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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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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Affirmed by Rawia Marwan Abdul Aziz Dabdoob.

……. ……..
Signature Date

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

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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_2 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_2 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