THE DEVELOPMENT OF ENERGY EFFICIENCY ESTIMATION SYSTEM FOR DOMESTIC HOUSING BY USING QUALITY FUNCTION DEPLOYMENT APPROACH

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In the name of Allah. The Most Gracious, The Most Merciful.

For my beloved father and mother,

Haji A. Rahman Bin Pawiroh and Hajah Natijah Binti Md Noh

My dearest husband,

Associate Professor Dr. Abdul Mutalib Bin Hj. Leman

and

My precious sons,

Muhammad Aiman Fahmi

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ABSTRACT

In this modern era of globalization, energy is regarded as a precious resource. In Malaysia, the domestic sector is the third largest consumer of energy and it has an impact on energy consumption in the country. Thus, energy efficiency and cost effectiveness are the key factors in maintaining economic growth. The purpose of this study is to develop the Energy Efficiency Estimation System (EEES) that considered the consumer needs. In the preliminary stage of this study, the response from 408 respondents about their energy awareness in terms of two components: i) knowledge, and ii) practice, was determined through the use of questionnaires in a survey on energy. The results showed that consumers have the highest knowledge about energy awareness, but they do not put that knowledge into practice. Testing and measurements of energy efficiency were also carried out to prove that the use of highly efficient electrical appliances can reduce electricity consumption at home. The tests were conducted on five types of electrical appliances for which it is mandatory to have the Energy Star Rating in Malaysia. Next, the Quality Function Deployment (QFD) approach was adopted in the system design in order to develop the system. The QFD approach focuses on the consumer's opinion on how the system should be developed. The selection of consumers was based on the residential areas in four main zones (South, North, East, and West) in Peninsular Malaysia. 184 respondents participated in this survey. The database for the developed system was related to the energy usage of electrical appliances based on the data obtained from the relevant ministry/agencies such as the Energy Commission, and Tenaga Nasional Berhad (TNB). The developed system was verified by means of its implementation in 30 houses in Larkin, Johore. The results showed that 66.7% of the respondents who fully applied the EEES were able to reduce their energy consumption by up to 30% within a month. By considered the knowledge and practice among consumers, the EEES was successfully developed by using the QFD approach and this system allow users to self-manage energy consumption by estimating energy efficiency and the energy saving percentage.

ABSTRAK

Dalam era moden globalisasi, tenaga adalah sesuatu yang amat bernilai. Di Malaysia, sektor domestik merupakan penyumbang ketiga terbesar dalam penggunaan tenaga dan ia memberi kesan kepada penggunaan tenaga di negara ini. Oleh itu, kecekapan tenaga dan keberkesanan kos adalah faktor utama dalam mengekalkan pertumbuhan ekonomi. Tujuan kajian ini adalah untuk membangunkan Sistem Anggaran Kecekapan Tenaga (EEES) yang mengambilkira keperluan pengguna. Pada peringkat awal kajian ini, respon daripada 408 responden mengenai mengenai kesedaran tenaga ditentukan oleh dua komponen: i) pengetahuan dan ii) amalan; dan telah dikumpulkan dengan penggunaan borang soal selidik kajian tenaga. Keputusan menunjukkan bahawa pengguna mempunyai pengetahuan yang tinggi dalam kesedaran tenaga tetapi mereka tidak mengamalkannya. Pengujian dan pengukuran kecekapan tenaga juga telah dilaksanakan untuk membuktikan penggunaan perkakasan elektrik yang mempunyai kecekapan tenaga yang tinggi boleh mengurangkan penggunaan elektrik di rumah. Pengujian dilakukan ke atas lima jenis perkakasan elektrik yang telah diwajibkan untuk mempunyai Penarafan Bintang di Malaysia. Seterusnya, pendekatan penggunaan kaedah *Quality Funtion Deployment* (QFD) diadaptasikan untuk rekabentuk sistem dalam proses pembangunan sistem. Pendekatan QFD memberi tumpuan kepada pendapat pengguna bagaimana sistem perlu dibangunkan. Pemilihan pengguna adalah berdasarkan kepada kawasan utama di empat zon utama (selatan, utara, timur, barat) di Semenanjung Malaysia. 184 responden terlibat di dalam tinjauan ini. Pangkalan data untuk sistem yang dibangunkan adalah berkaitan dengan penggunaan tenaga oleh peralatan elektrik berdasarkan data yang diperoleh daripada kementerian/agensi-agensi yang berkaitan seperti Suruhanjaya Tenaga dan Tenaga Nasional Berhad (TNB). Verifikasi terhadap sistem yang dibangunkan telah dilakukan kepada 30 buah rumah di sekitar kawasan Larkin, Johor. Keputusan menunjukkan 66.7% daripada pengguna yang mengamalkan EEES sepenuhnya berjaya

