



AWARENESS OF ENERGY-EFFICIENCY AMONG
OFFICE BUILDINGS USERS: STUDY CASE OF
PUTRAJAYA CORPORATION COMPLEX

BY

AMINE GHARBI

A dissertation submitted in fulfilment of the requirement for
the degree of Master of Urban and Regional Planning

Kulliyyah of Architecture and Environmental Design
International Islamic University Malaysia

AUGUST 2016

ABSTRACT

This research is motivated by the need to reduce energy consumption in buildings, which will subsequently cut Greenhouse Gas (GHG) emissions. At least one-third of global worldwide energy is used in buildings, which generate about 15 percent of global GHG emissions. In cities, up to 80 percent of CO₂ emissions are due to energy consumed by buildings. Consequently, the built environment is a critical part of the climate change problem and conversely, a solution. The improving of energy-efficiency (EE) within buildings is essential to reduce GHG emissions, lowering energy costs and ensuring energy security. Malaysia is currently making efforts to improve its EE status. In order to meet future demands, an effective EE strategy is likely to be a cost-effective alternative to developing new power sources. This study is in line with Malaysia's need for long-term solutions towards attaining sufficiency and sustainability in the energy sector. This study seeks to investigate the level of awareness among office building users towards EE. For the purpose of this study, the Putrajaya Corporation office building is selected for the case study since it features some of the energy-efficient elements and practices and the fact that the Putrajaya Corporation acts as a local authority with a mission to plan, manage and develop the federal administrative capital in an effective and efficient manner. This research aims to evaluate the current level of awareness towards EE among the building users; identify the main factors that are in correlation with the users' level of awareness and to what extent they are capable of changing the users' behaviour. The researcher manages to cover two groups within the building designated as technical staff and non-technical staff, and have been compared through the different analyses done by the researcher. This research is designed with the assumption that people from the technical group are more aware on EE as compared to the non-technical group. Questionnaires and interviews with representatives of the Putrajaya Corporation have been conducted for the purpose of data collection. The findings show that 92.3 percent of the respondents are aware of EE, where those from the technical group are more aware compared to those from the non-technical group. It has been found that the factors 'occupational post' and 'group affiliation' do influence the respondents' level of awareness. A significant association has been identified between the users' level of awareness and the behavioural pattern; the more the level of awareness, the more they use the building components efficiently. Furthermore, analyses done have revealed a significant association between the users' level of awareness and their willingness to participate to the building's EE; the higher the users' level of awareness, the higher they contribute to the building's EE. Based on these findings and issues that have been identified, recommendations and suggestions are given in order to enhance the EE level of awareness among the Putrajaya Corporation staff.

