Designing a Solid Waste Management Plan with 3R Integration in Malaysia Green City

Case Study of Putrajaya, Cyberjaya and Iskandar Malaysia

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ABSTRACT

Global warming is one of the most discussed environmental issues in the 21 century. Fighting global warming is now a joint responsibility of societies around the globe and was formally put on the international political agenda in 1992 under the United Nations Framework Convention on Climate Change and followed by Kyoto Protocol in 1997. The effort of reducing greenhouse gases emission is becoming a compulsory rather than an optional choice for the government in their movement towards sustainable development. More and more countries are adopting the concept of low-carbon society (LCS) to achieve the status of Green City in their town planning. For the field of waste management this marks a new challenge to incorporate the concept of sound material-cycle society in the building of LCS. Malaysia as a nation is also responsible in the effort of fighting global warming issues together with other nation globally. During 15th Conference of Parties, Copenhagen, held in December 2009, Malaysia Prime Minister announced that Malaysia is adopting an indicator of a voluntary reduction 40% in terms of GHG emission intensity of gross domestic products by 2020 compared to 2005 level and committed to ensure at least half of its land area remained as forest as pledged at the Rio Summit.

The main objective of this study is to support current solid waste management (SWM) planning quantitatively in the target cities with implementation of 3R concepts. In this study, instead of recycling, more weight is put on promotion of waste prevention through reduce and reuse, and self-treatment. SWM in this dissertation represent seven elements of the system: (1) Waste generation; (2) Waste prevention; (3) Self-treatment; (4) Source segregation; (5) Collection and transportation; (6) Pre-treatment and (7) Final treatment. The concept of feasibility study using backcasting method is applied in which the desired future condition is envisioned and later steps towards achieving the target are figured out. The whole study is divided into four main steps namely – target setting, scenario building, quantification, and scenario evaluation. Two targets representing two indicators of future scenario are set for this purpose; (1) SWM target - amount of total waste sent to final landfill after reduction through alternatives waste handling and pre-treatment; (2) Low-carbon target - amount of GHG emitted from each alternative method. Scenario of system structure and scenario of parameter setting are two aspect considered in developing the countermeasure (CM) scenarios. Scenario of system structure represents selection of solid waste management elements in the CM scenario and scenario of parameter setting represents selection of level to implement system structure that incorporates stake holder’s preference in shaping the future of their jurisdiction area. Quantification for all SWM elements are carried out using available documented data and projection based on the data. Finally evaluation of the calculation is carried out for both waste and GHG amount to figure out the potential of implementing suggested CM scenario in the study area.

The methodology is first tested in Federal Government City, Putrajaya a new planned city developed to be the federal government administrative centre. The study of Putrajaya Green City 2025 (PGC2025) is to support Putrajaya Corporation's - Putrajaya Structure Planning Draft. Actions 9, 10 and 11 from the Dozen Actions of PGC2025 are allocated for SWM under the theme of 3R Putrajaya. Two targets for PGC2025 – 3R Putrajaya are reduction of landfill waste by half and the reduction of GHGs by half using CM waste treatment methods than landfill. Base year and target year is set at 2007 and 2025, respectively. SWM elements considered in the study of PGC2025 are Reduce, Reuse, Home composting, Community composting, Community collection and Separate collection. After waste reductions at source through combination of waste prevention and self-treatment, three CM scenarios for waste treatment selection are introduced namely 2025CM1- separate collection without thermal treatment; 2025CM2- thermal treatment without separate collection and 2025CM3 - separate collection with thermal treatment. Both waste and GHG reduction targets are achievable under all scenarios tested.

The methodology is also tested in Multimedia Super Corridor City, Cyberjaya the core of Multimedia Super Corridor (MSC) in Malaysia. Compared to Putrajaya and Iskandar Malaysia, SWM in Cyberjaya is not being handled by the federal government but handled by Sepang Local Authority. There is no specific reference for future planning of SWM in the city. Under the Dozen Actions for Digital Green City 2025 (DGC2025), SWM is allocated under Smart 3R Cyberjaya theme for Action 7 of Reduce, Reuse, Recycle and Smart Management. Two targets for DGC2025 are 75% reduction of solid waste amount sent to landfill and 50% reduction of GHG emission from CM compared to 2025BaU scenario. Base year and target year is set at 2010 and 2025, respectively. SWM elements considered in the study of PGC2025 are Reduce, Reuse, Food disposer, and Separate collection. The CM scenarios are built based on the level of 2R implementation by the local authority. The scenarios are 2025CM1 – low level of enforcement; 2025CM2 – moderate level of enforcement and 2025CM3 – high level of enforcement. In order of reductions from most to least, the scenarios were 2025CM3, 2025CM2 and 2025CM1. Even though our target of 75% reduction of waste amount is only achievable at 2025CM3, waste reduction from other scenarios is also significant. Target of 50% GHG reduction is achievable at all counter measure selection.

Finally the methodology is tested in Iskandar Malaysia (IM) a newly developed economic region within Malaysia's most southern state, Johor. Iskandar Region Development Authority (IRDA) issued Comprehensive Development Plan – a development roadmap of IM for the next 20 years and Integrated Solid Waste Management Blueprint focuses on SWM. Action 11 – Sustainable Waste Management of Iskandar Malaysia 2025 (IM2025) study is to support IRDA's SWM targets as stated in these documents. Two targets for IM2025 are reduction of landfill waste by half and the reduction of GHGs by half using CM waste treatment methods than landfill. Base year and target year is set at 2005 and 2025, respectively. Combinations of SWM elements for Sustainable Waste

Management are Reduce, Reuse, Home composting, Food disposer, Community collection and Separate collection. CM scenario for IM2025 is set at high level of enforcement with combination of separate collection and thermal treatment. Both waste and GHG targets are achievable with the CM scenario.

Three fields studies - questionnaire, household and landfill survey; are also carried out in IM to collect primary data to support the modelling process. One thousand questionnaires were randomly distributed to households within IM and total of 512 questionnaires were returned, giving a response rate of 51%. Main finding from the questionnaire is that solid waste generated from household in IM is mainly constitutes food waste and paper waste, at 29% and 22% respectively. Statistical data analyses showed household size to be the most influential factor in per capita waste generation and in the waste generation model, household size and expenditure level were seen to influence waste generation in the study area. From the 100kg waste segregated at Seelong landfill, composition in wet basis is food (49.27kg, 41.06%), plastic (26.68kg, 22.23%), paper (25.12kg, 20.93%), and textile (9.29kg, 7.74%). Product and packaging materials are 48% and 52% respectively, with the most generators being paper for product and plastic for packaging materials. The moisture content, combustible content, and measured calorific values of the sample is 57%, 35%, and 1591 kcal/kg, respectively. Furthermore, waste characterization and assessment of alternative waste treatment shows that if waste separation is to be implemented in IM, besides landfilling, composting and incineration would be suitable.

This study is part of Development of Low-Carbon Society for Asian Regions, the first LCS study in the region with the aims to become the leader of low-carbon society (LCS) research in Asian countries. This LCS study covers various issues related to climate change and our study focuses on SWM. Methodology of implementing sound material-cycle society in the building of a LCS through integration of 3R elements is proposed in our study. The main focus is to move SWM system from sole dependency on landfill to a more sustainable and integrated method. The method was tested in three different cities with different characteristic in Malaysia that has the vision to be the pioneer in Green City township. Evaluation of the application shows that methodology proposed in this study is consistent and feasible to cities with different view and capability of carrying out an integrated SWM. At all case studies, both SWM and low-carbon target were achievable even with different combination of SWM elements and parameter settings. This method is applicable and expected to be adapted to other cities even with different income level and SWM ability that is trying to achieve green city level in SWM field.

Keywords: *household solid waste, 3R, waste prevention, sound material-cycle society, low-carbon society, green city, solid waste management, CO_2 emission, feasibility study, Malaysia Green City, Putrajaya, Cyberjaya, Iskandar Malaysia*

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List of Abbreviations

BaU	Business as usual
CDP	Comprehensive development plan
CM	Countermeasure
COP	Conference of Parties
DGC	Digital Green City
GC	Green City
GHG	Greenhouse gases
HSW	Household solid waste
IM	Iskandar Malaysia
IM-BP	Integrated Solid Waste Management Blueprint for Iskandar Malaysia
LA	Local authority
LCS	Low-carbon society
PGC	Putrajaya Green City
SMCS	Sound material-cycle society
SWM	Solid waste management
UN	United Nation
UNFCC	United Nation Framework Convention on Climate Change

1 INTRODUCTION

1.1 Research background

Global climate change was put on the international political agenda in 1992, and with that, the United Nations Framework Convention on Climate Change (UNFCCC) was agreed upon. Since then developments in both climate science and climate policies have been swift (Munasinghe & Swart, 2005). Following this, the Kyoto Protocol entered the climate change arena on 11 December 1997 during the Conference of Parties (COP-3) in Kyoto, Japan and by the end of 2010; the protocol had been ratified by 191 countries (UN Habitat, 2011).

