



A REVIEW OF HOMES IMPLEMENTING GREEN  
TECHNOLOGIES IN TWO CLIMATES

BY

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## **ABSTRACT**

Much effort has been focused on energy saving of green technologies, however, their actual performance is not widely known. This dissertation elucidates the performance of implemented green technologies in homes under two different climates, namely, tropical and cold climates. The aim is to firstly investigate the discrepancy between estimated performance during the designed phase and actual performance after occupancy. Secondly, to explore the impact of the occupants' behaviours on the performance of these technologies in energy saving. Lastly, to estimate the lifecycle saving of these technologies throughout their lifetime duration. The research focuses on green housing developments in Malaysia and the UK, where broad range of implemented technologies has been distinguished. Mesra Terrace Development in Kuala Lumpur was chosen to represent the context in Malaysia, while BedZED Development in Sutton in the UK was selected under the cold temperature zone. The study employed a quantitative method for the data collection. The empirical assessment of the after occupancy performance is based on the analysis of energy power and water consumptions as well as savings in both designed and operational phases. The findings indicate that simulation and modeling approaches, in some cases, did not reflect the actual performance of the green homes. Moreover, it shows how the occupants' behaviours and practices are important, when explaining households' energy savings. Public ecological awareness and green education have significantly contributed in directing the occupants towards proper practices, in terms of operating and utilizing the benefits of the green technologies. In addition, it has been asserted that lifecycle saving of the implemented green technologies in homes is determined by their green cost premiums, which depend on the green market and on their lifecycle maintenance and operational costs.

## ملخص البحث

كثير من الجهود تُبذل من أجل توفير الطاقة من خلال تطبيقات التكنولوجيا الخضراء، مع ذلك فإن الدراسات لم تتمكن بعد من تحديد أداء ما بعد الإشغال بشكل واضح. يناقش البحث أداء تطبيقات التكنولوجيا الخضراء في المنازل تحت تأثير مناخين مختلفين، هما المناخ الاستوائي والمناخ البارد. هدف هذه الدراسة ينطوي على التحقيق أولاً في حالة التناقض بين الأداء المتوقع والذي يتم تحديده في مرحلة التصميم وبين أداء الفعلي لما بعد الإشغال، ثانياً تأثير سلوك المستخدمين على الأداء وعلى توفير الطاقة، وأخيراً تحديد عائدات الاستثمار خلال دورة حياة التكنولوجيات الخضراء. يركز هذا البحث على تطوير المساكن الخضراء في ماليزيا والمملكة المتحدة حيث تضم مجموعة واسعة من تطبيقات التكنولوجيا الخضراء. وعليه تم اختيار مشروع الإسكان Mesra Terrace الواقع في العاصمة كوالالمبور في ماليزيا، بينما تم اختيار مشروع الإسكان ذو الطاقة الصفر BedZED والواقع في مدينة Sutton في المملكة المتحدة ذات الجو البارد. تبنى البحث المنهج الكمي لجمع المعلومات. إستند تقييم أداء تطبيقات التكنولوجيا الخضراء في المشروعين على تحليل استهلاك الطاقة والمياه، وأداء الطاقة المتجددة وتوفير استخدام المياه، وكذلك تقييم أداء الطاقة وعلاقتها بالتكاليف الأولية والمردود المالي. أظهرت استنتاجات البحث أن نهج المحاكاة و النمذجة الحاسوبية في بعض الحالات لا يمثل الأداء الفعلي للتكنولوجيا الخضراء في المنازل. إلى جانب ذلك، الوعي البيئي والتعليم حول التقنيات الخضراء له مساهمة كبيرة في توجيه الساكنين نحو الممارسات السليمة والمثلى في كيفية تشغيلها. إضافةً إلى ذلك، تم التأكيد بأن قيمة المردود المالي والعائدات تعتمد على تكلفة الأولية لها وعلى مصاريف التشغيل والإدامة.

## 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 Science in Building Services Engineering.

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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.

Rawia Marwan Abdul Aziz Dabdoob

Signature ..... Date .....