ملخص البحث

كان الدافع من وراء إجراء هذا البحث الحاجة للحدّ من استهلاك الطاقة في المباني، والتي ستخفّض في وقت لاحق من انبعاثات الغازات الدفيئة. يستخدم ثلث الطاقة العالمية على الأقل في المباني، والتي تولد نحو 15 في المئة من الانبعاثات العالمية للغازات الدفيئة. في المدن، تمثل الطاقة التي تستهلكها المباني ما يصل إلى 80 في المئة من إجمالي انبعاثات غاز ثاني أكسيد الكربون. وبالتالي، فإن البيئة المبنية تشكل جزءًا مهمًا من مشكلة تغير المناخ، وبالعكس، تمثل الحل. إن التحسين في الفعالية الطاقوية في المباني ضروري للحد من انبعاثات الغازات الدفيئة، وخفض تكاليف الطاقة، وضمان الأمن الطاقوي. تبذل ماليزيا حاليا جهودًا مكثفة لتحسين وضع الفعالية الطاقوية وذلك من أجل تلبية الطلب في المستقبل، حيث أنه من المرجح أن تكون إستراتيجية فعالة من حيث التكلفة لتطوير مصادر جديدة للطاقة. هذه الدراسة تتماشى مع حاجة ماليزيا لإيجاد حلول طويلة الأجل من أجل تحقيق الاكتفاء والاستدامة في قطاع الطاقة. تسعى هذه الدراسة إلى التعرف على مستوى الوعي بين مستخدمي المباني الإدارية فيما يخص الفعالية الطاقوية. كغرض لهذه الدراسة، تم اختيار المبنى الإداري لشركة بوتراجايا كحالة للدراسة نظرا لاحتوائه على بعض العناصر والممارسات الموفّرة للطاقة، وحقيقة أن شركة بوتراجايا تؤدي دور السلطة المحلية التي تهدف إلى تخطيط وإدارة وكذا تطوير العاصمة الإدارية الفدرالية بطريقة فعالة وكفؤة. يهدف هذا البحث إلى تقييم مستوى الوعي الحالي تجاه الفعالية الطاقوية بين مستخدمي المبنى، وكذا تحديد العوامل الرئيسة التي تؤثر على مستوى الوعي لدى مستخدمي المبنى وإلى أي مدى هي قادرة على تغيير سلوكهم. تمكّن الباحث من تغطية مجموعتين داخل المبنى والتي تم تحديدهما كموظفين تقنيين وموظفين غير تقنيين، حيث تمت مقارنتهما خلال مختلف التحليل التي قام بها الباحث. وقد تم تصميم هذا البحث مع افتراض أن الأشخاص الذين ينتمون إلى مجموعة التقنيين هم أكثر وعياً تجاه الفعالية الطاقوية بالمقارنة مع أولئك المنتمين إلى مجموعة غير التقنيين. وقد جرى توزيع الاستبيان وكذا مقابلات مع المسؤولين في شركة بوتراجايا لغرض جمع البيانات. وأظهرت النتائج أن 92.3 في المئة من المشاركين كانوا على علم بالفعالية الطاقوية، حيث أن أولئك من مجموعة التقنيين كانوا أكثر وعياً مقارنة مع أولئك من مجموعة غير التقنيين. وقد وجد أن عاملَي "المركز الوظيفي" و "الانتماء الجماعي" تؤثر على مستوى وعي المشاركين. وتمّ التعرف على ارتباط معتبر بين مستوى وعي مستخدمي المبنى ونمط السلوك؛ حيث أنه كلما زاد مستوى الوعي، زاد استخدام مكونات المبنى بفعالية. علاوة على ذلك، كشفت التحليلات عن وجود علاقة ذات دلالة إحصائية بين مستوى وعي مستخدمي المبنى واستعدادهم للمشاركة في الفعالية الطاقوية للمبنى. حيث أنه كلما ارتفع مستوى وعي مستخدمي المبنى، ارتفعت مساهمتهم في الفعالية الطاقوية للمبنى. وبناء على هذه النتائج وعلى المشاكل التي تم تحديدها، تم تقديم توصيات ومقترحات من أجل تعزيز مستوى الوعي تجاه الفعالية الطاقوية بين موظفي شركة بوتراجايا.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Urban and Regional Planning.

.....
Mansor Ibrahim
Supervisor

I certify that I have read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Urban and Regional Planning.

.....
M. Zainora Asmawi
Internal Examiner

This dissertation was submitted to the Department of Urban and Regional Planning and is accepted as a fulfilment of the requirement for the degree of Master of Urban and Regional Planning.

.....
Norzailawati Mohd Noor
Head, Department of Urban and
Regional Planning

This dissertation was submitted to the Kulliyyah of Architecture and Environmental Design and is accepted as a fulfilment of the requirement for the degree of Master of Urban and Regional Planning.

.....
Alias Abdullah
Dean, Kulliyyah of Architecture
and Environmental Design

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Amine Gharbi

Signature

Date

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

**DECLARATION OF COPYRIGHT AND AFFIRMATION OF
FAIR USE OF UNPUBLISHED RESEARCH**

**AWARENESS OF ENERGY-EFFICIENCY AMONG OFFICE
BUILDINGS USERS: STUDY CASE OF PUTRAJAYA
CORPORATION COMPLEX**

I declare that the copyright holders of this dissertation are jointly owned by the student and IIUM.

Copyright © 2016 Amine Gharbi and International Islamic University Malaysia. All rights reserved.

No part of this unpublished research may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without prior written permission of the copyright holder except as provided below

1. Any material contained in or derived from this unpublished research may be used by others in their writing with due acknowledgement.
2. IIUM or its library will have the right to make and transmit copies (print or electronic) for institutional and academic purposes.
3. The IIUM library will have the right to make, store in a retrieved system and supply copies of this unpublished research if requested by other universities and research libraries.

