

CARBON AND ENERGY USE REPORTING FOR
GOVERNMENT OFFICE BUILDINGS IN PUTRAJAYA

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

Faculty of Built Environment
Universiti Teknologi Malaysia

APRIL 2017

DEDICATION

Specially dedicated to my beloved father, mother, brother and sister
For your endless support

ACKNOWLEDGEMENTS

It is truly a great experience to conduct this research and able to complete the thesis. I am gratefully indebted to many people who have given their support to me in completing the thesis, without them the completion would not have been possible. I would first like to express my sincere gratitude to my thesis supervisor Prof. Dr. Ho Chin Siong for the guidance, advice and patience throughout my research and thesis writing. His valuable and enlighten comments have steered me in the right direction at the same time allowed this thesis to be my own work.

Besides my supervisor, I would like to thank the rest of my thesis committee: Associate Prof. Dr. Noorani binti Yusoff and Associate Prof. Datin. Dr. Norsiah binti Abd Aziz, for their insightful comments. My sincere thanks also go to Associate Prof. Dr. Muhammad Zaly Shah, Prof. Bert Scholtens, Mr. Steve Anthony Lojuntin and Ir. Syed Jaafar Idid for sharing your thoughts and immense knowledge during my research survey. I would also like to acknowledge Ms. Yuko Nishida and Mr. Kazuya Fujiwara for sharing precious information which had strengthened my understanding in this research.

To my friends, particularly Dr. Chee Ping Ngang, Dr. Chua Rhan See, Dr. Goh Hong Ching, Dr. Janice Jeevamalar Simson, Muhammad Hakimi Mohd Hussain, Farah Zaini, Thong Jia Wen and Chau Loon Wai, my deepest appreciation for the stimulating discussions and most importantly supporting me spiritually throughout writing this thesis. Last but not the least; Perbadanan Putrajaya for funding my master program which had made this wonderful experience possible.

ABSTRACT

The Malaysian Government has announced to develop Putrajaya as a pioneer Green Township in Malaysia. Policy to reduce the carbon footprint is stipulated in the Putrajaya Structure Plan 2025. Major carbon reduction is expected to be contributed by the building sector, particularly non-residential buildings due to their highest emissions volume and increasing emission trends. However, carbon reduction possibilities have yet to be identified and building sector's stakeholder engagement in emission mitigation remained uncertain. Carbon and energy use reporting is one of the mechanisms increasingly implemented by cities in developed nations but not commonly practiced in Malaysia. This research is to examine the application of carbon and energy use reporting in reducing emissions in Putrajaya's government office buildings. Literature reviews suggest that implementation of reporting programme should consider six (6) common driving factors (regulatory compliance, energy cost savings, leadership, enhancing reputation, fostering relationship with stakeholders and environmental awareness), key elements in reporting and implementation approach used in the empirical cases. This study has carried out interviews with questionnaire with all 29 facility managers of existing government office buildings in Putrajaya, to investigate the current reporting status, practices, their agreement and expectation towards reporting programme. The survey data were analysed using frequency analysis and chi-square test for independence to test the association between variables. The survey results showed that 82.8% of the facility managers conduct carbon and energy use reporting. This reporting status has no significant association with their company size ($p\text{-value}=0.371>0.05$). Regulatory compliance and fostering relationship with stakeholders are the key driving factors for facility managers' engagement in this reporting activity. Reporting obligation was based on contract scopes and stakeholders' request. Carbon abatement potential through benchmarking against other similar office buildings and public disclosure of building performance are not widely conducted, with less than 1/3 of facility managers practicing this. Future mandatory reporting was generally agreed by facility managers. This agreement has no significant association with their working experiences in Putrajaya ($p\text{-value}=1.00>0.05$). Based on the findings, recommendations have been proposed to improve the current reporting practice and future expansion to the whole building sector in Putrajaya, so that Government can lead by example to effectively encourage this new practice.

ABSTRAK

Kerajaan Malaysia telah mengumumkan supaya Putrajaya dibangunkan sebagai Bandar Hijau perintis di Malaysia. Satu polisi untuk mengurangkan karbon telah ditetapkan dalam Pelan Struktur Putrajaya 2025. Sumbangan pengurangan karbon yang utama dijangkakan daripada sektor bangunan, khasnya bangunan bukan kediaman berdasarkan jumlah pelepasan karbon yang tertinggi dan tren pelepasan yang meningkat. Namun, peluang pengurangan karbon belum dapat dikenalpasti dan penglibatan pihak berkepentingan sektor bangunan dalam tindakan pengurangan karbon masih tidak dapat ditentukan. Pelaporan karbon dan penggunaan tenaga merupakan salah satu mekanisma yang semakin lazim dilaksanakan oleh bandar di negara maju, tetapi belum diamalkan secara meluas di Malaysia. Kajian ini bertujuan mengkaji aplikasi pelaporan karbon dan penggunaan tenaga bagi bangunan pejabat kerajaan di Putrajaya untuk mengurangkan pelepasan karbon. Kajian literatur mencadangkan perlaksanaan program pelaporan harus mengambilkira enam (6) faktor penggerak (pematuhan kepada peraturan, penjimatan kos tenaga, kepimpinan, meningkatkan reputasi, mengeratkan hubungan dengan pihak berkepentingan dan kesedaran alam sekitar), elemen utama dalam penyediaan laporan dan pendekatan pelaksanaan yang digunakan oleh kes empirikal. Temu bual menggunakan borang soal selidik telah dijalankan bersama kesemua 29 pengurus kemudahan bangunan pejabat kerajaan di Putrajaya untuk menyiasat status pelaporan semasa, amalan, persetujuan dan harapan terhadap program pelaporan. Data kajian dianalisa menggunakan analisis frekuensi dan *chi-square test for independence* untuk menguji hubungkait antara pembolehubah. Hasil kajian menunjukkan bahawa 82.8% pengurus kemudahan telah terlibat dalam pelaporan karbon dan penggunaan tenaga. Status pelaporan ini didapati tidak berhubungkait dengan saiz syarikat mereka (nilai- $p=0.371>0.05$). Pematuhan kepada peraturan dan mengeratkan hubungan dengan pihak berkepentingan merupakan faktor penggerak utama bagi pengurus kemudahan melibatkan diri dalam aktiviti pelaporan ini. Obligasi melapor adalah berdasarkan kepada skop kontrak dan permintaan daripada pihak berkepentingan. Potensi pengurangan karbon melalui penanda aras terhadap bangunan pejabat lain yang mempunyai persamaan dan mendedahkan prestasi bangunan kepada orang awam masih belum dijalankan secara meluas, dengan kurang daripada 1/3 pengurus kemudahan mengamalkannya. Secara umumnya, pelaporan wajib pada masa depan adalah dipersetujui oleh pengurus kemudahan. Persetujuan ini tidak berhubungkait dengan pengalaman kerja pengurus kemudahan di Putrajaya (nilai- $p=1.00>0.05$). Berdasarkan penemuan kajian, cadangan telah dikemukakan bagi meningkatkan lagi amalan pelaporan semasa dan untuk diperkembangkan ke seluruh sektor bangunan di Putrajaya pada masa depan, supaya Kerajaan boleh menjadi satu teladan kepada pelaksanaan amalan baru ini.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiv
	LIST OF ABBREVIATIONS	xvi
	LIST OF SYMBOLS	xvii
	LIST OF APPENDICES	xviii
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Problem Statement	6
	1.3 Research Purpose and Questions	9
	1.4 Research Objectives	10
	1.5 Research Scopes	10
	1.6 Research Area - Putrajaya	11
	1.7 Research Significance	13
	1.8 Structure of the Thesis	15
2	LITERATURE REVIEWS	17
	2.1 Buildings and Low Carbon Cities	17
	2.2 Contribution of Buildings to Carbon Emissions	21