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

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TWO CLIMATES**

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.....  
Signature

.....  
Date

*To  
My Beloved Husband, Musa'ab  
and  
My Gorgeous Daughter, Asma*

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# TABLE OF CONTENTS

Abstract.....	ii
Abstract in Arabic.....	iii
Approval Page.....	iv
Declaration Page.....	v
Copyright Page.....	vi
Dedication.....	vii
Acknowledgements.....	viii
List of Tables.....	xiv
List of Figures.....	xvii
List of Abbreviations.....	xxi
<b>CHAPTER 1: INTRODUCTION.....</b>	<b>1</b>
1.0 Introduction.....	1
1.1 Problem Statement.....	4
1.2 Research Questions.....	6
1.3 Aim And Objectives of The Research.....	7
1.4 Significance of The Study.....	7
1.5 Justification of The Study Areas.....	8
1.6 Scope And Limitation of The Study.....	10
1.7 Structure of The Research.....	11
1.8 Summary.....	13
<b>CHAPTER 2: LITERATURE REVIEW.....</b>	<b>14</b>
2.0 Introduction.....	14
2.1 Density Housing Mass -Definitions .....	14
2.1.1 Typologies of Housing.....	15
2.1.1.1 Terrace Housing.....	16
2.1.1.2 Semi-detached.....	16
2.1.1.3 Detached dwellings.....	17
2.1.1.4 Apartments.....	17
2.1.2 High, medium, and Low Density Housing in Malaysia.....	17
2.2 Green Buildings-Definitions and Codes .....	18
2.2.1 Leadership In Energy And Environmental Design (LEED).....	18
2.2.1.1 The Energy Star Programme.....	20
2.2.2 The Code For Sustainable Homes in UK.....	20
2.2.3 Green Building Index (GBI) in Malaysia.....	21
2.3 Green Technologies Implemented in Homes .....	22
2.3.1 Solar Collector System.....	23
2.3.2 Heat Recovery System.....	24
2.3.3 Renewable Energy Systems.....	25
2.3.3.1 Solar Photovoltaic System.....	26
2.3.3.2 Wind Power System.....	28
2.3.3.3 Biomass Energy.....	29
2.3.4 Rainwater Harvesting System .....	30

2.3.5	Recycling and Reuse.....	31
2.3.5.1	Water Recycling System.....	31
2.3.5.2	Solid Waste Recycling.....	32
2.4	Occupancy Performance Of Green Technologies.....	33
2.4.1	Occupancy Evaluation Definition.....	34
2.4.2	Evaluation of Green Technologies.....	34
2.5	International Green Housing Developments.....	38
2.5.1	Green Housing Development In US.....	38
2.5.1.1	Wisdom Way Solar Village.....	39
2.5.1.1	Paisano Green Community, El Paso.....	42
2.5.2	Green Housing Development In UK.....	46
2.5.2.1	Freshney Green Development, Grimsby.....	46
2.5.2.2	One Earth Homes, Northampton.....	49
2.4.3	Green Housing Development In Malaysia.....	52
2.4.2.1	Sunway SPK 3 Harmon, Desa Park City.....	53
2.5	Summary.....	54
<b>CHAPTER 3: RESEARCH METHODOLOGY.....</b>		<b>55</b>
3.0	Introduction.....	55
3.1	Research Process.....	55
3.2	Choice of Methodology.....	57
3.2.1	Methodological Approach.....	57
3.2.2	Previous Methodologies.....	57
3.2.3	Methodological Approach of the Study.....	62
3.3	Description of the Study Areas.....	62
3.3.1	Description of Mesra Terrace Development.....	62
3.3.2	Description of BedZED Development.....	64
3.4	The Research Techniques of Inquiring and Data Collection Procedures.....	65
3.4.1	Period of Data Collection.....	67
3.4.2	Electricity and Water Tariff.....	67
3.4.3	Currency Converting.....	68
3.4.4	Energy and Water Savings Estimation.....	68
3.5	Approach To Data Analysis.....	70
3.6	Data Analysis Techniques.....	70
3.7	Summary.....	71
<b>CHAPTER 4: GREEN TECHNOLOGIES IMPLEMENTED IN BEDZED DEVELOPMENT THE INTERNATIONAL CASE STUDY.....</b>		<b>72</b>
4.0	Introduction.....	72
4.1	About Bedzed Development.....	72
4.1.1	Net Zero Energy Home Definition.....	73
4.2	Layout And Planning.....	73
4.3	The Overall Sustainable Concept .....	75
4.4	Green Features And Technologies In BedZED Development.....	78
4.4.1	Fabric Insulations.....	79
4.4.2	Waste Segregation and Composition.....	80
4.4.3	Solar Photovoltaic Panels.....	81
4.4.4	Bio-Fuelled Combined Heat And Power Unit (CHP).....	82