By signing this form, I acknowledged that I have read and understand the IIUM Intellectual Property Right and Commercialization policy.

Affirmed by Amine Gharbi

.....
Signature

.....
Date

ACKNOWLEDGEMENTS

I would first like to thank my thesis advisor Prof. Dato' Dr. Mansor Ibrahim of the Kulliyah of Architecture and Environmental Design at International Islamic University Malaysia. The door to Prof. Mansor office was always open whenever I ran into a trouble spot or had a question about my research or writing. He consistently allowed this paper to be my own work, but steered me in the right direction whenever he thought I needed it.

I would also like to thank the experts from Putrajaya Corporation who were involved in the data collection process for this research project: Mr. Azhar Bin Othman and Mr. Muhammad Hazwan Mohd Yunos. Without their passionate participation and input, the questionnaire survey could not have been successfully conducted. In addition, I would like to thank the participants in my survey, who have willingly shared their precious time during the process of data collection.

I would also like to acknowledge Asst. Prof. Dr. M. Zainora Asmawi of the Kulliyah of Architecture and Environmental Design at International Islamic University Malaysia as the second reader of this thesis, and I am gratefully indebted to her for her very valuable comments on this thesis.

Finally, I must express my very profound gratitude to my parents, to my family and to all of my friends for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this dissertation. This accomplishment would not have been possible without them. Thank you.

TABLE OF CONTENTS

Abstract	ii
Abstract in Arabic.....	iii
Approval page	iii
Declaration	v
copyright Page.....	vi
Acknowledgements	vii
List of Tables.....	xiii
List of Figures	xvii
List of Abbreviations	xviii
CHAPTER ONE: INTRODUCTION	1
1.1 Introduction	1
1.2 Background of the Study.....	2
1.3 Problem statement.....	3
1.4 Research questions.....	4
1.5 Research objectives.....	5
1.6 Scope of the study.....	5
1.7 Methodology of the study	6
1.7.1 Stage 1: Background and Theoretical Studies.....	6
1.7.2 Stage 2: Data Collection	6
1.7.3 Stage 3: Analysis of Findings.....	7
1.7.4 Stage 4: Conclusions and Recommendations.....	7
1.8 Significance of the study	9
1.8.1 Significance towards Community	9
1.8.2 Significance towards Planning	10
1.8.3 Significance towards Local Authority	10
1.9 Conclusion.....	10
CHAPTER TWO: LITERATURE REVIEW	11
2.1 Introduction	11
2.2 What is Energy-Efficiency?	11
2.3 Principles of Energy-Efficiency in Building Design: An Overview	12
2.3.1 Reduce Heating, Cooling and Lighting Loads	13
2.3.2 Utilise Active Solar Energy and Other Environmental Heat Sources.....	13
2.3.3 Increase the Efficiency of Appliances and HVAC Systems	13
2.3.4 Implement Commissioning and Improve Maintenance	14
2.3.5 Change the Users Behaviour	14
2.3.6 Utilise System Approaches to Building Design	15
2.3.7 Minimise Halocarbon Emissions.....	15
2.3.8 Consider Building Form, Orientation and Related Attributes	15
2.4 Benefits of Energy-Efficiency	16
2.4.1 Lowering Energy Bills	16
2.4.2 A Cost-Effective Investment.....	17
2.4.3 Fast and Significant Energy Savings	18