2.2.1	Factors Affecting Carbon Emissions of Buildings in Use	22
2.2.2	Carbon Reduction Measures for Buildings in Use	25
2.3	What is Carbon and Energy Use Reporting?	27
2.4	The Roles and Contributions of Carbon and Energy Use Reporting	32
2.4.1	Reporting and Urban Energy Planning	33
2.4.2	Reporting and Carbon Emissions Mitigation	36
2.5	Driving Factors for Reporting	41
2.5.1	Regulatory Compliance	42
2.5.2	Energy Cost Savings	43
2.5.3	Leadership	44
2.5.4	Enhancing Reputation	45
2.5.5	Fostering Relationship with Stakeholders	47
2.5.6	Environmental Awareness	48
2.6	Measuring and Reporting Emissions from Building Operations	51
2.6.1	Reporting boundary	52
2.6.2	Emissions Calculation	55
2.6.3	Performance Metrics	57
2.6.4	Reduction Target	59
2.7	Conclusion	60

3	BEST PRACTICES OF CARBON AND ENERGY USE REPORTING PROGRAMME	62
3.1	Introduction	62
3.2	Tokyo Metropolitan Area: Carbon Reduction Reporting Programme	63
3.2.1	Reporting Obligation and Disclosure Level	64
3.2.2	Performance Evaluation	67
3.2.3	Technical Assistance and Incentive	67

3.3	Seattle City: Building Energy Benchmarking and Reporting Programme	69
3.3.1	Reporting Obligation and Disclosure Level	70
3.3.2	Performance Evaluation	72
3.3.3	Technical Assistance and Incentive	74
3.4	Houston City: Green Office Challenge	75
3.4.1	Reporting Obligation and Disclosure Level	75
3.4.2	Performance Evaluation	76
3.4.3	Technical Assistance and Incentive	77
3.5	Policies and Tools in Supporting Carbon and Energy Use Reporting	80
3.5.1	Efficient Management of Electrical Energy Regulations 2008	80
3.5.2	Building Consumption Input System	82
3.6	Conclusion	84
4	RESEARCH METHODOLOGY	86
4.1	Introduction	86
4.2	Research Design	86
4.3	Research Approach	88
4.4	Data Collection	89
4.5	Respondents	92
4.6	Research Instrument	93
4.6.1	Pilot Surveys	95
4.7	Data Analysis	96
4.8	Conclusion	98
5	RESULTS AND DISCUSSIONS	99
5.1	Introduction	99
5.2	Demographic Profile of Respondents	99
5.2.1	Respondents' Profession	100
5.2.2	Experiences Managing Government Office Buildings in Putrajaya	100

5.2.3	Company Size	101
5.3	Carbon and Energy Use Reporting Status	102
5.3.1	Reporting Status and Company Size	104
5.4	Driving Factors and Barriers for Carbon and Energy Use Reporting	105
5.4.1	Driving Factor for Reporting	106
5.4.2	Barriers for Reporting	108
5.5	Existing Carbon and Energy Use Reporting Practices	110
5.5.1	Reporting Obligation	110
5.5.2	Reporting Methods	112
5.5.2.1	Reporting Boundary and Emissions Profile	112
5.5.2.2	Calculation Tool	114
5.5.3	Carbon Abatement Potential	115
5.5.3.1	Performance Evaluation	115
5.5.3.2	Emissions Reduction Measures	120
5.5.3.3	Disclosure level	124
5.6	Agreement and Expectation on Reporting Programme	126
5.6.1	Agreement on the Role of Reporting	126
5.6.2	Agreement on Mandatory Reporting	128
5.6.3	Expectation on Technical Assistance and Incentive	130
5.7	Conclusion	132
6	CONCLUSIONS AND RECOMMENDATIONS	135
6.1	Introduction	135
6.2	Research Findings	137
6.2.1	Status of Carbon and Energy Use Reporting	138
6.2.2	Existing Reporting Obligation	139
6.2.3	Comprehensiveness and Comparability of Reporting Methods	140
6.2.4	Carbon Abatement Potential	141