4.4.5	Rainwater Harvesting System.....	84
4.4.6	Green Water Treatment Plant (GWTP).....	85
4.5	The Performance of the Green Features and Technologies in Bedzed Development.....	86
4.5.1	Fabric Insulations.....	87
4.5.2	Solar Photovoltaic Panels.....	87
4.5.3	Bio-Fuelled Plant (CHP) .....	88
4.5.4	Rainwater Harvesting System.....	90
4.5.5	Green Water Treatment Plant.....	91
4.6	Trends in Actual Energy Use and Savings Assessment .....	92
4.6.1	Energy Consumption.....	92
4.6.2	Net Energy Power Consumption of the Dwellings of BedZED Development.....	93
4.6.3	Energy Savings Trends.....	95
4.7	Actual Trends in Water Consumption.....	97
4.8	Importance of Occupants Awareness.....	99
4.9	Summary.....	100

**CHAPTER 5: GREEN TECHNOLOGIES IMPLEMENTED IN MESRA TERRACE DEVELOPMENT THE LOCAL CASE STUDY..... 102**

5.0	Introduction.....	102
5.1	About Mesra Terrace Development.....	102
5.2	Layout And Planning.....	103
5.3	The Overall Sustainable Concept.....	105
5.3.1	Sustainable Planning Concept .....	105
5.3.2	Sustainable design Principles.....	107
5.3.3	Sustainable Materials Specifications.....	108
5.3.4	Reducing Lighting Energy Consumption.....	109
5.4	Green Features And Technologies In Mesra Terrace Development.....	109
5.4.1	Double Cavity Wall.....	110
5.4.2	Roof Insulation.....	111
5.4.3	Condenser Heat Reclaim System.....	111
5.4.4	Solar Photovoltaic Power System.....	113
5.4.5	Rainwater Harvesting System.....	114
5.4.6	Waste Recycling.....	117
5.5	The Green Technologies and Features– Aspects of Performance.....	118
5.5.1	Estimated Energy Saving of Double Cavity Wall.....	118
5.5.2	Performance of Double Cavity Wall After occupation.....	119
5.5.3	Estimated Energy Saving of Condenser Heat Reclaim System..	120
5.5.4	Trends in Condenser Heat Reclaim System After Commissioning.....	120
5.5.5	Estimated energy saving of the solar photovoltaic system.....	122
5.5.6	Trends in Solar Photovoltaic System After Commissioning.....	123
5.5.6.1	Export The Energy Power to TNB.....	125
5.5.7	Estimated Rainwater Volume Collected by The Rainwater Harvesting System.....	126
5.5.8	Trends in Rainwater Volume Collected by The Rainwater Harvesting System.....	128
5.6	Trends In Actual Energy Use And Savings Assessment.....	129