2.4.4 Delivering Environmental Benefits	18
2.4.5 Promoting Economic Development.....	19
2.5 Barriers to Energy-Efficiency.....	19
2.5.1 Policy Barriers.....	19
2.5.2 Market Barriers.....	20
2.6 Energy performance of the building	21
2.6.1 Building Energy Performance	21
2.6.2 Measuring Index	23
2.6.3 Energy, Thermal and Environmental Performances.....	24
2.7 The Context of aware energy-efficiency in Malaysia.....	25
2.8 The Occupant’s behaviour impact on energy use.....	28
2.9 Behavioural Approach versus Technological Approach.....	31
2.10 The “10% Energy Challenge” Programme In Singapore as a cursory case study.....	33
2.10.1 Programme Overview	33
2.10.2 Behaviour Change Strategies Employed.....	34
2.10.3 Key Lessons Learned.....	35
2.11 Conclusion.....	35
CHAPTER THREE: RESEARCH METHODOLOGY	36
3.1 Introduction	36
3.2 Preliminary Understanding and Theoretical Study.....	36
3.3 Data Collection Methods.....	36
3.3.1 Questionnaire Survey.....	37
3.3.1.1 Section A: Respondent’s Background	37
3.3.1.2 Section B: Energy-Efficiency User’s Awareness and Understanding	38
3.3.1.3 Section C: Energy-Efficiency User’s Practice	39
3.3.1.4 Section D: Energy-Efficiency User’s Participation.....	40
3.3.2 Interviews.....	41
3.4 Sampling Design.....	41
3.5 Methods of Data Analysis	42
3.5.1 Chi-square test of independence.....	43
3.5.2 Spearman's rank-order correlation.....	44
3.6 Putrajaya Corporation Office Building as Case Study	45
3.6.1 Putrajaya Background	45
3.6.2 The Putrajaya Corporation Complex	47
3.7 Conclusion.....	49
CHAPTER FOUR: FINDINGS AND ANALYSIS OF DATA.....	51
4.1 Introduction	51
4.2 Section A: Respondent’s Background	51
4.2.1 Category of Respondents	52
4.2.2 Age of Respondents.....	52
4.2.3 Gender of Respondents	53
4.2.4 Nationality of Respondents	54
4.2.5 Marital Status of Respondents.....	54
4.2.6 Income of Respondents.....	55
4.2.7 Educational Level of Respondents	56

4.2.8 Occupational Post of Respondents	56
4.2.9 Working Experience of Respondents	57
4.3 Section B: Energy-Efficiency User’s Awareness and Understanding	58
4.3.1 Awareness and Comprehension of the Term Energy-Efficiency.....	58
4.3.2 Awareness and Comprehension of the Term Energy-Efficient Building	60
4.3.3 Awareness of the Efficient Components, an EEB Consists of.....	62
4.3.4 Awareness of Benefits from Energy-Efficiency in Buildings.....	63
4.3.5 Awareness of Factors Affecting the Building’s Energy-Efficiency, the Most	65
4.3.6 Overall Awareness of Energy-Efficiency	67
4.4 Section C: Energy-Efficiency User’s Practice	68
4.4.1 Part 1: Heating, Ventilating and Air Conditioning Systems (HVAC Systems)	68
4.4.1.1 Preferred Room Air Temperature (Cooling Setpoint) During Cooling	68
4.4.1.2 Cooling Setpoint 26°C	69
4.4.1.3 Awareness of Cooling Energy Use.....	70
4.4.1.4 Windows Position during Cooling	71
4.4.1.5 Feeling Cold inside the Building	71
4.4.1.6 Awareness of Windows Position Affecting Energy Use.....	73
4.4.1.7 Using Fan Together With Air Conditioning	74
4.4.1.8 Preferred Method of Using HVAC Systems	75
4.4.1.9 Turning off HVAC Systems Tendency.....	76
4.4.1.10 Overall Attitude towards HVAC Systems Use	77
4.4.2 Part 2: Daylighting versus Artificial Lighting.....	78
4.4.2.1 Artificial Lighting Use	78
4.4.2.2 Awareness of the Building’s Design	79
4.4.2.3 Awareness of Artificial Lights Relationship to Cooling Energy Use.....	79
4.4.2.4 The Tendency of Turning off Artificial Lights	80
4.4.2.5 Turning off the Lights within Work Area	81
4.4.2.6 Overall Attitude towards Artificial Lighting Use.....	82
4.4.3 Part 3: Plug Loads.....	83
4.4.3.1 Undertaken Action for Equipment Not in Use	83
4.4.3.2 Devices on Standby Mode Consume Energy	84
4.4.3.3 The Use of Extra Electrical Plugs (Electrical Extensions).....	85
4.4.3.4 Tendency in Turning off the Majority of Appliances.....	87
4.5 Section D: Energy-Efficiency User’s Participation	88
4.5.1 Level of Energy-Efficiency	88
4.5.2 Reducing the Building’s Energy Consumption.....	90
4.5.3 Measures to Reduce Energy Use	91
4.5.4 Initiatives towards Energy-Efficiency	92
4.5.5 Superiors’ Role in Reducing Energy Consumption	93
4.5.6 Providing Information on Energy-Efficiency	94