6.2.5	The Agreement and Expectation on Reporting Programme	142
6.3	Recommendations	143
6.3.1	Establishing a Uniform and Consistent Reporting Obligation	144
6.3.2	Benchmarking and Performance Rating System	145
6.3.3	Phase in Implementation Approach	147
6.3.4	Stakeholder Engagement through Task Force Setting	151
6.4	Research Limitation and Problem	157
6.5	Suggestions for Further Research	158
6.6	Conclusion	158
	REFERENCES	160-175
	Appendices A - C	176

LIST OF TABLES

TABLE NO.	TITLE	PAGE
1.1	Summary of Putrajaya Development Status	12
2.1	Driving Factors for Implementation of Carbon and Energy Use Reporting	49
2.2	Four Common Emissions Sources in CCM Building Sector Greenhouse Gas (GHG) Calculator	54
2.3	Grid Emission Factor for Peninsular Malaysia, Sabah and Sarawak from Year 2012-2014	56
3.1	Low Carbon Benchmark Range	67
3.2	Seattle's 2013 Annual Benchmarking Reporting Compliance Rates	70
3.3	2013 Energy Performance Ranges for Seattle's Building Types	73
3.4	Evaluation Criteria for Building Owner	76
3.5	Summary of Key Elements in Case Examples Reporting Programme	79
3.6	Putrajaya Public Buildings Performance Data in BCIS	83
5.1	Cross Tabulation between Status of Carbon Reporting and Energy Use Reporting	103
5.2	Cross Tabulation of Reporting Status and Company size	104
5.3	Chi Square Test (Reporting Status and Company size)	105
5.4	Driving Factors for Carbon and Energy Use Reporting	106
5.5	Comparison of Driving Factors between Group A and Group B Facility Managers	108
5.6	Summary of Reporting Obligation Examples	111
5.7	Physical Reporting Boundary	113

5.8	Examples of Reduction Targets among Facility Managers	119
5.9	List of Carbon Emissions Reduction Programme Regularly Conducted by Facility Managers	123
5.10	Cross Tabulation of Agreement for Mandatory Reporting and Experiences	129
5.11	Chi Square Test (Agreement on Mandatory Reporting and Experiences)	129
5.12	Rank of Technical Assistances by Facility Managers	131
5.13	Rank of Incentives by Facility Managers	132
6.1	Summary of Task Force Members and Collaboration Areas	155

LIST OF FIGURES

FIGURE NO	TITLE	PAGE
1.1	Putrajaya GHG Emissions by Three Main Sectors for 2007, 2012-2014	3
1.2	Economic Mitigation Potential by Sector, 2030	4
1.3	Regional Context and Putrajaya Land Use Plan 2025	12
2.1	Contributors to Greenhouse Gas Emissions	18
2.2	Building Life Cycle	19
2.3	Life Cycle Phases with Several Cycles for the Use Phase	20
2.4	Building Life Cycle Emissions	21
2.5	Comparison of BEI for Government Buildings	24
2.6	Overview of Corporate Accounting and Reporting Boundaries	31
2.7	Overview of Facility Physical Boundary	31
2.8	Three pillars of Green Urbanism	34
2.9	City Transition towards a Low Carbon Energy System	36
2.10	GHG Management Cycle	37
2.11	Relationship between Disclosure Levels and Achievement of Reductions	41
2.12	Steps in Preparing Emissions Report	52
2.13	Overview of Scopes and Emissions	53
2.14	Examples of Emissions Sources in MYCarbon	53
2.15	Example of Emission Factor Calculation Approach	56
3.1	Paradigm Shift in Carbon Reduction Reporting Programme	64
3.2	Reporting Threshold for Tokyo's Carbon Reduction Reporting Programme	65

3.3	Transition of Carbon Emissions by Facilities Submitted the Report in Four Consecutive Years	66
3.4	Schematic View of Carbon Reduction Reporting Programme for Small and Medium Facilities in Tokyo	68
3.5	Green Office Challenge Milestones	77
3.6	Data Collection in BCIS	82
4.1	Research Flow Chart	87
5.1	Share of Respondents by Profession	100
5.2	Share of Respondents by Experiences	101
5.3	Facility Management Firms by Number of Employees	102
5.4	Overall Reporting Status among Facility Managers	102
5.5	Share of Facility Managers by Barriers	109
5.6	Share of Facility Managers by Types of Reporting Obligation	110
5.7	Carbon Emissions Calculation Tools Used by Facility Managers	114
5.8	Building Performance Metrics Used by Facility Managers	116
5.9	Overall Status of Reduction Target Setting by Facility Managers	117
5.10	Number of Facility Managers by Reduction Targets	118
5.11	Performance Evaluation Practices by Facility Managers	120
5.12	Types of Carbon Emissions Reduction Measures Conducted/Planned by Facility Managers	121
5.13	Share of Facility Managers by Carbon Emissions Reduction Measures	122
5.14	Different Disclosure Level Undertaken by Facility Managers	124
5.15	Medium Used for Different Disclosure Level	125
5.16	LCD Monitor as Medium Used for Public Disclosure	126
5.17	Agreement on Reporting Enable Emissions Reduction	127
5.18	Agreement on Mandatory Reporting	128
6.1	Proposed Implementation Phases and Core Activities	148
6.2	Proposed Stakeholder Network in Reporting Programme	152

LIST OF ABBREVIATIONS

BCIS	-	Building Consumption Input System
BEI	-	Building Energy Index
CCM	-	Common Carbon Metric
CDP	-	Carbon Disclosure Project
CIDB	-	Construction Industry Development Board Malaysia
DEFRA	-	Department for Environment, Food and Rural Affairs
EMEER	-	Efficient Management of Electrical Energy Regulations
ERM	-	Environment Resources Management Limited
FiT	-	Feed-in-tariff
GHG	-	Greenhouse Gas
IEMA	-	Institute of Environmental Management & Assessment
IPCC	-	Intergovernmental Panel on Climate Change
JKR	-	Public Works Department
JPM	-	Prime Minister Department
KeTTHA	-	Ministry of Energy, Green Technology and Water
KPI	-	Key Performance Indicator
LCCF	-	Low Carbon City Framework
LEED	-	Leadership in Energy and Environmental Design
MGTC	-	Malaysian Green Technology Corporation
NRE	-	Ministry of Natural Resources and Environment
OECD	-	Organization for Economic Co-operation and Development
TMG	-	Tokyo Metropolitan Government
UNEP-SBCI	-	United Nations Environment Programme-Sustainable Buildings & Climate Initiative
WRI	-	World Resources Institute