5.6.1	Energy Consumption.....	129
5.6.1.1	Energy Consumption by the Common Area.....	129
5.6.1.2	Energy Consumption by the Household Dwellings.....	131
5.6.2	Net Energy Consumption of Mesra Terrace Development.....	134
5.6.3	Energy Saving Trends.....	135
5.7	Actual Trends in Water Comsumption.....	137
5.7.1	Water Consumption via The Common Area .....	137
5.7.1	Outdoor Water Saving.....	138
5.8	Importance of Occupants Awareness.....	139
5.9	Summary.....	140
<b>CHAPTER 6: OPERATIONAL SAVING COST.....</b>		<b>142</b>
6.0	Introduction.....	142
6.1	Cost-Benefit Analysis.....	142
6.1.1	Green Premium Cost.. ..	143
6.1.1.1	Green Premium Cost of the Implemented Green Technologies in Mesra Terrace Development.....	146
6.1.1.2	Green Premium Cost of the Implemented Green Technologies in BedZED Development.....	148
6.1.2	Life-cycle Saving of the Green Technologies .....	150
6.1.2.1	Life-cycle Saving of the Implemented Green Technologies in Mesra Terrace Development.....	152
6.1.2.2	Life-cycle Saving of the Implemented Green Technologies in BedZED Development.....	153
6.2	Summary.....	155
<b>CHAPTER 7: DISCUSSION.....</b>		<b>156</b>
7.0	Introduction.....	156
7.1	Performance of the Green Technologies After Occupancy.....	156
7.1.1	Predicted Performance of Green Technologies.....	157
7.1.1.1	Simulation and Modelling of Green Technologies in Mesra Terrace Development.....	157
7.1.1.2	Simulation and Modelling of Green Technologies in BedZED Development.....	158
7.1.2	Type of Green Technologies Implementation in the Development.....	159
7.1.2.1	Individual and Shared Green Technologies.....	160
7.1.2.2	Dependent and Independent Green Technologies.....	160
7.1.2.3	Green Technologies Adjustment.....	160
7.2	Impact Of Occupants Behavior on the Performance of the Green Technologies.....	161
7.2.1	The Impact of Occupant’s Behavior on the Performance of the Green Technologies in Mesra Terrace Development.....	161
7.2.1.1	Trends Of Energy Consumption in Mesra Terrace Development.....	162
7.2.1.2	Energy Usage in Mesra Terrace Development Compared with Conventional Local Homes.....	163
7.2.2	The Impact of Occupant’s Behavior on the Performance of the Green Technologies in BedZED Development.....	164

7.2.2.1 Trends Of Energy Consumption in BedZED Development.....	164
7.2.2.2 Energy Usage in BedZED Development Compared with Conventional Local Homes in Sutton.....	164
7.2.3 Occupants' Awareness Upon Operating The Green Technologies. ....	165
7.3 The Return on Investment.....	166
7.3.1 Green Cost Premium and Marketing.....	166
7.3.2 Green Cost Premium and Energy Savings.....	167
7.3.3 The Impact of Operational savings on the Performance of the Green Technology.....	167
7.4 Summary.....	167
<b>CHAPTER 8: CONCLUSION.....</b>	<b>169</b>
8.0 Introduction.....	169
8.1 The Finding Of The Study.....	169
8.1.1 Objective One.....	169
8.1.2 Objective Two.....	170
8.1.3 Objective Three.....	170
8.2 The Implications of The Findings.....	171
8.2.1 The Significance of Improving Government Support of Green Development in Malaysia.....	171
8.2.2 The Significance of Increasing Public Awareness Towards Green Concepts in Malaysia.....	172
8.2.3 The Significance of Promoting Local Investigative Experiential Approach of Performance Evaluation.....	174
8.3 Contribution of The Research.....	174
8.4 Recommendations and Future Suggestions.....	175
8.5 Summary.....	176
<b>BIBLIOGRAPHY.....</b>	<b>180</b>
APPENDIX (A1): Electricity Bills of Mesra Terrace Dwellings.....	189
APPENDIX (A2): TNB Solar Reset of Mesra Terrace Development.....	191
APPENDIX (A3): Water Bills of the Common Area of Mesra Terrace Development.....	199
APPENDIX (A4): The Simulation of the Double Cavity Wall in Mesra Terrace Development.....	205
APPENDIX (A5): The Simulation of the Heat Reclaim System in Mesra Terrace Development.....	208
APPENDIX (A6): The Performance of the Bed ZED Development.....	209