As we step into the second decade of the new millennium, climate change together with rapid urbanization threaten with the exceptional negative impacts upon quality of life, economy and social stability of city dwellers (UN Habitat, 2011). The timing and magnitude of future climate change is uncertain; and some of its effects may be harmful, and some beneficial. It will have consequences for the human health, ecosystems, economic activity and social well-being (New Horizons in Regional Science 2006). Globally we already experience the exacerbating effects of climate change in the form of many weather related catastrophes namely; the increase in the duration and intensity of storms, sea-level rise, salt water intrusion which affects drinking water supplies, coastal erosion and the reductions in liveable land space (IPCC 2001).

In this chapter, three terms that closely related to fighting global warming are introduced and discussed. It is important to understand that the lowering of CO_2 emission is not just focused towards the goal of reducing the effects of climate change but it is also an important move towards sustainable development (Simson, Ho, Matsuoka, & Gomi, 2011).

1.1.1 Low carbon society

Japan has defined a Low Carbon Society (LCS) as a society which should (Skea & Nishioka, 2008):

1) Take actions that are compatible with the principles of sustainable development, ensuring that the development needs of all groups within a society are met.

2) To make an equitable contribution towards the global effort to stabilize the atmospheric concentration of CO_2 and other greenhouse gases (GHG) at a level that will avoid dangerous climate change, through deep cuts in global emissions

3) Demonstrate a high level of energy efficiency and use low-carbon energy sources and

production technologies

4) Adopt patterns of consumption and behaviour that are consistent with low levels of GHG emission.

Japan has been a pioneer in the low carbon arena together with other developed nations such as United Kingdom and Germany. With the background in climate change and all its effects, many developing countries have now jumped in this bandwagon towards developing a LCS. Malaysia likewise is moving in this same direction and it is the objective of this thesis research to develop a methodology where Low Carbon Society Policies can be implemented at Local Authorities level in Malaysia.

1.1.2 Sound material cycle society

A sound material-cycle society (SMCS) is a society in which the amount of resources to be extracted is minimize at all stages of social and economic activities, from resource extraction through production, distribution, consumption and disposal, through a range of measures such as reduction of waste generation and use of circulative resources, thereby minimizing environmental loads (Fundamental Plan for Establishing a SMC Society, 2008). In Japan, towards the establishment of the SMC society, legislation based on the Waste management and Public Cleansing Law and various recycling laws were adopted. It is important to have a strong fundamental in promoting such a big transformation. In addition to the development of the legal infrastructure, the development of other facilities vital to the establishment of an SMC Society is crucial. The facilities should be able to cope with comprehensively promoting 3R activities. Other important steps in the establishment of a SMC society is quickly and accurately understanding information about waste and the like; preparing statistical information for analysis and publication; and conducting research and promoting science and technology that contribute to the establishment of an SMC society, ranging from materials development and production processes to cyclical use and disposal.

One of main issues in establishing the SMC society is further promotion of 3R focused on reducing waste management and ensuring appropriate waste management. Various problems merge in the recent years related to SWM due to mass generation of solid waste and variation in its composition. These problems include inappropriate cyclical use and disposal of waste, a shortage landfill capacity at final disposal sites, disposal of hazardous waste and illegal dumping. All these problems are very common in developing countries including Malaysia. For this reason, to promote establishment of the SMC society there is the strong need to develop technologies and systems that will reduce the input of non-renewable resources and energy, effectively utilize biomass materials that can be generated in nature as resources and energy, and reduce environmental loads caused by release into the environment of harmful substances and GHG.

1.1.3 Green city

Green cities (GC) are defined as those that are environmentally friendly. Indicators measuring environmental performance can include: levels of pollution and carbon emission, energy and water consumption, water quality, energy mix, waste volumes and recycling rates, green-space ratios, primary forests, and agricultural land loss (Meadows 1999, Brugmann 1999). Other indicators include the share of apartment living, motorization rate, and modal share of urban transport. Another important measure of humanity's demand on nature is the Ecological Footprint (Ewing et al. 2010). Defining green cities by their environmental performance does not mean social equity issues are ignored. In fact, greener living environments can play an important role in making cities more equitable for their residents.

Ecologists emphasize the importance of tracking the size of a city's ecological footprint in defining a GC. This approach focuses on how much people consume and how much carbon dioxide is produced as a by-product of urban consumption and production. Public health experts focus on the health consequences of exposure to local air pollutants, dirty water, and other environmental factors that promote disease. Based on this approach, a city is considered green if the incidence of environmentally linked diseases is relatively low. Finally, many economists evaluate the urban environment by examining differences in real estate prices across cities at a point in time or for the same city over time. Each approach has advantages and disadvantages. Equally important, the three approaches can lead to different conclusions about urban environmental quality but the main indices to develop a future city.

In 2011, a panel of global experts in urban environment sustainability advised Economist Intelligence Unit (EIU) in developing the methodology for the Green City index evaluating more than 120 cities around the world. The Asian Green City Index measures the current environmental performance of 22 major Asian cities, as well as their commitment to reducing their future environmental impact. The Index scores cities across eight categories - energy and CO_2, land use and building, transport, waste, water, sanitation, air quality, and environmental governance. Besides, cities are rank based on 29 individual indicators. Fourteen are quantitative and measures how a city currently performs – for example, a city's water leakage or waste production. The remaining 15 qualitative indicators assess policies and plans – for example, a city's commitment to reducing the environmental impact of energy consumption, green standards for public building projects, reducing congestion or recycling waste.

In term of waste, four indicators were selected to represent a GC, two each for quantitative and qualitative.

i. Share of waste collected and adequately disposed

Share of waste collected by the city and adequately disposed either in sanitary landfills, incineration sites or in regulated recycling facilities. It is expressed in terms of the total volume of waste generated by the city.

ii. Waste generated per capita

Total annual volume of waste generated by the city, including waste not officially collected and disposed, in kg per capita.

iii. Waste collection and disposal policy

Measure of a city's efforts to improve or sustain its waste collection and disposal system to minimize the environmental impact of waste

iv. Waste recycling and re-use policy

Measure of a city's efforts to reduce, re-use and recycle waste

Within the 22 cities in Asia, the overall results rank Kuala Lumpur under average band. Kuala Lumpur's strongest and weakness categories are transport and air quality, and waste and water, respectively.

1.2 Research objective

The main objective of this study is to come out with alternative SWM to fulfil the building of

SMCS in the LCS. The focus is on developing country where the main option of SWM is open dumping landfill. This dissertation especially focuses on three newly develop cities in Malaysia which each city plays different role from the conventional cities in the country. Some of the important aspect in the study of SWM in developing countries is the lack of reliable documented data and no clear vision in term of quantitative towards future of SWM.

Following are the main aspect of this study:

i. To come out with alternative SWM plan other than open dumping landfill for the newly develop economic region
ii. To support available SWM planning in the study area quantitatively

1.3 Scope of study

i. This study focuses only on household solid waste (HSW).
ii. This study covers seven elements of SWM – generation, prevention, self-treatment, source segregation, collection and transportation, pre-treatment, and final treatment
iii. This study method were tested in three different cities in Malaysia:

(1) Federal Government City, Putrajaya

Putrajaya is the newly develop city dedicated for Malaysia administration center in which 90% of the resident is government officer. The special characteristic of this city as the face of the country put all the government focus on turning Putrajaya as the Pioneer Township in Green Technology as a showcase for the development of other township.

(2) Multimedia Super Corridor City, Cyberjaya

Cyberjaya is developed to be the core for Malaysia Multimedia Super Corridor with the aspiration of "Silicon Valley of Malaysia". The special characteristic of Cyberjaya is it is built with the idea of an information technology themed city with the central theme for the development is to building a leading edge multimedia center. Cyberjaya is the city that moves 24 hours on business basis. The office worker commute into the city mainly for working purpose and this influences the different needs of SWM in the city.

(3) Iskandar Malaysia

The special economic zone of IM grew out of a 2005 government requested feasibility study by the Khazanah Nasional which found that the development of such a zone would be economically, socially and developmentally beneficial. IM was singled out as among the high-impact developments of the Ninth Malaysia Plan. In November 2006, Comprehensive

Development Plan (CDP) for IM was revealed which includes attention in lots of life quality unfortunately left out the SWM plan.