LIST OF SYMBOLS

CO ₂	-	Carbon dioxide
kgCO ₂	-	Kilogram carbon dioxide
kgCO ₂ /m ²	-	Kilogram carbon dioxide per square meter
ktCO ₂	-	Kilo tonne carbon dioxide
kWh	-	Kilowatt hour
kWh/m ²	-	Kilowatt hour per square meter
ktoe	-	Kilo tonne oil equivalent
MWh	-	Megawatt hour
tCO ₂	-	Tonne carbon dioxide
tCO ₂ /MWh	-	Tonne carbon dioxide per megawatt hour

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	List of Facility Managers for Government Office Buildings in Putrajaya	176
B	Questionnaire	178
C	Reasons for Not Including Emissions Sources Scope 1 and Scope 3	184

CHAPTER 1

INTRODUCTION

1.1 Introduction

During the United Nations Framework Convention on Climate Change, Conference of Parties (COP21) on November 2015 Malaysia has announced a new voluntary GHG emissions intensity reduction target of 45 percent by year 2030 (Intended Nationally Determined Contribution of the Government, 2015). The new target is to be achieved within 10 years' time frame from 2021 to 2030 (Intended Nationally Determined Contribution of the Government, 2015). This is the reviewed reduction target which is higher compared to the previous target made during COP15 in year 2009 which was 40 percent by the year 2020. The reduction is expected to be contributed from energy, building, transportation and waste management sector (Yong et al., 2011). The federal government's vision for carbon emissions reduction has been extended to city level through the announcement of Putrajaya and Cyberjaya to be developed as pioneer Green Township in Malaysia and focusing on the aspect of reducing carbon footprint in the city (KeTTHA, 2011).

In accordance with the above national vision, Putrajaya had incorporated a long term vision in the Putrajaya Structure Plan that the city will be transformed from the garden city to the green city by year 2025 (Perbadanan Putrajaya, 2012a). This vision has been further interpreted into a more specific policy under the Policy 5 of the Putrajaya Structure Plan 2025 which has emphasized the initiatives to reduce carbon footprint in the city through application of green practices in city planning and management (Initiative 5.2), as well as the adoption of sustainable building

practices (Initiative 5.3). In order to support these initiatives, programmes will be implemented to encourage efficient use of water and alternative water source, efficient use of energy and use of renewable energy. Apart from that, the new buildings need to be designed with a low energy system, while to undertake continuous monitoring of building performance for existing buildings. Vision and policies stated in this important statutory document have provided a clear direction for Putrajaya to undertake emissions reduction initiatives in the different stages of urban development, both design and operation stage.

As a starting point, the local government of Putrajaya has conducted a citywide GHG emissions inventory to identify the base year emissions and estimated future potential emissions reduction (Perbadanan Putrajaya, 2012b). In this study the base year has been determined as 2007 and the target year for emissions reduction is 2025, in line with the vision stated in Putrajaya Structure Plan 2025. Three (3) main GHG emitting sectors in Putrajaya were identified, which are the building sector (51 percent), land transport sector (27 percent) and waste sector (22 percent). For the building sector, carbon emissions were focused on the energy consumed (purchased electricity, district cooling) during the building operation. Existing government office buildings were estimated to account for 54 percent of the total emissions in the building sector in base year 2007. To achieve the status of low carbon city, Putrajaya has set an ambitious citywide reduction target to reduce its carbon emissions related to energy use by 60 percent from the level of 2025 business as usual scenario. The reduction contribution anticipated from the building sector was 33 percent due to its highest emissions coverage. To monitor this quantified reduction progress from existing building stocks in the city and pursue further reduction possibilities remain as the biggest challenges to the local government of Putrajaya towards achieving the reduction target.

Being an urbanized area which is still experiencing development, emissions level in the building sector has showed significant growth which was about 3 times from the base year level of 335ktCO₂ in 2007 to 1,038ktCO₂ in 2014 as shown in Figure 1.1 (Perbadanan Putrajaya, 2015). The carbon emissions intensity of floor area has increased about 1.8 times from 0.07tCO₂/m² in year 2007 to 0.13tCO₂/m² in

the year 2014. However, within the same inventory period the growth rate for completed floor spaces in the city was about 1.7 times, which is lower than the growth rate in total carbon emissions and emission intensity by floor area as mentioned earlier. The inventory results reflected that increased of carbon emissions in building sector may not only cause by the growth in floor spaces, instead could be due to inefficiency of energy use in building operations. Hence, there could be further carbon emissions reduction possibilities within the existing individual building yet to be identified. In addition, the above scenarios also indicate that the rate of completed floor spaces added each year is not as high as the emission growth rate from existing building stocks. Under such circumstance, a bottom up building's carbon and energy use performance monitoring is necessary to provide more accurate performance data for existing building stocks in Putrajaya. This is also to support the programme under Initiative 5.2 in Putrajaya Structure Plan 2025 that required a continuous building performance monitoring to be undertaken.