## LIST OF TABLES

<u>Table No.</u>		<u>Page No.</u>
1.1	Sustainable Home Assessment Tools Around The World	3
2.1	Residential density of high, medium, and low density housing	15
2.2	Credit Category of LEED	19
2.3	LEED Classification	19
2.4	UK Code Categories	20
2.5	UK Code Classification	21
2.6	GBI Code Categories	22
2.7	GBI Code Classification	22
3.1	Methodology of Previous Studies	61
3.2	Period of collected bills of Mesra Terrace Development	67
3.3	Monthly Domestic Electricity Tariff by TNB in 2013	67
3.4	The currency converting value from \$ and £ to RM	68
4.1	Actual energy generated from solar panels	88
4.2	Energy generated by bio-fuelled plant	89
4.3	Energy consumption in BedZED Development during the year 2007	93
4.4	Net grid electricity consumed in BedZED Development	94
4.5	Energy consumption in BedZED Development	95
4.6	Predicted and actual energy reduction in BedZED Development	96
4.7	Energy saving in BeZED homes comparatively with the conventional homes performance in Sutton	97
4.8	Water efficiency in BedZED Development	98

4.9	Water Saving in BedZED Development	98
4.10	The performance of the green technologies in BedZED Development	100
5.1	Estimated cooling energy savings of double cavity wall	119
5.2	Estimated energy heating saving of two condenser heat reclaim systems through representative year	120
5.3	Estimated generated energy by the solar photovoltaic system	123
5.4	Energy Generated from Solar Panels During The First Year of Occupancy	123
5.5	Energy Generated Details	124
5.6	Total sold energy o TNB in 2012	125
5.7	Energy Generated Details	126
5.8	Water consumption prediction	127
5.9	Compound monthly electricity bills of total energy consumption of the common area	130
5.10	Energy consumption of the common area per dwelling and occupant	131
5.11	Monthly electricity bill for each dwelling in the Development	132
5.12	Number of occupants in selected 15 units with energy consumption	133
5.13	Energy consumption in Mesra Terrace dwellings	134
5.14	Net energy consumption in Mesra Terrace Development	135
5.15	Energy saving per dwelling	137
5.16	Monthly water bill usage of the development	138
5.17	Water saving of outdoor demands	139
5.18	The performance of the green technologies in Mesra Terrace Development	141
6.1	The green premium cost and energy saving of the selected study areas in US, UK, and Malaysia	144

6.2	The details of the additional cost of the green features and technologies in Mesra Terrace Development	147
6.3	The details of the additional cost of the green features and technologies in BedZED Development	149
6.4	Life-cycle saving of the integrated green technologies in Mesra Terrace Development and their payback period	152
6.5	Life-cycle saving of the integrated green technologies in BedZED Development and their payback period	154
7.1	Energy saving via BedZED dwelling comparing with conventional home	165



## LIST OF FIGURES

<u>Figure No.</u>		<u>Page No.</u>
1.1	Mesra Terrace phase 2	11
2.1	Housing typologies	16
2.2	The concept of solar collector system	23
2.3	The concept of the heat recovery ventilator and heat pump water heaters	24
2.4	The concept of solar photovoltaic system	27
2.5	The concept of the wind power system	28
2.6	The concept of the rainwater harvesting system	30
2.7	The dwelling of Wisdom Way Solar Village	40
2.8	The site plan of Wisdom Way Solar Village Development	40
2.9	Low energy ventilation system installed in the first floor ceiling	41
2.10	The double cavity wall with insulation and vapor mish	42
2.11	The site plan of Paisano Green Community	43
2.12	View from central courtyard of Paisano Green Community	43
2.13	The passive design of dwellings in Paisano Green Community	44
2.14	The rooftop installed solar photovoltaic power system in dwellings in Paisano Green Community	45
2.15	Two wind turbines power systems installed in Paisano Green Community	46
2.16	Layout of Freshney Green development, Grimsby	47
2.17	Freshney Green development, Grimsby	48
2.18	Water butts	49