1.4 Dissertation framework and organization

The whole study is presented in seven chapters and shown in **Figure 1**. **Chapter 1**, “Introduction” is the introductory chapter where issues related to global warming, and term of LCS, SMCS and GC in the global context is introduced. These three terms are the centre point of this dissertation where the objective of the study is to incorporate both concepts of LCS and SMCS in the development of GCs in Malaysia. Framework and setting of this dissertation is also introduced in this chapter.

Chapter 2, entitled “Overview of solid waste management” provides a throughout description of elements in an integrated SWM system. Integrated SWM here represents a management system that includes 3R – Reduce, Reuse and Recycle. Concept of these three actions is discussed in details in this chapter in order to move from conventional SWM system that focuses only on landfilling. History and information of SWM in Malaysia is also provided in this chapter. This includes the introduction of Act 672; Solid Waste and Public Cleansing Management Act 2007 and literature review of other SWM related studies previously carried out in Malaysia.

Chapter 3, “Methodology”, explains how the whole process of designing the alternative SWM for Malaysia Green Cities is carried out. The whole chapter is divided into five section namely – general framework, target setting, scenario building, quantification methodology and evaluation. Each section represents the steps towards achieving the objective of this study. “Target setting” section explains selection of waste and GHG indicator to represent the desired future society. “Scenario building” describes scenario of system structure and scenario of parameter setting that are considered in developing the CM scenario. “Quantification methodology” provides the tools and methodologies to represent seven elements of SWM quantitatively for both waste and GHG amount. Finally, “Evaluation” section explains how each CM scenarios is evaluated for its possibility to achieve the target of waste and GHG reduction.

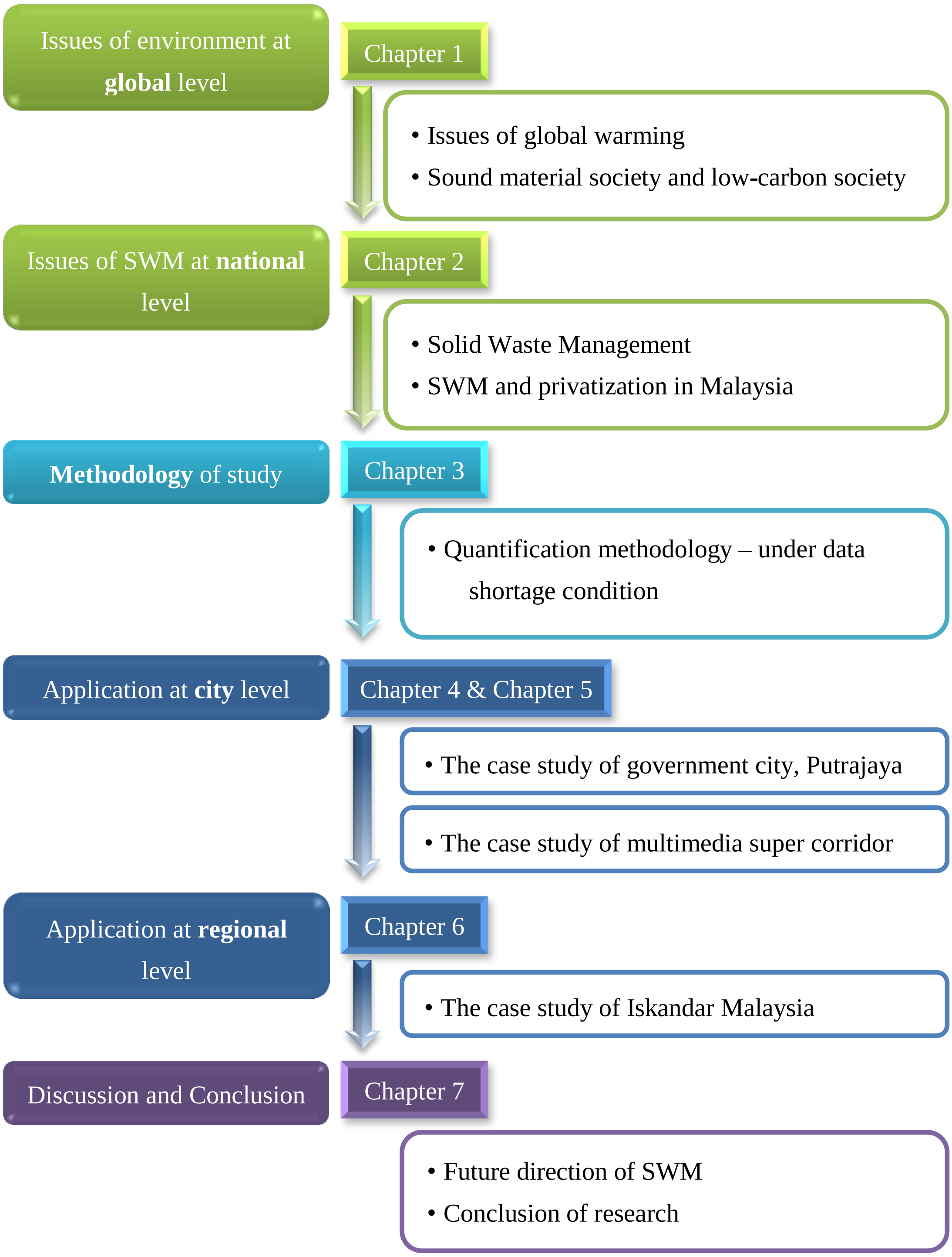

Figure 1 Dissertation framework flow

Chapter 4 discussed application of this study method in Putrajaya under Putrajaya Green City 2025 (PGC2025) preliminary study. Three out of twelve actions constructed for PGC2025 are dedicated for "3R Putrajaya". Two targets for PGC2025 are reduction of landfill waste by half and the reduction of GHGs by half using alternative waste treatment methods than landfill. Base year and target year is set at 2007 and 2025, respectively. Generation and reduction of both waste and GHG are estimated using methodology introduced in Chapter 3.

Chapter 5 discussed application of this study method in Cyberjaya under Cyberjaya Digital Green City 2025 (DGC2025) preliminary study. Action 7 of "Reduce, Reuse, Recycle and Smart Management" from twelve actions of DGC2025 is allocated for "Smart 3R Cyberjaya" which covers SWM issues in the study area. Two targets for DGC2025 are 75% reduction of solid waste amount sent to landfill and 50% reduction of CO_2 emission from CM compared to 2025 business as usual (BaU) scenario. Base year and target year are set at 2010 and 2025, respectively. Generation and reduction of both waste and GHG are estimated using methodology introduced in Chapter 3.

Chapter 6 discussed application of this study method in IM under study of Project for Development of Low Carbon Society Scenarios for Asian Regions. Action for SWM is allocated at Action 11 – Sustainable Waste Management under Green environment theme. Two targets for IM2025 are reduction of landfill waste by half and the reduction of GHGs by half using alternative waste treatment methods than landfill. Base year and target year are set at 2005 and 2025, respectively. Generation and reduction of both waste and GHG are estimated using methodology introduced in Chapter 3. In order to collect primary data for the IM2025 study purpose, three field study were carried out which is – questionnaire survey, household survey and landfill characterization. Details of the three field study are also discussed in this chapter.

Chapter 7, "Discussion and Conclusion" discussed the result of all case studies in a whole and summarized the main conclusions of the dissertation. The chapter also shows the reasonable suggestion for managing and improving HSW in the cities of various levels in developing countries. Additionally, recommendations for future research and the possible development are presented.

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2 OVERVIEW

2.1 Solid waste management

2.1.1 Concept and terminology

Waste is generated in every human activity. Any material or product that has no value in the perception of the generator or consumer is considered waste. SWM may be defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid waste in a manner that is accord with the best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations, and that is also responsive to public attitudes (George Tchobanoglous, et. al, Integrated Solid Waste Management).

In the context of this dissertation, SWM covers seven elements of the system (**Figure 2**)

(1) Waste generation

The quantities of solid waste generated and collected are of critical importance in determining appropriate handling and treatment method. Proper knowledge about waste generation is a prerequisite for planning and designing a good waste management system. Waste generation in this dissertation covers both amount and composition.

(2) Waste prevention

Waste prevention is related to concepts and terms of cleaner technology, cleaner production, clean-up technology and waste minimization. Waste prevention takes place before products or materials are identified or recognized as waste (OECD, 2000). Reduce and reuses are the two waste prevention methods discuss in this dissertation.

(3) Self-treatment

Self-treatment in this study context represents biological treatment method for food waste from household. Biological treatment involves composting, anaerobic digestion and a combination thereof. This dissertation focuses on composting and installment of food disposer for self-treatment in the household.