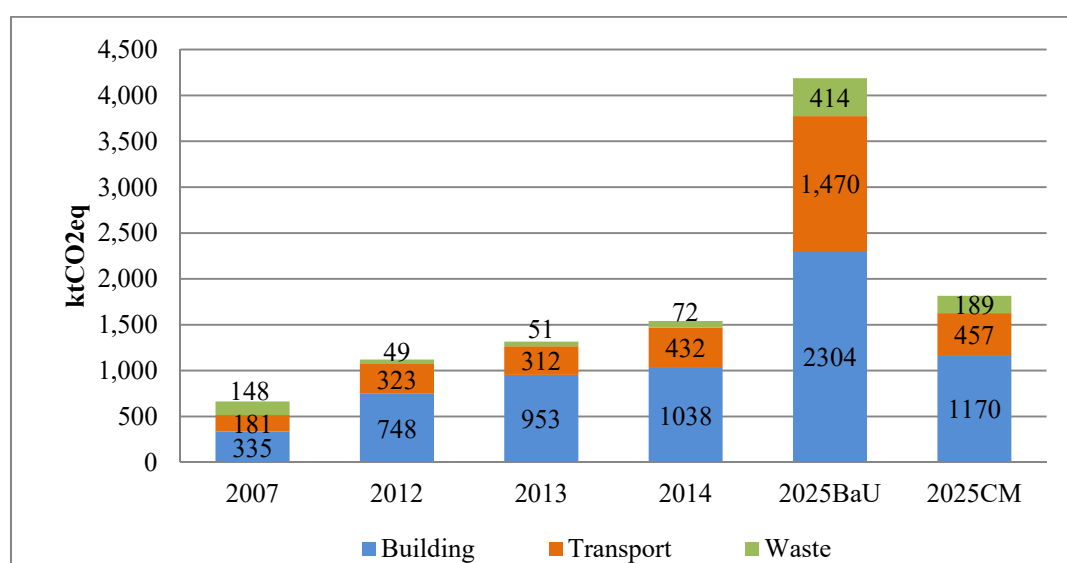


Figure 1.1: Putrajaya GHG Emissions by Three Main Sectors for 2007, 2012-2014

Source: Adapted from Perbadanan Putrajaya, 2012b, 2013, 2014, 2015b

Buildings are a long-lived land use component in city areas which in the common circumstances would have life expectancies longer than its designer, constructors, users and perhaps other land use components in our built environment as well. Its potential life span can last for hundreds of years with well maintenance and regular repair (Konig, Kohler, Kreibig, & Lutzkendorf, 2010). Yet, its emissions

have occurred throughout the whole life cycle and particularly high during the use phase when buildings in operation. Hence, it is essential to monitor the negative environmental impact of resource-consuming activities by buildings before any effective measures can be undertaken. Furthermore, Putrajaya is still developing therefore the built up area are expected to grow continuously and stimulate more energy-related emissions. Thus, buildings' energy-related emissions performance should be monitored for further improvement in order to stabilize the city's emissions level.

In the context of urban sustainability, it is necessary to establish a mechanism which allows the continuous monitoring to eliminate negative environmental impact associated with the operation of this long-lived land use component. From the perspective of economic development benefit building sector has the largest potential for long term, cost effective and significant emissions reduction (IPCC, 2007; UNEP, 2009; WRI, 2016). Figure 1.2 presents the building sector economic mitigation potential as compared to other sectors. As recommended by the United Nations Environment Programme (UNEP) - Sustainable Buildings and Climate Initiative (SBCI) report (2009), the government is also encouraged to take the lead in prioritizing building sector in their climate change strategies through effective policies such as collecting comprehensive data and information for building sector, comparable energy performance, systems and frameworks for consultation with all major stakeholders.

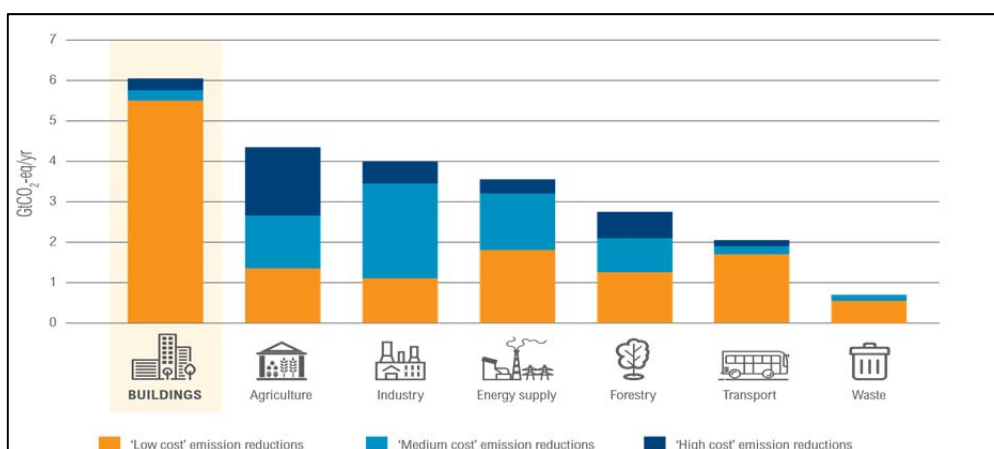


Figure 1.2: Economic Mitigation Potential by Sector, 2030

Source: WRI, 2016

For this purpose, several policy options are available worldwide to mitigate and manage energy-related carbon emissions from existing buildings such as carbon and/or energy use reporting, energy use benchmarking scheme, performance rating/certification scheme and emission trading scheme. One common requirement for these policy options is the information about emissions and energy performance from building operations. Such kind of building operational performance disclosure can fit into a general policy trends which have been applied in other areas (Hsu, 2013). Reporting of building's operational performance is an increasingly popular policy option at city level, mostly targeting on large scale non-domestic urban buildings. The important role of information can be evidenced through the efforts to mandate building performance disclosure in United States (Hsu, 2013). In Tokyo, the world's first urban cap-and-trade scheme for large facilities including office buildings was a step-up measure based on their prior carbon reporting programme for buildings started in 2002 (Nishida & Hua, 2011; TMG, 2012a). Asian cities such as Hong Kong and Singapore, which are highly urbanized and having high density buildings are also practicing reporting programme to monitor the emissions and energy use of existing office buildings (Building and Construction Authority Singapore, 2015; Lai, 2014). In the United States, benchmarking scheme is a favourable policy for city to mitigate carbon emissions from buildings, eleven cities have started implementation which required submission of emissions and energy data by building owners (Palmer & Walls, 2015).