4.5.7 Users' Overall Assessment of The Building's Energy Management.....	94
4.5.8 Respondents' Suggestions to Improve the Building's Energy-Efficiency.....	96
4.6 Factors Influencing the Respondents' Level of Awareness	96
4.6.1 Age.....	97
4.6.2 Gender.....	98
4.6.3 Marital Status	99
4.6.4 Income.....	100
4.6.5 Educational Level.....	101
4.6.6 Occupational Post.....	102
4.6.7 Working Experience	103
4.6.8 Group Affiliation (technical/non-technical).....	104
4.7 Identification of the Relationship between Behavioural Pattern and the User's Level of Awareness.....	105
4.7.1 The Relationship between User's Level of Awareness and Attitudes towards HVAC Systems Use.....	105
4.7.2 The Relationship between User's Level of Awareness and Attitudes towards Artificial Lighting Use	107
4.7.3 The Relationship between User's Level of Awareness and Attitudes towards Electrical Plugs Use	108
4.8 Identification of The Relationship between the Users' Level of Awareness and their Willingness to participate to the Building's Energy-Efficiency.....	109
4.9 Summary of the Findings	111
4.9.1 The Users' Awareness and Comprehension of Energy-Efficiency.....	111
4.9.2 The User's Practice with HVAC systems, artificial lighting and plug loads	112
4.9.3 Energy-Efficiency User's Participation	113
4.9.4 Factors influencing the respondents' level of awareness.....	114
4.9.5 Relationship between behavioural pattern and the user's level of awareness.....	114
4.9.6 Relationship between users' level of awareness and their willingness to participate to the building's energy-efficiency.....	115
4.10 Conclusion.....	115
CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS	117
5.1 Introduction	117
5.2 Salient Findings	117
5.3 Recommendations.....	119
5.4 Suggestions for Prospective Research	120
5.5 Conclusion.....	121
REFERENCES	122
APPENDIX A: CHI-SQUARE TEST OF INDEPENDENCE AND SPEARMAN'S RHO CORRELATION ANALYSIS SPSS CONTINGENCY TABLES	127

APPENDIX B:	QUESTIONNAIRE.....	132
APPENDIX C:	INTERVIEW-BASED CHECKLIST.....	138
APPENDIX D:	IMPLEMENTING AN ENERGY-EFFICIENCY AWARENESS PROGRAMME.....	141

LIST OF TABLES

Table 2.1	Occupant Behaviour Categorized into Three Workstyles	31
Table 3.1	Type of Relationship According to Correlation Coefficient	45
Table 4.1	Respondents Distribution According to Respondent Group	52
Table 4.2	Respondents' Age According to Respondent Group	53
Table 4.3	Respondents' Gender According to Respondent Group	54
Table 4.4	Respondents' Marital Status According to Respondent Group	54
Table 4.5	Respondents' Income According to Respondent Group	55
Table 4.6	Respondents' Educational Level According to Respondent Group	56
Table 4.7	Respondents' Occupational Post According to Respondent Group	57
Table 4.8	Respondents' Working Experience According to Respondent Group	58
Table 4.9	Awareness of the Term Energy-Efficiency vs. Respondent Group	59
Table 4.10	Comprehension of the Term Energy-Efficiency vs. Respondent Group	60
Table 4.11	Awareness of the Term Energy-Efficient Building vs. Respondent Group	60
Table 4.12	Comprehension of the Term Energy-Efficient Building vs. Respondent Group	61
Table 4.13	Awareness of EEB Components vs. Respondent Group	62
Table 4.14	Awareness of Energy-Efficiency Benefits vs. Respondent Group	64
Table 4.15	Awareness of Factors Affecting the Building's Energy-Efficiency vs. Respondent Group	66
Table 4.16	Overall Awareness of Energy-Efficiency vs. Respondent Group	67
Table 4.17	Preferred Cooling Setpoint vs. Respondent Group	68
Table 4.18	Cooling Setpoint 26°C vs. Respondent Group	69
Table 4.19	Awareness of Cooling Energy Use vs. Respondent Group	70