(4) Source segregation

Source segregation is the organized storage of waste at source before its collection and transportation to a pre-treatment of final treatment facility. The purpose of source segregation is to remove the recyclable material from the source of generation. The generated waste is segregated at source into different waste types, and material fractions or sub-fractions for separate collection and pre-treatment.

(5) Collection and transportation

Collection in this dissertation context are defined as the organized collection of waste at the pick-up location – at the house and central location points, routing the collection vehicle to different pick-up locations until the vehicle is full or has completed its task. Transportation is the transport of waste from where the collection was completed and until unloading of the waste at a treatment facility. Transportation also involves transport of treated waste or treatment residue.

(6) Pre-treatment

Pre-treatment represents the act of handling recyclable material before going through final treatment such as incineration or landfilling. At this level, the collected recyclable materials go through size reduction, density separation, magnetic separation, and densification. All these process normally take part in a materials recovery facility (MRF).

(7) Final treatment

Two types of final treatment discuss here are:

i Thermal treatment

Even though thermal treatment involves incineration and pyrolysis or gasification, this study only considers incineration. Waste incineration is thermal conversion of waste with a surplus of air. This releases energy and produces solid residues as well as a flue gas emitted to the atmosphere.

ii Landfill

Landfill represents the dedicated use of land for disposing waste in an engineered facility. Landfills can be designed in many different ways, depending on the waste to be landfilled and the length of the time period accepted before the landfill is integrated into the surrounding environment and the control procedures can stop. Two types of landfilling that practiced in Malaysia are:

a. Open dumps

The landfill was often clay and gravel pits or other low-value land filled with whatever waste that might appear and dumped from the truck where possible.

b. Sanitary landfill

The landfill offered a more orderly appearance by limiting access to the site using fences, organizing the disposal activities and often covering of the waste with soil. The sanitary landfill site designated with consideration of leachate generation and gas capture.

In all the case studies, there is no specification for landfill method in the BaU case but proposed sanitary landfill for CM scenario.

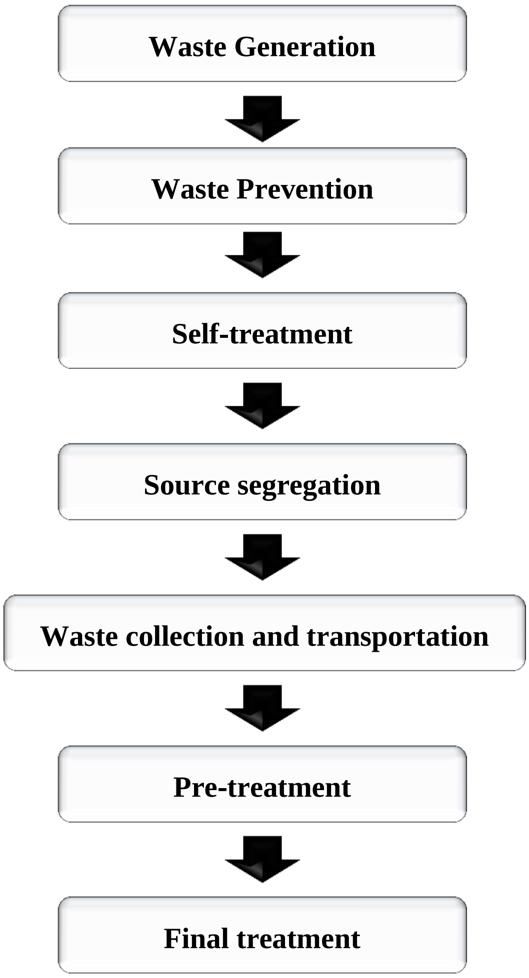

Figure 2 Diagram of solid waste management elements in this dissertation

2.1.2 Issues and challenges

The concept of sustainability was introduced by the World Commission and Development in 1987 in Brundtland report entitled Our Common Future (WCED, 1987). Sustainability is defined as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.' Sustainability has and environmental as well as a social and economic dimension. The definition does not provide much guidance as to waste management, but has fostered a way of thinking suggesting that long-term issues should receive more attention, that each generation should solve its own problems that local solutions should be sought. The lack of concrete guidance in SWM strategy has inhibited the introduction of the sustainability concept in SWM context. For example, the European Union (EU) landfill directive (CEC, 1999) contains several elements of sustainability although it is not directly said. The EU thematic strategies on waste prevention and recycling (CEC, 2005a) and on the use of natural resources (CEC, 2005b) also pledge for sustainable development related to waste management.

Under conventional circumstances, waste disposal has become the base of a waste management hierarchy followed by energy recovery, recycling, reusing and reducing. Final disposal being inevitable, landfilling has become the largest component in the waste management pyramid (**Figure 3**). The sole use of landfill dumping for waste handling is the current situation for at least 95% of the solid waste generated globally (Mutasem, 1997). Even though it is well understood that depending solely on landfill is not sustainable, it is almost impossible to change this situation. This is attributable to the limited budget allocated for alternative waste treatment plants such as incinerators and fuel generation plants that have not only very high facility set-up costs but also high running and maintenance costs, as well as there being a lack of technology and expertise. Nevertheless, a reverse SWM system is desired for the future generation. This future vision is feasible through implementation of 3R concepts in the SWM system.

Figure 3 Waste management pyramid

(1) 3R

3R represents Reduce, Reuse and Reuse which are the feasible options for achieving reduced material use and waste generation. The government of Japan, including the Ministry of Economy, Trade and Industry, and the Ministry of environment defines 3R as, Reduce - reducing the amount of waste by increasing the efficiency of resource use and extending the useful life of products; Reuse - using "recyclable resources" from used items again, as products or parts, after giving them proper treatment; Recycle - using "recyclable resources" as raw materials to make new products. The 3R Initiative in Japan aims to reduce waste, encourage recycling, reduce barriers to trade in goods and materials for recycled and remanufactured products, and promote science and technology on these transformation technologies. 3R was initiated by G8 Sea Island Summit 2004 based on the proposal of Japanese Government, and officially launched at the 3R Ministerial Conference held in Tokyo, 2005. At the conference, 20 countries and international organizations discussed the importance of 3R in the context of sustainable development, agreed to promote 3R within each country, regional and global level, and decided how to promote 3R. International Solid Waste Association (ISWA) stated that 3R can be achieve in three basic ways of reducing the amount of material used per product without sacrificing the utility of that product, increasing the lifetime of a product and eliminating the need for the product.

(2) Zero Waste

Concept of zero waste is one example of communicating the goal of waste minimization. The concept of zero waste includes the concept of producing less waste, known in the industrial sector as a cleaner production. At the municipality level, the zero waste concepts is a catchy message used to improve recycling, composting and other means to utilize waste at the expense of landfill and mass incineration. In practice, the zero waste goal is a goal of avoiding the landfilling of waste.

2.2 Solid waste management in Malaysia

2.2.1 Background and overview

In Malaysia, until the late 1960s, city streets were cleaned by the local district health office and the Local Government Act 1976 and the Street, Drainage and Building Act 1974 were passed for public cleansing services and sanitary disposal. Malaysian laws were too general and were far from satisfactory due to lack of resources and faced municipal budget constraint. The budget for waste collection was ranging from 20% to 70%, according to the size of the municipality (Hassan et al. 2000). Dumping of wastes in open fields and rivers are common even until today and a study of waste disposal behaviour in Kuala Lumpur indicated that 31.9% of waste were disposed by open burning, while 6.5% were dumped into the river system (Murad & Siwar 2007). Hence the environmental safety concern in Malaysia was secondary and most municipalities had a tough time in finding new disposal sites as, the existing disposal sites were nearly exhausted (Hassan et al. 2000).

In September 1995, Federal Cabinet decided to privatize responsibilities of the Local Authorities (LA) in 1997. The objective of privatization was to provide an integrated, effective, efficient, and technologically advanced SWM system. It is also expected to resolve the problems in SWM faced by the LAs such as finance, lack of expertise, and lack of proper waste treatment facility (Zainal, 1997). Thus, since January 1997, the SWM responsibility of 48 LA has been privatized to four concession companies

i Alam Flora Sdn. Bhd., which is responsible for the central and eastern region
ii Northern Waste Industries Sdn. Bhd., which is responsible for the northern region
iii Southern Waste Management Sdn. Bhd., which is responsible for the southern region
iv Eastern Waste Management Sdn. Bhd., which is responsible for East Malaysia

At present, the privatization of SWM is carried out as an interim management agreement between the LA and the concessionaires concerned, where during the period, the level of services provided should not be less than that given by the LA. Generally the process of privatization shifted the burden from the LA to the waste consortium but the level of services has remained stagnant. Besides the privatization, legislation to streamline the strategies and measures in the National Strategic Plan were to be enacted. SWM was under Local Government Act, 1976; Street, Drainage and Building Act 1974 and now it is under National Solid Waste Management Department and Solid Waste and Public Cleansing Management Corporation Act 2007.