However, implementation approaches are varied across the cities through regulatory or voluntary requirement in order to engage the involvement of building stakeholders in their reporting programme and to secure the commitment for further carbon reduction actions. Through reporting programme, the actual carbon emissions from energy use during the building operations have to be measured and monitored consistently by building stakeholders. The information collected is useful to identify the gap between expected performance and actual performance so that corrective actions can be taken. There are several attractive features identified by prior research related to emissions and energy use reporting. First, by establishing such reporting system it allows government to collect data and gain insight of bottom-up emissions reduction possibilities and as a crucial first step in GHG

management process particularly in improving energy efficiency (Ayalon, Lev-On, Lev-On, & Goldrath, 2014). Second, mandatory reporting emissions and energy use data is needed to support other government actions and policy for emissions reduction (KPMG, 2010). Third, transparent and timely performance information enable city leaders and decision-makers to track performance against targets (WRI, 2016). Fourth, its implementation cost is relatively lower as compared to other energy efficiency policy options and any necessary mandatory requirement for reporting can be passed at state or local level (Hsu, 2013).

Based on the advantages above, reporting programme can be considered an effective tool for any city to start on before undertaking any advance measures in building sector carbon reduction management. Apart from that it is also useful to track the progress of any carbon reduction measures which have been implemented. Hence, this study is an attempt to discover the usefulness and the implementation approach of carbon and energy use reporting in managing emissions reduction for the building sector. Most importantly in supporting the national carbon reduction efforts and Putrajaya's vision moving towards low carbon city by 2025.

1.2 Problem Statement

The further analysis by share for citywide GHG inventory results in 2014 showed that non-residential buildings contributed 91 percent of the total carbon emissions in building sector as compared to residential buildings which contributed a minimal share of 9 percent (Perbadanan Putrajaya, 2015). Non-residential buildings include government office buildings, commercial buildings (office complexes/shops/shopping malls/hotels), public amenities (neighbourhood complexes/schools/hospital/clinics/mosques/markets) and utility buildings (gas district cooling plants/TNB sub stations/water & sewerage treatment plants). Among the non-residential buildings, government office buildings accounted highest carbon emissions, which were 60 percent of total emissions in the building sector. This building category is also currently occupying the largest floor spaces among the non-

residential buildings which is about 33.6 percent of total floor area of existing building stocks within the city (Perbadanan Putrajaya, 2015b). With regards to this, existing government office buildings should be considered as a priority target building type and to serve the purpose of government lead by example in any carbon emissions mitigation plan in Putrajaya.

Presently, it is still lack of a city scale bottom up monitoring mechanism implement by the local government, to monitor the carbon and energy use performance of existing building stocks in Putrajaya. Therefore, further reduction possibilities yet to be identified. A uniform and standard monitoring approach shall be implemented in order to effectively monitor a large number of building stocks in the city. To accomplish the city scale carbon reduction target, it is necessary for the local government to engage the involvement of respective building stakeholders in their carbon emissions reduction initiatives. To what extent, the carbon emissions reduction has been incorporated by building stakeholders in their daily operations are remain uncertain. The next challenge is how local government can reduce this information gap and ensure the wide spectrum of building stakeholders share the common goal in order to stabilize the upward carbon emissions trend in the city.

Carbon and energy use reporting is one of the policy instruments which is increasingly implemented by governments of developed countries in mitigating carbon emissions at corporate and facility (building, factory, outdoor equipment) level. In Malaysia, a national voluntary corporate GHG reporting programme (MYCarbon) has been initiated by Ministry of Natural Resources and Environment (NRE) since year 2013 (NRE, 2014). The programme is aimed for corporate level emissions reporting, particularly those in private sectors and required a consolidation of emissions reporting from all its facilities, subsidiaries and other organization within the determined boundary. The importance of building level emissions measuring and reporting at city level have been highlighted in Low Carbon Cities Framework to allow consistent emissions assessment, comparison and improvement for buildings (KeTTHA, 2011). However, the implementation of operational carbon and energy use monitoring has not been widely practiced and promoted as compared to green building design through existing efforts such as establishment of MS1525:

Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-residential Buildings; green building design rating tools to recognize the adoption of green features for new buildings such as Green Building Index (GBI); enforcement of green building design for large scale buildings in the Planning Permission and Building Plan approval in Putrajaya.

Based on the above scenarios, it is reflected that the implementation of carbon and energy use reporting at building level still rather new and worth to be explored as one of the measures in emissions reduction management for existing urban buildings. Prior studies related to carbon and energy use reporting mostly found in the research areas of climate change reporting, environmental reporting and corporate social responsibility (CSR) reporting. Studies were mainly conducted in developed countries such as United States (Erin M. Reid, 2009; Villiers & Van Staden, 2011; Matisoff, 2012; Hsu, 2013, 2014; Burman, Hong, Paterson, Kimpian, & Mumovic, 2014; Hong, Paterson, Burman, Steadman, & Mumovic, 2013; Mathew et al., 2014), United Kingdom (Ennis, Kowitz, Lin, & Markusson, 2012; Kolk, Levy, & Pinkse, 2008; Scholtens & Kleinsmann, 2011), Australia (Andrew & Cortese, 2011; Lodhia & Martin, 2011; Rankin, Windsor, & Wahyuni, 2011; Wong & Zapantis, 2013; Wong, Lindsay, Cramer, & Holdsworth, 2015), Japan (Nishida & Hua, 2011; Nishida, Hua, & Okamoto, 2016) and Canada (Talbot & Boiral, 2013).

The majority of the prior studies has focused on company and organization level reporting compared to building level reporting. Research areas were related to content analysis (corporate annual reports/ websites/ standalone report) identifying the quantity and quality of information reported, literature reviews on the different reporting framework, examine the relationship between reporting activity and performance (carbon/financial). In Malaysia, carbon and energy use reporting for building sector is still new and minimal research. It is not much concern to address the roles of reporting in carbon emissions mitigation and implementation approach at the city level to engage building stakeholders' continuous involvement. Hence, it would be interesting to examine the application of this reporting practice in the local context of a city with the aim to reduce buildings' energy use carbon emissions in mind.

