climates is not readily available. Many essential and important data about detail hospital energy consumption used to be non-existence or incomplete. Nevertheless, in the Malaysian context, most of these raw energy data should be readily available due to the requirement of the hospital support services organization to keep full records of hospital building services activities. This record-keeping requirement is set under the Privatization Project of the Hospital Support Services (MOH, 1996).

The key issue and concern to be looked at will be on the use of electrical energy for the maintenance of comfort in hospital environment. This is the area where energy is consumed most in all buildings in hot and humid climatic regions. It is hoped that this study can be a useful basis in formulating and establishing a full understanding of energy characteristics in hospital buildings in the region.

1.4 Method and Approach

One of the key tasks in identifying energy performance characteristic is the collection of all energy related data. Assessment and analysis of actual detail energy consumption of individual system or building would be the best way in finding energy performance characteristic. The practicality of actual monitoring will depend on the availability of adequate energy metering and monitoring tools. Preliminary desktop data collection using surveys and questionnaires are used to minimise fieldwork. With some method of accuracy verification, the information gathered should be able to estimate or model hospital's annual energy consumption and its energy end uses aggregation.

By specifying and classifying the hospital building samples, data collection includes information about function, operational and occupancy characteristics of hospital building. Other parameters include types of hospital building, total gross floor area, operating hours, indoor environmental condition, system performance data, monthly energy consumptions and local weather data. From these data, statistical analyses can be performed to obtain the correlation and relationship between the different energy related parameters.