2.19	One Earth Terrace Homes in Upton Square, Northampton	50
2.20	The integrated renewable energy systems on the roof of the homes	51
2.21	The equipped rainwater harvesting system in each home	52
2.22	Sunway SPK 3 Harmon Development	53
2.23	The site plan of Sunway SPK 3 Harmon Development	53
3.1	Research Process	56
3.2	Location of Mesra Terrace development in Kuala Lumpur	63
3.3	Location of BedZED development in Sutton, London	64
4.1	View of BedZED Terrace Block	73
4.2	BedZED Site Plan	74
4.3	Section and Plan of Single BedZED Block	74
4.4	Section of BedZED dwelling illustrates passive lighting and solar heat gain during winter and summer	76
4.5	Passive ventilation system including wide cowls on the rooftop and ducts	76
4.6	Double cavity wall with insulation	79
4.7	Waste bins in the kitchen of each dwelling	80
4.8	BedZED Top reef Solar Photovoltaic Panels	81
4.9	Bio-fuelled plant in BedZED Development	82
4.10	Hot water cylinder inside the bathrooms	83
4.11	Gasification process of woodchips in the bio-fuelled plant	83
4.12	The rainwater collected roof and the roof garden of the dwellings	84
4.13	Green Water Treatment Plant	85
4.14	Green water treatment plant processes	86
4.15	Water distribution system	91

4.16	Actual electricity power consumption for 56 BedZED dwellings in 2007	92
4.17	Visible meters in the kitchen of BedZED homes	99
5.1	Mesra Terrace Development	103
5.2	Overall layout of the communal residential development of Mesra Terrace Development	104
5.3	Overall floors of Mesra Terrace Dwelling	104
5.4	Site Plan of Mesra Terrace Development	105
5.5	Three-dimensional simulation model of the giving shade by neighboring high rises during the day	106
5.6	Testing the roof ventilation effectiveness by dwelling model	107
5.7	The façade design and size of windows	108
5.8	The layers of green wood flooring	108
5.9	The construction of the double cavity brick walls	110
5.10	The concept of the double cavity brick wall	110
5.11	Roof timber truss, insulation layers, and wire mesh	111
5.12	The cylinder of heat reclaim system	112
5.13	Heat reclaim system operational concept	113
5.14	Roof plan for the club house where solar photovoltaic panels were installed	113
5.15	Roof plan for the club house explaining the tilted of solar photovoltaic panels	114
5.16	The collection downpipes system	115
5.17	The collection sump under construction	115
5.18	Excavation, formwork, and casting the storage tank	116
5.19	The construction of the storage tank	117
5.20	The concept of hybrid hot water system operation	122

5.21	The trend of energy power generated by solar photovoltaic system in Mesra Terrace	124
5.22	Comparison between FIT Programme and the conventional returns from TNB	126
5.23	The common area in Mesra Terrace Development which includes the landscape of the courtyard and the clubhouse	129
7.1	Frequency of monthly energy consumption via Mesra Terrace dwellings	162
7.2	Matrix of energy consumption and number of occupants in Mesra Terrace dwellings	163
8.1	Post occupancy evaluation approach	179

## LIST OF ABBREVIATIONS AND TERMS

ACEM	Association of Consulting Engineers Malaysia
BedZED	Beddington Zero Energy Development
CHP	Bio-fuelled combined heat and power unit
DCLG	The UK Government Department for Communities and Local
EPA	The U.S. Environmental Protection Agency
FIT	Feed-in Tariff Programme
GBI	Green Building Index of Malaysia
GDP	Gross Domestic Product
GWTP	Green Water Treatment Plant
HUD	The United States Department of Housing and Urban Development
KeTTHA	Minister of Energy, Green Technology and Water in Malaysia
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt peak of power
l	Liter of water
LCC	Lifecycle cost
LCS	Lifecycle saving
LEED	Leadership in Energy and Environmental Design
MBIPV	Photovoltaic Technology Application Project
PAM	Malaysian Institute of Architects
POP	Post occupancy performance
PV	Solar photovoltaic panels
RM	The Malaysian Ringgit
ROI	Return on investment
RWDP	Rain Water Drain Pipe
SCORE	Special Committee on Renewable Energy
SREP	Small Renewable Energy Programme
SURIA-1000	Green solar energy programme
UNCED	Earth Summit in United Nations Conference on Environment and Development
W	Watt

# CHAPTER ONE

## INTRODUCTION

### 1.0 INTRODUCTION

There have been various developments in the evolution of the green homes with green technologies, and sustainable design principles due to the world global awareness of environmental concerns. Principles of green building reduce the debilitating impact on the environment via reducing CO<sub>2</sub> emission, which contributes to global warming and climate change (Underwood, 2010).