Public leadership programmes are policy option that considered effective and cost-efficient used to demonstrate new practices and technologies (Diana, Koeppe, & Mirasgedis, 2007). With this reason, adoption of carbon and energy use reporting among government office buildings could serve for demonstration purpose, deliver significant effect to transform the market and also had education effect. The role of government has been seen as an essential component towards environmental sustainability and their dedicated efforts are in the strong demand (Sim, Federik, Law, & Azhaili, 2014). This can be observed through the implementation of New Key Economic Areas (NKEA) for Oil, Gas and Energy Sector, Entry Point Project 9 (EPP-9) - Improving Energy Efficiency, which has identified Government Lead by Example (GLBE) in spearheading efficient use of energy in buildings amongst the measures (SEDA, 2012). Hence, this study will investigate to what extent the carbon and energy use reporting has been incorporated into the existing reporting practices among government office buildings. This is also important information to provide insight into the potential use of reporting as a policy instrument for building sector carbon performance monitoring in Putrajaya particularly for large scale non-residential buildings. In addition, in the long term, it may support for the future implementation of cap-and-trade by local government.

1.3 Research Purpose and Questions

This research is to examine the application of carbon and energy use reporting for emissions reduction in Putrajaya's government office buildings. This research is expected to give insight into the implementation of carbon and energy use reporting for building sector at city level. To achieve the research purpose, there are few questions arising from this study as follows:

- i) What are the roles and driving factors for carbon and energy use reporting?
- ii) What are the implementation approaches for building level carbon and energy use reporting?

- iii) To what extent are the carbon and energy use reporting incorporated into the existing reporting practices to monitor carbon emissions from government office buildings?

1.4 Research Objectives

To achieve the research purpose and the questions arise, this study is conducted based on the following objectives:

- i) To identify the roles and driving factors for carbon and energy use reporting.
- ii) To review the key elements of reporting and programme implementation.
- iii) To investigate the current carbon and energy use reporting status and practices by facility managers for existing government office buildings in Putrajaya.
- iv) To give recommendations for improving the existing carbon and energy use reporting practices of government office buildings and future expansion to the whole building sector.

1.5 Research Scopes

In this study, four research scopes have been included as follows:

- i) The study focused on carbon and energy use reporting for buildings in the life cycle stage II – building in use phase and energy consumption related carbon emissions.
- ii) This study will identify the roles and contributions of reporting in carbon emissions mitigation as well as the driving factors for building stakeholders to undertake carbon and energy use reporting. The scope also includes an understanding of key elements in measuring and reporting emissions from building operations.

- iii) The review of carbon and energy use reporting approaches included reporting programmes conducted at city level with the purpose to monitor:
 - a. Carbon performance and/or
 - b. Energy use performance (ultimately decrease carbon emissions)
- iv) Case study of carbon and energy use reporting status and practices in government office buildings of Putrajaya.

1.6 Research Area – Putrajaya

Putrajaya is the federal government administrative centre of Malaysia, a mega township development initiated by the national government. Sustainable development principles that underpin the city's master plan was approved in 1995 (Perbadanan Putrajaya, 1997). Two underlying planning concepts in the master plan of Putrajaya were 'City-in-a-garden' and 'Intelligent City'. The city is strategically located within the Multimedia Super Corridor and in between Kuala Lumpur and Kuala Lumpur International Airport (Figure 1.3).

The total area of Putrajaya is 4,931 hectares. In line with the city-in-a-garden concept approximately 40 percent of its total land area has been designated as parks and open spaces including a man-made lake and the remaining 60 percent of land will be developed with major components such as residential, non-residential buildings and roads (Perbadanan Putrajaya, 2012c). The total planned population was 350,000 and a daytime population of 500,000. The city has been divided into 20 precincts with designated core function including the following: government precinct at Precinct 1, central business district at Precinct 2 to Precinct 5, surrounded by 14 residential precincts which is Precinct 6 to Precinct 19 and end at Precinct 20 which was designated as integrated cemetery areas for all religion uses.