mengurangkan sehingga 30% daripada penggunaan tenaga sebulan. Dengan mengambilkira pengetahuan dan amalan di kalangan pengguna, EEES telah berjaya dibangunkan dengan menggunakan pendekatan kaedah QFD, dan sistem ini juga membenarkan pengguna untuk menguruskan sendiri penggunaan tenaga dengan mengganggarkan kecekapan tenaga dan peratusan penjimatan tenaga.

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LIST OF SYMBOLS AND ABBREVIATIONS

kWh	kilo Watts hour
σ^2	Variance
σ_X	Standard Deviation
$\sum$	Summation
r	Correlation
μ	Mean score
n	Sample size
N	Size
p	Significant level
Amp	Ampere Voltage
mb/d	million barrels a day
Btu	British thermal unit
Mtoe	Million Tons of Oil Equivalent
kWh/m2/year	kilo Watt hours per square metre per year
W	Input power
V	voltage
P_{on}	Power at on mode
P_{ps}	Power at passive standby mode
P_{as}	Power at active standby mode
T_{as}	Time on active standby mode (hour)
COP	Coefficient of Performance
hp	Horsepower
EEF	Energy Efficiency Factor
EER	Energy Efficiency Ratio

AC	Alternating Current
APEC	Asia-Pacific Economic Co-operation
APERC	Asia Pacific Energy Research Centre
AWER	Association of Water and Energy Research Malaysia
CO_2	Carbon Dioxide
COA	Certificate of Approval
DC	Direct Current
EC	Energy Consumption
EE	Energy Efficiency
EEES	Energy Efficiency Estimation System
EEI	Energy Efficiency Index
EEI_B	Building Energy Index
ESCO	Energy saving company
ETP	Economic Transformation Program
GB	Green Building
GBI	Green Building Index
GDP	Gross Domestic Product
GHG	Green House Gases
GIS	Geographic Information System
HoQ	House of Quality
GUI	Graphical User Interface
IDE	Integrated Development Environment
IEA	International Energy Agency
IPP	Independent Power Producer
KeTTHA	Ministry of Energy, Water and Green Technology
LEED™	Leadership in Energy and Environmental Design
NEEAP	National Energy Efficiency Action Plan
NKEA	National Key Economic Areas
MEPS	Minimum Energy Performance Standards
MHTPI	Green Technology and the Climate Change Council
MySQL	Hyper Text Markup Language (HTML)
OGE	Oil, Gas and Energy
PHP	Hypertext Preprocessor
QFD	Quality Function Deployment

RE	Renewable Energy
RM	Ringgit Malaysia
SEDA	Sustainable Energy Development Authority Malaysia
SD	Sustainable Development
ST	Energy Commission (*Suruhanjaya Tenaga*)
S&L	Standard and Labelling
TNB	Tenaga Nasional Berhad
USGBC	United State Green Buiding Council
VoC	Voice of Customer

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CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter explains the background of the study. The introduction to energy efficiency (EE) is presented, together with the related issues. This chapter discusses the problem statement for the study based on the background provided, as well as the resulting objectives, significance of the study, the scope of the study and its limitations. This chapter also highlights the management of the whole thesis.

1.2 Background of the Study

In recent years, our planet has been facing an unprecedented energy challenge. Recently, the introduction of EE policies and the implementation of strategies have met with full success, while the global primary energy demand is expected to increase by 41% between 2012 and 2035, with 95% of that growth coming from rapidly-growing emerging economies (BP Group, 2014). This will have a dramatic impact on energy costs and energy security, competition for resources, access to energy for the poorest members of societies, economic growth and climate change (Tricoire, 2013). One of the most important questions of our time is with regard to how the world is going to satisfy its hunger for energy in the decades to come. Hence, the global

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