Table 4.20	Windows Position during Cooling vs. Respondent Group	71
Table 4.21	Feeling cold inside the Building vs. Respondent Group	72
Table 4.22	Awareness of Windows Position Affecting Energy Use vs. Respondent Group	73
Table 4.23	Using Fan together with Air Conditioning vs. Respondent Group	74
Table 4.24	Method of Using HVAC Systems vs. Respondent group	75
Table 4.25	Turning off HVAC Systems Tendency vs. Respondent group	76
Table 4.26	Overall Attitude towards HVAC Systems Use vs. Respondent group	77
Table 4.27	Artificial Lighting Use vs. Respondent Group	78
Table 4.28	Awareness of Building Design vs. Respondent Group	79
Table 4.29	Awareness of Artificial Lights Relationship to Cooling EnergyUuse vs. Respondent Group	80
Table 4.30	Turning off Artificial Lights Tendency vs. Respondent group	81
Table 4.31	Turning off the Lights within Work Area vs. Respondent Group	82
Table 4.32	Overall Attitude towards Artificial Lighting Use vs. Respondent Group	83
Table 4.33	Undertaken Action for Equipment not in Use vs. Respondent Group	84
Table 4.34	Awareness of Devices on Standby Mode (Energy Consumption) vs. Respondent Group	85
Table 4.35	The Use of Extra Electrical Plugs vs. Respondent Group	85
Table 4.36	Purpose of Use of Extra Electrical Plugs vs. Respondent Group	86
Table 4.37	Tendency in Turning off Appliances vs. Respondent Group	87
Table 4.38	Level of Energy-Efficiency vs. Respondent group	89
Table 4.39	Reducing Energy Consumption vs. Respondent Group	90
Table 4.40	Measures to Reduce Energy Use	91
Table 4.41	Initiatives towards Energy-Efficiency	92
Table 4.42	Superiors' Role in Reducing Energy Consumption vs. Respondent Group	93

Table 4.43	Suggested Tools for Providing Information about Energy-Efficiency	94
Table 4.44	Overall Assessment of the Building's Energy Management vs. Respondent Group	95
Table 4.45	Analysis Summary: Age Relationship to Respondent's Level of Awareness	97
Table 4.46	Analysis Summary: Gender Relationship to Respondent's Level of Awareness	98
Table 4.47	Analysis Summary: Marital Status Relationship to Respondent's Level of Awareness	99
Table 4.48	Analysis Summary: Income Relationship to Respondent's Level of Awareness	100
Table 4.49	Analysis Summary: Educational Level Relationship to Respondent's Level of Awareness	101
Table 4.50	Analysis Summary: Occupational Post Relationship to Respondent's Level of Awareness	103
Table 4.51	Analysis Summary: Working Experience Relationship to Respondent's Level of Awareness	104
Table 4.52	Analysis Summary: Group Affiliation Relationship to Respondent's Level of Awareness	104
Table 4.53	Analysis Summary: Level of Awareness Relationship to HVAC Systems Use	106
Table 4.54	Analysis Summary: Level of Awareness Relationship to Artificial Lighting Use	107
Table 4.55	Analysis Summary: Level of Awareness Relationship to Electrical Plugs Use	109
Table 4.56	Analysis Summary: Level of Awareness Relationship to the User's Energy-Efficiency Participation	110
Table 4.57	Findings Summary: Users' Awareness and Comprehension of EE	111
Table 4.58	Findings Summary: Users' Practice with HVAC Systems, Artificial Lighting and Plug Loads	112
Table 4.59	Findings Summary: EE Users' Participation	113
Table 4.60	Findings Summary: Factors Influencing the Respondents' Level of Awareness	114

Table 4.61	Findings Summary: Relationship between Behavioural Pattern and the User's Level of Awareness	114
Table 4.62	Findings Summary: Relationship between Users' Level of Awareness and their Willingness to Participate to the Building's EE	115
Table 5.1	Salient Findings	118
Table 5.2	Recommendations According to Identified Issues	120

LIST OF FIGURES

Figure 1.1	Study Methodology Flowchart	8
Figure 2.1	Comparison of Electric Spending on Supply versus Efficiency	17
Figure 2.2	Sources of Emissions	18
Figure 2.3	Major Components of Building Energy Performance	22
Figure 2.4	Energy, Thermal and Environmental Performances of Buildings	25
Figure 2.5	Statistics of Energy Uses in Malaysia	28
Figure 3.1	Putrajaya Places of Interest Map, Adapted from Map Selangor (Putrajaya)	46
Figure 3.2	The Putrajaya Corporation Complex Viewed from Different Angles	48