3R in Malaysia was first launched in late 1980s and the campaigns were focused mainly on the recycling activities but unfortunately it failed to improve the existing waste management practice. To understand and overcome the failure issues, few studies at national level were carried out, such as Policy for Integrated Solid Waste Management in Malaysia – 2001, National Strategic Plan for Solid Waste Management in Malaysia – 2005 and Master Plan on National Waste Minimization - 2006. **Table 1** and **Table 2** summarized Malaysia SWM target towards the year of 2020, and waste generation in Malaysia based on the national studies, respectively.

Table 1 Malaysia solid waste management target towards Vision 2020 (%)

Level of service	2005	2010	2015	2020
Extend collection service	75	80	85	90
Reduction & recovery	4	10	15	17
Closure of dump sites	(112 sites)	50	70	100
Source separation	0	20	80	100

Table 2 Waste composition in Malaysia (%)

	1975	1980	1985	1990	1995	2000	2005
Food	63.7	54.4	48.3	48.4	45.7	43.2	45.0
Paper	7.0	8.0	23.6	8.9	9.0	23.7	7.0
Plastic	2.5	0.4	9.4	3.0	3.9	11.2	24.0
Glass	2.5	0.4	4.0	3.0	3.9	3.2	3.0
Metal	6.4	2.2	5.9	4.6	5.1	4.2	6.0
Other	8.7	4.3	8.8	32.1	6.4	14.5	15.0

(2) The study on National Waste Minimisation in Malaysia (2006)

The Study on National Waste Minimisation in Malaysia was carried out in 2006 by Japan International Cooperation Agency (JICA). The objective and vision of this study is to provide vision, strategies and Roles of stakeholders to minimize the amount of solid waste disposed in Malaysia and to realize a "Material Cycle Society", where minimisation activities are systemized and sufficiently enrooted in the behavior of government, private sector and the people in Malaysia. This study act as the master plan for waste minimisation in Malaysia with set the target to increase recycling rate in the country from 5% to 22% by 2020 (**Table 1**). Towards achieving the target, six action plans were introduced:

i. Enhancement of Awareness raising activities under the National Recycling Program (NRP)
ii. 3R activities in schools
iii. Formulation of stakeholders networking and development of partnership activities on 3R
iv. Strengthening of legal, regulatory and financial mechanism

v. Improvement of information management
vi. Provision of guidance to LAs on Local Action Plan on Waste Minimisation (LAP-WM)

(3) Solid Waste and Public Cleansing Management Corporation Act 2007

SWMPC Act 2007 was approved by Parliament on 17 July 2007 and gazette on 30th August 2007 by vesting executive power to the Federal Government to implement SWM and public cleansing. The corporation viewed the issue on the overall basis and not merely collection of garbage and construction of dumps and is responsible to monitor, supervise and enforce SWM and public cleansing in the country. It also inculcates public awareness for sustainable management of public waste and cleansing and is also responsible for recycling technology. Department of National Solid Waste Management (NSWMD) was created to propose policies, plans, and strategies along with setting standards, specifications and codes of practices and to enforce the law and regulations, set guidelines, monitor and give approval.

The Act defines Solid Waste as, any scrap material or other unwanted surplus substance or rejected products arising from the application of any process; any substance required to be disposed of as being broken, worn out, contaminated or otherwise spoiled. The Act focuses on recycling and has a special allocation for separation of wastes at the source. Improper disposal of household hazardous wastes like pouring down the drain, on the ground, into storm sewers, or putting them out with the trash can pollute the environment and pose a severe threat to mankind. Services of SWM are separation, storage, collection, transportation, transfer, processing, recycling, treatment and disposal of controlled solid waste which are classified into 8 categories namely commercial, construction, household, industrial, institutional, imported, public and others which can be prescribed from time to time. The act provides power for Federal Government to enter into agreement with any person to undertake, manage, operate and carry out SWM services or public cleansing and to establish PSP Tribunal.

2.2.2 Literature review

Besides the studies of solid waste that are carried at national level, study of solid waste in Malaysia is also carried out by researcher from educational institutions. This section of this dissertation introduced some of main findings from the studies by other researchers.

(1) Waste generation

Table 3 shows the trends of waste generation in major urban areas in Peninsular Malaysia from 1970-2002, as presented in study of MSW management in Malaysia – Changes for

Sustainability (Agamuthu, 2010). Urban waste generation in the country increased 3% annually due to urban migration, affluences and rapid development (Agamuthu, 2011). In 2008, approximately 31,000 tons of waste were disposed of into 260 landfills in Malaysia and estimated to be doubled by 2020 (Agamuthu et al, 2009). The increase in urban population in Peninsular Malaysia from 6.05 million in 1988 to more than 16.5 million in 2007 resulted in the acceleration of waste generation in urban areas. Level of per capita solid waste generation changed accordingly with urbanization of more areas, as well as with the improvement to the quality of life. The rate in the 1980's was 0.5kg/d and had increased to 1.3 kg/d in 2006. Currently, generation rate range from 1.5 to 2.0 kg/d in most cities in around the nation (Sekarajasekaran et al, 1982, Nasir et al, 2000, Agamuthu, 2001).

(2) Waste composition

Waste composition in Malaysia is dominated by organic waste comprising approximately 50% of the total waste stream. A study conducted by the Ministry of Housing and Local Government (MHLG) reported that the solid waste composition in Malaysia is dominated by organic waste, followed by paper and plastic (Hoorwerg and Thomas, 1999). Study by Fauziah and Agamuthu in 2003 shows similar trend and presented in **Table 2**.

(3) Waste characteristic

The most common methods currently being practiced to evaluate the hating value of municipal solid waste (MSW) are by using the equation derived by Dulong, or experimentally by using the bomb calorimeter. There have been numerous other mathematical equations, which were created based on data from the physical composition, proximate or elemental analysis of the MSW. In 2000, S. Kathrivale et al. carried out details analysis of waste sample from Municipality of Kuala Lumpur. Result of the proximate analysis and elemental analysis are shown in **Table 4**.

Table 3 MSW generation in Malaysia major urban areas (1970-2002) (t/d)

Urban centre	1970	1980	1990	2002
Kuala Lumpur	98.9	310.5	586.8	2754
Johor Bahru (Johor)	41.1	99.6	174.8	215
Ipoh (Perak)	22.5	82.7	162.2	208
Georgetown (P. Pinang)	53.4	83	137.2	221
Klang (Selangor)	18	65	122.8	478
Kuala Terengganu (Terengganu)	8.7	61.8	121	137
Kota Bharu (Kelantan)	9.1	56.5	102.9	129.5
Kuantan (Pahang)	7.1	45.2	85.3	174
Seremban (N. Sembilan)	13.4	45.1	85.2	165
Melaka	14.4	29.1	46.8	562

Table 4 Proximate analysis and elemental analysis

Proximate analysis (wet)	Weight, %		ppm
Moisture	55.01	Heavy metal (dry)	8.84
Volatile	31.36	Chlorine	0.99
Fixed carbon	4.37	Cadmium	0.27
Ash	9.26	Mercury	26.27
		Lead	14.41
Elemental analysis		Chromium	
Carbon	46.11		
Hydrogen	6.86	Other parameters	
Nitrogen	1.26	Bulk density (kg/m3)	240
Oxygen	28.12	Net calorific valu (kcal/kg)	2180
Sulfur	0.23		

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3 METHODOLOGY

3.1 General framework

In this study, we used the approach of baseline study and back-casting method to achieve our objectives. **Figure 4** shows the schematic flow of the whole study that is divided into four main steps namely – target setting, scenario building, quantification, scenario evaluation. Two indicators used in this study are amount of waste sent to final landfill site and amount of GHG emitted from waste pre-treatment and final treatment. In the target setting amount of waste amount and GHG emitted from waste treatment are set for the target year and compared to base year. In the scenario building we take into account the scenario of system structure and the scenario of parameter that considered in developing the CM scenario. Our quantification and calculation covers the seven elements of SWM from waste generation towards waste final treatment. Finally evaluation of the CM scenarios is carried out based on the ability of the alternative SWM methods to fulfil the targets.

