ENERGY SAVING OPPORTUNITIES FOR MALAYSIAN HOSPITALS

KHAIRUL AZMY KAMALUDDIN

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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

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CERTIFIED BY ;

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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 collects 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 (EEUI) 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.

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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 garispanduan 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.

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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
ß	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/m2/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
R^2	Coefficient of Determination
RMSE	Root-Mean-Squared Monthly Error

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

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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

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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

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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.