LIST OF ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning
BCIS	Building Consumption Input System
BEI	Building Energy Index
BEMS	Building Energy Management System
CETREE	Centre for Education and Training in Renewable Energy
CFL	Compact Fluorescent Lamp
EE	Energy-Efficiency
EEB	Energy-Efficient Building
EUI	Energy Utilisation Index
GFA	Gross Floor Area
GHG	Greenhouse Gas
GWh	Gigawatt Hour
HFC	Hydrofluorocarbon
HVAC	Heating, Ventilating and Air Conditioning
IDP	Integrated Design Process
KWh	Kilowatt Hour
LEO	Low Energy Office
MEWC	Ministry of Energy, Water and Communication
MSC	Multimedia Super Corridor
NGO	Non-Governmental Organisation
PPJ	Perbadanan Putrajaya (Putrajaya Corporation)
PTM	Pusat Teknologi Maklumat (Centre of Information Technology)
TNB	Tenaga Nasional Berhad (National Energy Company)

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

This research was motivated by the need to reduce energy consumption in buildings, which would subsequently cut Greenhouse Gas (GHG) emissions. At least one-third of global worldwide energy is used in buildings, which generate about 15 percent of global GHG emissions (Wafula, 2012). In cities, up to 80 percent of CO₂ emissions are due to energy consumed by buildings (Wafula, 2012). Consequently, the built environment is a critical part of the climate change problem and conversely, a solution. Moreover, the majority of existing buildings were not designed to be energy-efficient. The improving of energy efficiency within buildings is essential to reduce GHG emissions, lowering energy costs and guaranteeing energy security.

Reducing the use of energy in buildings is crucial for attaining carbon reduction commitments. The achievement of this goal can be done through the involvement of a different set of stakeholders. Most of the undertaken actions in this area follow a physical, technical and economic model of the built environment (Lutzenhiser, 1993). In this situation, architects, engineers and efficiency promoters are the major players; they can make technical enhancements to existing buildings and designing new ones with higher standards. The use of energy in buildings can be considered as a social problem rather than a technological one (Nader, 1980). How people are motivated to reduce their energy consumption has been occasionally evoked by social scientists for more than a century (Rosa, Machlis, & Keating, 1988). From this angle, it can be argued that the reduction of energy use in buildings involves

modifications in the entire fabric of society, not just changing the shape and nature of the buildings.

1.2 BACKGROUND OF THE STUDY

According to the report of Tenaga Nasional Berhad (TNB) 2008 on electric power generation by energy sources, energy sources from gas and coal have 54.46 percent and 27.96 percent of the generation rate respectively, while the power generation rate for hydropower and other types of energy sources have the generation rate of 17.47 percent and 0.11 percent respectively (Kok, 2009).

In fact; most of the electricity consumed by buildings is generated using fossil energy (Raman, 2009). With such trends, the building sector will soon consume as much as industry and transport sectors combined, which is quite alarming since Malaysia has one of the fastest growing building industry in the world (Zainordin, Abdullah, & Baharum, 2012). While it may be a reason for worry, there are opportunities for the development of sustainable energy technology.

The energy used in Malaysian office buildings is mostly consumed by air conditioners (57 percent), followed by lighting (19 percent), lifts and pumps (18 percent) and other equipment (6 percent) (Saidur, 2009). Because of the increase in living standards, a growth in electricity use has resulted, especially during hot and humid periods where there is an increasing demand for air conditioners capable of providing occupants with thermal comfort. The buildings' energy consumption is in terms of the Building Energy Index (BEI), the Malaysian average BEI is 269 kWh/m²/year (Zainordin et al., 2012).

In 1989, the Malaysian Ministry of Energy, Water and Communication (MEWC) presented guidelines for energy-efficiency in Non-Domestic buildings.

These guidelines were revised as the Malaysian Standard MS1525: 2007. This standard was aimed to boost the use of renewable energy within the existing and the new buildings in order to reduce the dependence on non-renewable energy sources. However, this standard cannot be applied immediately as mandatory by the Malaysian government since it does not ensure that all new buildings will be built as energy-efficient buildings. On the other hand, there is a chance to improve the current situation above the average construction practices. The constant improving of the standard need to be done in order to enhance the energy-efficiency in buildings in Malaysia.