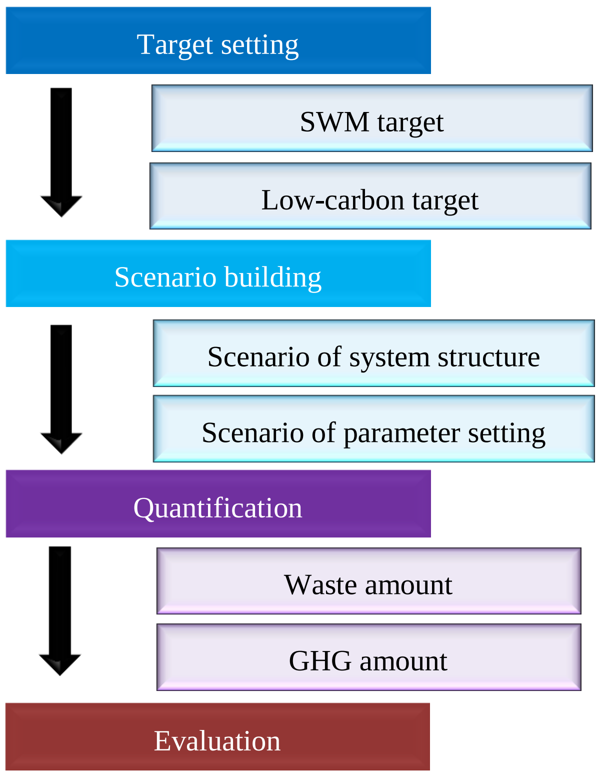

Figure 4 Flow of research framework

3.2 Target setting

UN defines a baseline study as the "pre-operation exposure" condition for the set of indicators that will be used to assess achievement of the outcomes and impact expressed in the program's logical framework. The baseline study forms the basis for a 'before and after' assessment or a 'change over time' assessment. In relation to the programme cycle, a baseline study should be conducted prior to the onset of operation activities in order to establish the pre-operation exposure conditions of the outcome and impact level indicators. While back casting is defines as a method that starts with defining a desirable future then works backwards to identify policies and programs that will connect the future to present. Back casting approaches the challenge of discussing the future from the opposite direction. "A method in which the future desired conditions are envisioned and steps are then defined to attain those conditions, rather than taking steps that are merely a continuation of present methods extrapolated into the future". Based on these two concepts we chose two indicators to represent our desired society which is

i. Solid waste management target

ii. Low-carbon target

The former is amount of total waste sent to final landfill after reduction through alternatives waste handling and pre-treatment. The latter is amount of GHG emitted from each alternative method. Each the SWM and low-carbon target for target year is compared to BaU in target year. These two indicators are also adopted in the study of Malaysia Economic Monitor; Smart cities by The World bank. In which it is stated in the study that both of these fields are already seeing initiatives in Malaysia but also where significant needs for concerted action remain (Reference – Smart city).

3.3 Scenario building

3.3.1 Scenario of system structure

Scenario of system structure represents selection of SWM elements in the CM scenario. At this level combinations of the seven SWM elements are considered to come out with the best combination that suits the local needs of the targeted area. In this study, instead of recycling, more weight is put on promotion of waste prevention through reduce and reuse, and self-treatment. Even though recycling through implementation of high-technology waste treatment like thermal treatment could reduce waste largely in a less time and effort it is a costly option which should be avoided in the developing countries. Besides, reduce and reuse promotion also benefits publics in the long term to decrease the needs of dependence on material.

3.3.2 Scenario of parameter setting

Scenario of parameter setting represents selection of level to implement system structure that incorporates stake holder's preference in shaping the future of their jurisdiction area. One application of parameter setting is rating of 2R actions through focus group discussion (FGD). FGD is a rapid assessment, semi-structured data gathering method in which a purposively selected set of participants gather to discuss issues and concerns based on a list of key themes drawn up by the researcher or facilitator (Escalda, 2007). FGD is mainly carried out to get opinion and feedback from the LA and various stake holders involved in the planning process and FGD is a popular method to collect qualitative data.

3.4 Quantification methodology

Waste amount and GHG are the two values that we present in this study. The estimation of waste amount is carried out for seven elements of SWM as shown in **Figure 2**. The first element, waste generation of solid waste is calculated for both base year and target year. The second element, waste prevention is projected for twelve reduce and five reuse actions. The third element, self-treatment is quantification of biodegradable waste that is treated in the household by mean of composting or food disposer. The fourth element, source segregation is quantification of recyclable material collected through community collection or separate collection. The fifth element, collection and transportation model waste collection route from waste generator to treatment facility and treatment facility to final landfill site using GIS software. The sixth element, pre-treatment is estimation of recyclable material collected from source segregation treated at MRF. The seventh element, final treatment is quantification of remaining waste to be treated at the thermal treatment facility or directly sent to landfill site. The quantification of GHG is carried out at final landfill, recyclable materials treatment and waste collection and transportation. The GHG estimation considered CO_2, CH_4 and N_2O.

3.4.1 Waste

(1) Generation

Waste generation is the starting point of the waste system and defines the waste in term of waste categories, waste types, quantities, material fractions and substances. All these information are crucial for further consideration of waste handling and treatment. Boundary of waste types considered in this study is limited to household waste without considering bulky waste and household hazardous waste. Two types of waste generation are projected in this study. The first is generation of waste based on its material fractions and the second one is its sub fractions. Categories of material fraction and sub-fraction are – product (food paper, plastic, glass, metal, textile and other); packaging (paper, plastic, glass, and metal).

In order to estimate waste amount in this study, main parameters as in **Table 5** is selected. Socioeconomic conditions are considered to have big influence in this study as waste generation is largely influences by household structure and consumption preference.

Table 5 Parameters for projection of waste amount

Index	Explanation
Population	Total number of people residing in an area
Per capita waste generation of high and middle income	Amount of waste generated by one person in a day for whom belong to household with income more than RM3000
Per capita waste generation of low income	Amount of waste generated by one person in a day for whom belong to household with income less than RM3000
Waste recovery rate at base year	Amount of recyclable material collected from waste generation source and not directly sent to landfill site
Household final consumption expenditure	Expenditure including imputed expenditure, incurred by resident households on individual consumption goods and services, including those sold at prices that are not economically significant
Absorption Matrix, Purchasers' Value	The uses of imported and domestically produced commodities in different industries as well as final demand valued at purchasers' values
Household actual final consumption	Household actual final consumption consist of the consumption goods or services acquired by individual households by expenditures or through social transfers in kind received from government units or non-profit institution serving households (NPISHs)
Consumer Price Index (CPI)	A measure that examines the weighted average of prices of a basket of consumer goods and services. Changes in CPI are used to assess price changes associated with the cost of living.
Deflator	An economic metric that accounts for inflation by converting output measured at current prices into constant GDP. The GDP deflator shows how much a change in the base year's GDP relies upon changes in the price level.

i Total amount

The amount of total waste generation is estimated using the formula shown below.

[Total waste generation (t/d)] = [Per capita waste generation (kg/cap/d)] x [Population number (person) x 0.001]

Documented data on waste composition do not exist in Malaysia by state. Therefore, the waste composition for the country from "*The Study on National Waste Minimisation in Malaysia*" is used as a reference value (**Table 6**).

Table 6 Waste composition from The Study on National Waste Minimisation in Malaysia (%)

	Food	Paper	Plastic	Glass	Metal	Others
Composition	40	31	8	4	3	15

The estimation for total waste generation was carried out under the following key assumptions:

1. Per capita waste generation for medium and high income households is taken to represent urban household where in 2005 the rate is 0.7 kg/cap/d.
2. Waste generation rate for rural is calculated based on the ratio of urban: rural published by Economic Planning Unit (EPU), where in 2005 the ratio is 1:0.65

ii Product and packaging waste

In order to estimate amount of waste reduction at source through Reduce and Reuse actions, waste generation by material sub-fraction is estimated. **Figure 5** shows the flow of estimation. The estimation is based using input-output table of absorption matrix and principal statistics of manufacturing industry. Prior to the estimation, waste is classified into sub-fraction as **Table 7**. The rows represent expenditure groups and the column represents waste type. Six out of twelve household actual final consumption groups that contribute to waste generation are listed in the table with five main waste material fractions.