Around 20% of total global energy use is consumed by the residential sector compared to other sectors (Islam et al, 2009). In Malaysia, residential energy power consumption notably increased to 51% during last ten-year starting from the year 2000. Approximately 26% of the greenhouse gases are emitted from the residential sector where almost 85% of this emission is committed during occupancy and operational phase (Zaid, 2013).

During the 1960s, the threat of an inevitable energy crisis instigated domestic energy conservation (Broome, 2007). In addition, the oil embargo in 1973 spurred the development of passive solar design including renewable energy systems in residential buildings (Rovers, 2008). Developments in green homes was established following the Earth Summit in 1990s when the global green agenda was set (Broome, 2007; Underwood, 2010). Green technologies are defined as any product, element, material, and equipment which are added on or integrated in a design of an otherwise conventional home to upgrade environmental saving, social well-being, and financial savings (Friedman, 2007; Rovers, 2008). Recently, there have been various

developments on green homes, and green construction. Various green technologies such as solar hot water, heat recovery system, solar photovoltaic system, rainwater harvesting system, and wind power system have been implemented to achieve increasing sustainable standards in homes. According to the United States Green Building Council (USGBC), “a green home uses less energy, water, and natural resources; creates less waste; and is healthier for the people living inside” (Underwood, 2010: 3). The green home is defined by its sustainable performance and its green technologies including renewable energy systems to meet the target of CO<sub>2</sub> emission reduction through less energy consumption (Underwood, 2010). The green home concept is part of various green building scheme developed in many countries in the hopes of promoting energy savings on a wide scale (Alias et al., 2010). Various governments around the world have established their own mandatory and voluntary green home codes in respect with their targets and development scheme. This is to achieve standards, regulations, compliance in sustainable performance or to achieve green labelling or certification or to highlight and market the homes as being sustainable. Green home codes and policies are assessment and rating tools to guide and evaluate home design and performance in terms of environmental impact. The outcome of green homes codes and policies is the escalating of green technologies use to achieve a lower energy consumption that enables house-owners to realize energy saving criteria (Jones & Vyas, 2008).

Green codes upgrade green market and industry by promoting green practices, techniques, technologies, and applications aiming to comply with energy efficiency and saving codes’ requirements. In Malaysia, green building index for homes (GBI) has been developed as a voluntary programme. Table 1.1 encapsulates various sustainable homes assessment tools regulated by different countries around the world.

A more detailed description of some of green sustainable home codes achievability is presented in Chapter 2, section 2.3.

Table 1.1 Sustainable Home Assessment Tools Around The World

Assessment Tool Name	Country	Year
BREEAM-Domestic Refurbishment Course for Existing Assessors	UK	1990
Passivhaus	Germany	1991
LEED Mexico for homes	Mexico, US	1993
LEEDH-Leadership in energy and environmental design for homes	US	1998
EEWH for residential buildings	Taiwan	1999
Built Green Alberta Homes	US	2001
CASBEE for homes	Japan	2004
Go Green homes	Canada	2004
Green Mark for homes	Singapore	2005
Green Star certified new homes	South Africa	2008
LEED-India homes	India	2008
Green Star certified new homes	New Zealand	2007
FGBC Green Home	Florida, US	2002
BASIX home	Australia	2004
NAHB-The National Association of Home Builders	US	2005
Green Communities	US	2005
The Code for Sustainable Homes	UK	2006
NABERS for homes	Australia	2006
BEES-building Energy Efficiency Standard	Alaska, US	2007
Living Building Challenge	US	2007
Minnesota Green Star for homes	US	2007
LEED-Brazil for homes	Brazil	2008
Teri Griha for homes	India	2008
Green Building Index	Malaysia	2009

Source: Bakar et al. (2011)

Green building is a concept developed in the West. Since Malaysia adopted these concepts like other developing countries, many Malaysian developers refer to western developments in implementing green technologies in their projects. Accordingly, there is lack of after occupancy studies of these green technologies in Malaysia. Hence, the aim of this study is to review and study after occupancy impact