1.3 PROBLEM STATEMENT

Reducing energy use in buildings is a critical component of meeting carbon reduction commitments. This research argues that building users play a critical but poorly understood and often overlooked role in the built environment. Both advanced technologies used and energy use behaviour changed measures can realise energy efficiency in buildings (Yen & Wai, 2010). The behavioural way to energy saving is a simple and easy way, which does not necessitate any capital investment. It simply encourages the change of energy usage in daily life, and energy-savings are remarkable. Meanwhile, the technical energy conservation way will need additional investment, and the energy-saving effects are not effective immediately.

The vitality of behavioural approach in any energy conservation programme whereby energy use is considered as a key success factor in energy management. Compared to the technological approach, the behavioural approach can be effective and can make a significant difference in energy-efficiency. Hence, problem statement could be listed in three points;

- i. The Building's technological components have developed to be more energy-efficient but buildings as a whole have not due to unchanged users' behaviour regarding energy wastage.
- ii. The key obstacles to improving energy-efficiency in the existing office buildings are the users' behaviour. The lack of awareness is usually the reason for energy inefficiency.
- iii. Energy awareness programs not inclusive of significant energy awareness measurement among the office building users.

The investigation of awareness among the energy users within the office buildings is very relevant to this study. Typically, office buildings consume about 21% of a country's total commercial energy use (Chirarattananon & Taweekun, 2003). Based on this assumption, it is estimated that total energy used by Malaysian office buildings is about 6090 GWh (Saidur, 2009). By referring to Statistics of energy uses in Malaysia, it has been found that the commercial sector, the second largest user, accounts for about 32% of the total energy use in Malaysia (Saidur, 2009).

1.4 RESEARCH QUESTIONS

Based on the issues argued in the statement of the problem, three research questions have been identified:

- i. What is the existing level of awareness and comprehension of energy-efficiency in office buildings?
- ii. What are the factors influencing the users' energy conservation behaviour?

- iii. What are the energy-efficiency awareness models probable to improve the building's energy-efficiency?

1.5 RESEARCH OBJECTIVES

This research was aimed to evaluate the users' level of awareness at the Putrajaya Corporation office building and how it is affecting the behavioural pattern towards energy consumption. Therefore, the following research objectives have been formulated:

- i. To measure the users' level of awareness towards energy-efficiency in the selected office building.
- ii. To detect factors affecting the energy conservation behaviour.
- iii. To propose awareness programs, approaches and recommendations likely to increase the building's energy-efficiency.

1.6 SCOPE OF THE STUDY

This study attempts to cover the important aspects regarding energy-efficiency. However, the focus will be mainly on evaluating the level of awareness among the selected office building users and how it is influencing their attitudes towards energy consumption. The fundamental concepts and principles of energy-efficiency will be included in this study in order to examine the users' knowledge regarding the topic. Furthermore, the study will identify the main factors that are in correlation with the users' level of awareness and to what extent they are capable of changing the users' behaviour. The study did not cover the broader environmental or socio-economic issues often associated with energy-efficiency studies. This research only focuses on

evaluating the energy-efficiency level of awareness, and its effectiveness in achieving deep energy savings within the Putrajaya Corporation office building.

1.7 METHODOLOGY OF THE STUDY

This study was conducted following four different stages, namely background and theoretical studies, gatherings of data, analysis of data and findings, lastly conclusions and recommendations. The flowchart illustrated in figure 1.1 demonstrates the four stages of this study.

1.7.1 Stage 1: Background and Theoretical Studies

The first stage of this study commenced with a preliminary study that comprised readings from different references relevant to the topic of interest, which is awareness of energy-efficiency. This phase is very important since it leads to the identification of the issues and problems related to the topic, and subsequently, the formulation of the research problem statement, the objectives of the study, the scope and the contribution of this study. This phase is essential because it allows the researcher to acquire a general comprehension of the topic besides of determining a preliminary theoretical approach to the study. This stage is demonstrated in Chapter 1 and Chapter 2 of the study.

1.7.2 Stage 2: Data Collection

This stage consists of the discussion on the gathering of different types of data from both primary and secondary sources. The primary data was collected through the distribution of questionnaires to the users of the case study building (Putrajaya Corporation) from different categories namely officers, engineers, technicians and