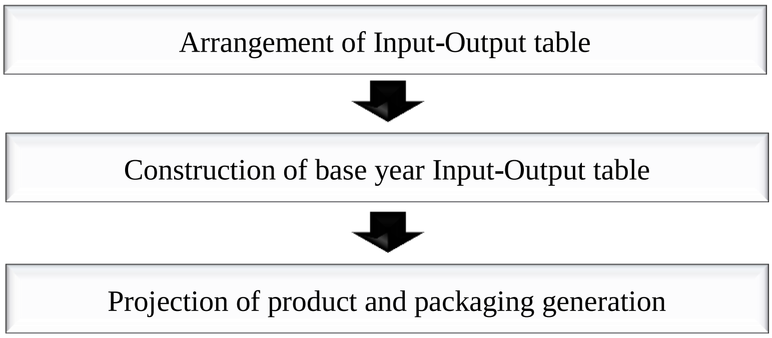

Figure 5 Estimation of product and packaging waste

Table 7 Classification of product and packaging waste

	Paper	Plastic	Glass	Metal	Other
Food	Pc	Pc	Pc	Pc	-
Beverages	Pc	Pc – PET	Pc	Pc	-
Clothing and footwear	Pc	Pc	-	-	Pr
Household maintenance	Pc	Pr	Pr	Pr	-
Recreation and culture	Pr	Pr	-	-	-
Miscellaneous	-	Pc	-	-	-

Note: Pc: Packaging, Pr: Product

(i) Arrangement of Input-Output table

A large number of researchers proved that economic growth is the main factor affecting consumption expenditure that is the main influence in waste generation. Significant change has also occurred in the consumer behaviour and consumption patterns during the past decades as a result of rapid economic growth. Correspondingly, consumption behaviour is considered to be a function of such parameters as economic growth, demographic changes, socio–cultural, socio–economic and policy measures. A wide variety of studies have indicated that the lifestyle of residents, socio–economy and socio-demography constitute a latent factor in the consumption pattern, and has an indirect impact on waste generation or recycling behaviour. Thus to project the generation of product and packaging waste, we first re-arrange the IO table industry sector's into seven group of household consumption expenditure groups that contributed to waste generation. The new arrangement is shown in **Table 8**.

Table 8 Industrial sectors and household final consumption

Industry sector	Household final consumption
Meat & meat products Dairy products Preserved fruits & vegetables Preserved seafood Oils and fats Grain mill products Bakery products Confectionery Ice Other food	Food
Wine and spirits Soft drinks	Beverage
Yarns & cloth Knitted fabrics Other textile Wearing apparel Leather products Footwear	Clothing and footwear
Furniture	Recreation – Games, toys, hobby, sports equipment
Paper & board	Recreation – Books, newspaper and magazine
Soap & cleaning preparations	Miscellaneous – Products for personal care
China, glass & pottery	Household equipment – Glassware, tableware, other household utensil

(ii) Construction of base year Input-Output table

In all three of the case studies, IO table for the base year is not available; therefore it has first to be constructed based on available documented data. Extrapolation using Malaysia IO table from 1987, 1991 and 2000 is carried out based on newly arranged IO table. All prices are converted into constant price in the base year as follows:

$$P_R = \frac{P_N}{Def_R} \times 100 \qquad (1)$$

where P_R, P_N and Def_R represents real price in targeted base year, price in current year of documented data and deflator for base year, respectively. The Growth Domestic Product (GDP) deflator is utilized as a measure of shifts in the prices of products and services that are produced. It is understood that the GDP deflator can help provide a more accurate picture of the current status of the gross domestic product within the country.

(iii) Projection of product and packaging waste

Projection of product and packaging waste coefficient is carried out using the result and amount of waste generated from each fraction as following **equation 2**:

$$K_w = \frac{W_w}{S_w} \qquad (2)$$

In which, K_w denotes the waste generation coefficient. w is the waste type, being paper, plastic, glass, metal and other. W_w is waste amount of each waste category, and S_w is the sum of production for each material. $\boldsymbol{S_w}$ is calculated as below:

$$S_w = \sum \left(a_{ij} \times \frac{b_{jh}}{B_j} \right) \qquad (3)$$

a_{ij} is supply of product i to industry j. For example, supply of plastic products to food industry is considered as plastic packaging of food industry. b_{jh} is the amount of household consumption on the products. B_j is the total productions of the products.

Principal statistic of manufacturing industry is used to estimate details of shared composition of industries in the total manufacturing process. Main assumptions in the estimations are as follows and summarized in **Table 9:**

1. Product waste
   a. Input from ‘manufacture of corrugated paper and paperboard, and containers of paper and paper board’ to food, beverage, and wearing apparel industries are meant for paper packaging.

b. Input from ‘manufacture of plastic bag and films’ and ‘manufacture of plastic foam products’ to food, beverage, wearing apparel and miscellaneous goods are meant for plastic packaging.
c. Input from ‘manufacture of glass and glass product’ to food and beverage industries is meant for glass packaging.
d. Input from ‘manufacture of tin cans and metal boxes’ to food and beverage industries is meant for glass packaging.

2. Packaging waste
   a. 38% from ‘manufacture of paper and paper products’ to ‘manufacture of pulp, paper and paperboard’ is meant for production of paper for printing materials.
   b. 12% from ‘manufacture of plastic products’ to ‘manufacture of plastic blow moulded products’ is meant for production of plastic container for household maintenance.
   c. 24% from ‘manufacture of plastic products’ to ‘manufacture of furniture’ is meant for productions of games, toys and sports goods.
   d. 29% from ‘manufacture of other fabricated metal products’ to ‘manufacture of other fabricated metal products’ is meant for productions of household utensils.

Table 9 Share composition of various industries in Malaysia manufacturing

Description	Industry Code
Manufacture of paper and paper products	170
Manufacture of pulp, paper and paperboard	17010
Manufacture of corrugated paper and paperboard and of containers of paper and paperboard	17020
Manufacture of envelopes and letter-card	17091
Manufacture of household and personal hygiene paper	17092
Manufacture of gummed or adhesive paper in strips or rolls and labels and wallpaper	17093
Manufacture of effigies, funeral paper goods, joss papers	17094
Manufacture of other chemical products	202
Manufacture of soap and detergents, cleaning and polishing preparations	20231
Manufacture of perfumes and toilets preparations	20232
Manufacture of plastic products	222
Manufacture of plastic articles for the packaging of goods	22203
Manufacture of other fabricated metal products; metal working service activities	259
Manufacture of tins and cans for food products, collapsible tubes and boxes	25991
Manufacture of general-purpose machinery	281
Manufacture of office machinery and equipment (excepts computers and peripheral equipment)	28170
Other manufacturing	329
Manufacture of stationery	32901

(2) Prevention

Waste prevention at source is one of the main elements of this study. This element incorporates SWM with integration of 2R – Reduce and reuse. Even though recycling is a choice that could reduce volume of waste largely in a shorter time, it also involves high-technology and high cost that barely affordable by developing countries. On top of that, in the fast developing countries with rapid increase in per capita GDP there is the trend of major changes in the generated waste composition. This trend of material-based lifestyle need to be stop and avoided in order to control the changing of waste composition that leads to complication in waste treatment. Promotion of 2R requires an enormous amount of time for it to become a custom especially with history of several failures in Malaysia, nevertheless it is no longer an option but is now a requirement to ensure sustainability in the new SWM system. Four steps towards incorporating waste prevention in this study quantification methodology is shown in **Figure 6**

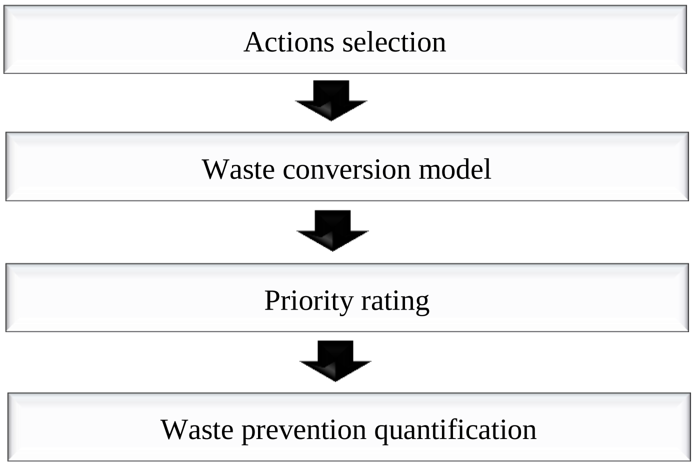

Figure 6 Flow for quantification of waste prevention actions

(i) Action selection

In August 2007, Ministry of Housing and Local Government (MHLG) came out with 3R actions guide or what they called 3RAG. The set of guide introduces tips for ten types of activities and facilities. Each group of tips is intended for certain stakeholders such as household, offices and schools. Unfortunately, this has never been enough promoted to publics and left the effort unknown to other stake holder than the MHLG. Based on 3RAG as our reference, 15 2R actions to promote waste prevention at household are selected for this study and listed in **Table 10**.