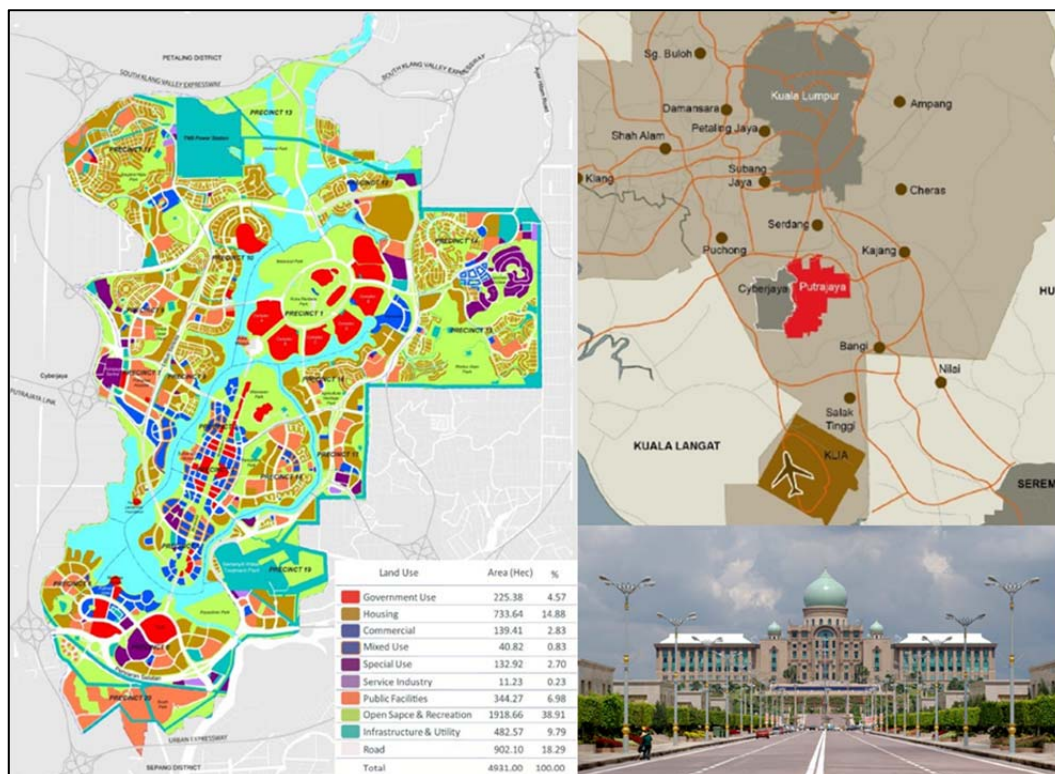


Figure 1.3: Regional Context and Putrajaya Land Use Plan 2025

Source: Adapted from Perbadanan Putrajaya, 2012c

Establishment of this new city has marked the 20th anniversary on August 2015 (Perbadanan Putrajaya, 2015b). Presently, the existing building stocks in Putrajaya are mainly residential buildings followed by non-residential buildings such as government office buildings and commercial buildings (Table 1.1). Apart from Precinct 1, government office buildings are also located in Precinct 2 to Precinct 5. All 21 ministries have moved from Kuala Lumpur to Putrajaya and fully operating as planned by the Federal Government. In general, there are two types of government office buildings in Putrajaya, which are shared use office building by several ministries or government departments and non-shared use office building occupied by single ministry or government department (JPM, 2003).

Table 1.1: Summary of Putrajaya Development Status

Status	Planned (2025)	Current
Population	350,000 people	82,200 people
Housing	65,000 units	27,589 units
Government office space	3.4 million square meter	2.7 million square meter
Commercial space	4.5 million square meter	0.7 million square meter

Source: Perbadanan Putrajaya, 2015b

For the building sector low carbon initiatives have been undertaken by local government of Putrajaya since 2011 by imposing conditions in Planning Permission and Building Plan approvals to include green building design for large scale non-residential new developments such as commercial complexes (Perbadanan Putrajaya, 2012c). Developers are also required to obtain green building certification for the above new development. As of 2014, seven buildings have obtained green building certification and thirteen more in the planning stage. Low carbon initiatives for existing building stocks are more depending on voluntary actions by building owners, managers or users conduct necessary retrofitting works and other energy saving programmes. Thus, it can be observed that current efforts for existing building stocks still not much concern and should be further strengthened by the local government of Putrajaya.

1.7 Research Significance

This research is important to provide insight into the usefulness of carbon and energy use reporting as a mechanism for building sector carbon emissions mitigation in achieving urban sustainability. Apart from that, other significances of this study are highlighted as follows:

- i) This study intends to fill the gap in the existing literatures of carbon and energy use reporting, particularly in the context of facility (building) level which is still minimal research. This research addresses the roles and contributions of carbon and energy use reporting in the overall GHG management cycle, which may assist in accelerating the building sector's emissions reduction targeted by any local government. The planned low carbon policies outlined in the Structure Plan will require a policy instrument such as carbon and energy use reporting to materialize and obtaining a stakeholders' engagement in the implementation.

- ii) The important driving factors and barriers which could influence building stakeholders' initial engagement in reporting and further sustain their engagement that have been identified in this study can be a guide to formulate policy for increasing the reporting rate and participation among building stakeholders.
- iii) The research findings demonstrate the current state of participation in carbon and energy use reporting by facility managers for existing government office buildings. This will provide as a basis for local government in deciding the design and direction for future reporting scheme in Putrajaya and evidences to support public leadership programme.
- iv) In terms of contributions to the practice, the research findings reveal the strength and weaknesses of current carbon and energy use reporting practices which could be used as a showcase and further improvement in the future city scale reporting programme. This is also indirectly saving the efforts and time of local government, particularly by enhancing the existing features rather than to start from fresh.

An overview of the current practice is essential to ensure any new policy to be established shall considered elements which majority of the building stakeholders is familiar. This will reduce the hassles during the introduction phase of the reporting programme.

- v) Last but not least, stakeholders' perceptions collected from the study provide an understanding of their agreement and expectations towards the carbon and energy use reporting programme. This can be a reference for local government to allocate necessary human and financial resources in providing educational opportunities, technical assistance and incentives.

1.8 Structure of the Thesis

This thesis consists of six chapters. Chapter 1 explains the research background and discusses the importance of carbon and energy use reporting as a policy instrument for building sector carbon reduction mitigation, research purpose, questions, objectives, study scopes, brief introduction to the research area and the significance of this study.

Chapter 2 begins by reviewing the relationship and significance of buildings in combating the negative environmental impact in the broader context of low carbon city development, providing the background for the needs of carbon and energy use reporting in the building sector. The second part of this chapter reviews the concept and theories of carbon and energy use reporting. This included identifying its roles and contributions in regards to two aspects, urban energy planning and carbon reduction management. Besides, common driving factors which influencing stakeholders for undertaking reporting practices have been reviewed. The last part elaborates on key elements in measuring and reporting emissions from building operations.

Chapter 3 discusses key elements in terms of implementation approaches used to engage building stakeholders' involvement through several empirical case examples conducted in other countries. The last part of this chapter discusses the related policy and tool in the local context which may complement the carbon and energy use reporting programme.

Chapter 4 describes the overall research design, technique and instrument use in this study. The data sources and collection process for both primary and secondary data are explained and the data analysis technique as well.

Chapter 5 is the analysis of data collected through questionnaire surveys. Quantitative analysis is applied. The analysis results in relation to current reporting status, practices and perceptions among the facility managers for government office

buildings are discussed in this chapter. Findings from the survey provide the foundation for identifying further improvement in the implementation of carbon and energy use reporting programme.

Chapter 6 is the last part of this research and will conclude the overall research findings on current carbon and energy use reporting practices for government office buildings', recommendations for further enhancement in the practices and suggestions for future research directions.

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