Table 10 2R actions for household sector

Index	Explanation
Buy according to need	Excess expenditure will leads to excess waste generation
Buy in bulk	Buying in bulk reduces generation of packaging waste
Buy refill and concentrate	Refill and concentrate mostly comes in simple packaging and large amount
Buy local product	Most of local products are sold directly before being pack and local products are usually transported in short distance and require minimum packaging
Not to buy over packaged product	Choosing for simple package product prevent from excess generation of packaging waste
Do not take plastic bag	When buying small amount of product choose to refuse the packaging bag
Use my shopping bag	Using my bag prevent generation of plastic waste and promotes ‘reuse’ of textile waste for hand-made bag
Rent or borrow instead of buying	Products that rarely use are better borrowed or rent. It saves money and storage space, and reduce the amount of waste generated
Sharing	Big items such as party supplies or big machines (grass cutter, gardening tools) can be shared within community
Choose for durable items	Durable item are longer lasting product that can be used again and again
Choose on-line service	This apply to all service than can be done online such as online music, newspaper and etc, to avoid printed materials
Choose for reusable items	This will increase the possibility of reuse and lower the need to buy new products
Buy product from recycled materials	This will not only encourage the recycling activities but also reduce the need to use raw materials
Repair broken item	Exchanging partly broken item prevent excess generation of waste
Pack leftover food	Packing leftover reduces the amount of food waste and the needs to buy food

(ii) Waste conversion model

Waste conversion is calculated based on the possibility of waste reduction from the action.

a. Buy in bulk

$$\mathrm{Red}_{bulk} = \left(\frac{W_n}{W_c}\right)^{-1/3} \quad (4)$$

where,

Red_{ref} = Reduction rate of expenditure changes for buying bulky item

W_c = Size of original packaging

W_n = Size of refill packaging

In this calculation we set the calculation conditions to changes of buying PET bottle drinks from 350 mL to 2L, and buying other liquid products such as detergent and shampoo from 1L bottle to 2L bottle.

b. Buy refill and concentrate

$$Red_{ref} = \frac{\mathrm{W}_c + W_n \times f_n}{\mathrm{W}_c \times f_c} \quad (5)$$

where,

Red_{ref} = Reduction rate of expenditure changes for buying refill and concentrate

W_c = Size of original packaging

W_n = Size of refill packaging

F_n = refill frequency

F_c = buying frequency

The calculation condition is that for 100ml liquid products packaging weight are 13g and 2.6g for original bottle and refill package, respectively. Within one year period refill frequency is 5 times of 6 times purchasing at the rate of one purchasing made for every two months.

c. Choose for durable item

$$\text{Red}_{dur} = \frac{\text{L}_c+1}{\text{L}_n+1} \qquad (6)$$

where,

Red_{dur}	= Reduction rate of expenditure changes for durable items
L_n	= Extended life time
L_c	= Current life time

Calculation condition is that for every products purchase, 2 years usage lifetimes were added.

(iii) Priority rating

Priority rating method is adopted to estimate waste reduction at source. It is a method which LAs and waste manager in the study area were asked to rate the priority of promoting 2R actions with regard to expected changes in household consumption pattern. The rating table is as **Table 11** where the stake holder were asked to rate 0 for actions that had no effect, 1 for little effect, 2 for moderate effect, and 3 for the biggest effect on household consumption. The rating is carried out through FGD with the selected stake holders.

Table 11 2R actions rating table

	Food and beverages	Clothing and footwear	Non-durable household goods	Printed materials	Leisure items	Misc
Reduce						
Buy according to need	3	3	3	3	3	3
Buy in bulk	1	2	3	0	0	2
Buy refills and concentrates	0	0	3	0	0	3
Buy local products	3	2	3	0	1	3
Do not buy over-packaged products	3	3	3	3	3	3
Don't take plastic bags unless needed	3	3	3	3	3	3
Rent or borrow instead of buying	0	2	0	3	3	0
Buy online	0	0	0	0	3	0
Bring own lunch	3	0	0	0	0	0
Share	0	3	3	3	3	1
Reuse						
Choose durable items	0	3	0	3	3	1
Buy products made from recycled materials	0	2	2	2	2	2
Repair broken items	0	3	0	0	3	0
Use reusable items	0	3	3	3	3	3
Use my own bag for shopping	3	3	3	3	1	3

(iv) Waste prevention quantification

In order to estimate waste reduction from 2R actions, priority selection based on CM implementation is carried out as in **Table 12**. At low level of law implementation only actions rated 3; biggest effect on household consumption is selected. Respectively, at medium and high level of law implementation actions rated 2 and 3, and 1, 2, and 3 are selected.

Table 12 Priority selection based on CM implementation

		Priority		
		Little	Moderate	Biggest
Implementation	Low			✓
	Medium		✓	✓
	High	✓	✓	✓

Calculation of waste reduction from waste prevention is represented in the following equation 7:

$$W_{2R} = (\text{Red} \times P_i \times E_i) \times W_{BaU} \quad (7)$$

Red indicates the effect of actions rating on waste generation from the waste conversion model; P_i indicates participation level; E_i indicates law implementation level in response with CM scenarios($i = 1, 2, 3$). All waste types except food are calculated.

The estimation for reduction at source is carried out under the following key assumptions:

a. Only paper, plastic, glass, and metal are considered
b. Reduce
   i. Projection are for both product and packaging waste
   ii. 70% of products waste are recyclable materials
   iii. 100% of packaging waste are recyclable materials
c. Reuse
   i. Projection is for only product waste
   ii. 70% of products waste are recyclable materials
   iii. 100% of packaging waste are recyclable materials

(3) Self-treatment

Self-treatment in this study included two types of treatment for food waste namely composting and food disposer.

i Composting

Composting is the aerobic degradation of solid matter. In nature the process evolves spontaneously in plant litter decomposition and in animal residues and manure transformation. The fundamental of composting is as follow

$$\text{Complex organic} + O_2 \rightarrow CO_2 + H_2O + NO_3^- + SO_4^{-2} + less\ complex\ organic + heat$$

Surabaya City, Indonesia has successfully reduced its waste generation by more than 20% over a short period of time. The daily average waste generation which used to be more than 1,500t/d before 2005, has decreased to 1,300t/d in 2007 and 1,150 t/d in 2008. The city has intensively promoted composting practices by setting up more than a dozen composting centres and distributing thousands of compost baskets to residents and community groups. Remarkably, this is not a feat achieved by a small city, but by the second largest city in Indonesia of three million populations. Therefore, this option is not considered to be one that is unique to small cities, but applicable to other big cities as well (Maeda, 2009).

ii Food disposer

In the past 20 years, the use of kitchen food waste disposer has gained such wide acceptance in developed countries especially in the big cities that, in some areas, nearly all new houses are equipped with the disposer. Food disposer is used primarily for wastes from food preparation, cooking and leftover. Functionally, waste material passes through food disposer are rendered to suit transportation through sewer system. The use of food disposer does not only reduce the weight of waste to be collected but could also enable increase the time period between collections because remaining waste is non-rotten material.

Estimation of waste reduction from self-treatment is as follows:

$$W_{Sf} = (En_i \times E_i) \times W_{BaU} \quad (8)$$

En_i indicates enforcement level in response with CM scenario.

(4) Source segregation

i Community collection

This action is projected for recyclable materials with high value that are accepted at buyback centres. Waste types whose collection is projected under this action are product waste and packaging waste for paper, plastic, glass and metal. For this action, due to the influence of incentives garnered by selling the recyclable materials, a high participation rate can be expected; however, in order to participate in this action, residents are expected to bring their recyclable materials to the buyback centres. This 'bring' collection scheme, compared to the current 'kerbside' collection scheme, is likely to cause a decrease in participation rate.

ii Separate collection

Separate collection applied to waste collected by concessionaires under a mandatory separate collection policy. Waste types estimated under this action are paper and plastic product waste and paper, plastic, glass, and metal packaging waste. Separate collection is to be compulsory; therefore, a high participation was assumed.

Estimation of waste reduction from source segregation is as follows:

$$W_{Ss} = (P_i \times E_i) \times \left(W_{2R_{Prod}} + W_{2R_{Pack}}\right) \quad (9)$$

Where;

W_{Ss} : Amount of waste reduced from source segregation

$W_{Pr_{Prod}}$: Amount of product waste generated after waste prevention; paper and plastic

$W_{Pr_{Pack}}$: Amount of packaging waste generated after waste prevention; paper, plastic, glass and metal

(5) Collection and transportation

Waste transportation practice in the base year is limited to door-to-door collection in all three study areas. Even though high collection and participation rates in waste separation can be foreseen using this method; it is unfortunately quite unsustainable due to GHG emissions by garbage trucks. Shortest-distance waste collection routing is proposed using a geographic information system (GIS).

Two steps in this method are:

i Building a waste distribution map

Waste distribution map is map that shows waste generation amount according to residential area. Thus identification of waste generation amount is predictable based on housing type and population density. Using Visual Basic for GIS, the whole collection area is equally distributed into smaller cells according to the collection truck capacity. **Figure 7** is the example of estimation result, where based on capacity of collection truck and waste distribution, one cell is divided recursively until each cell represent waste amount collectable by the selected truck at each trip.

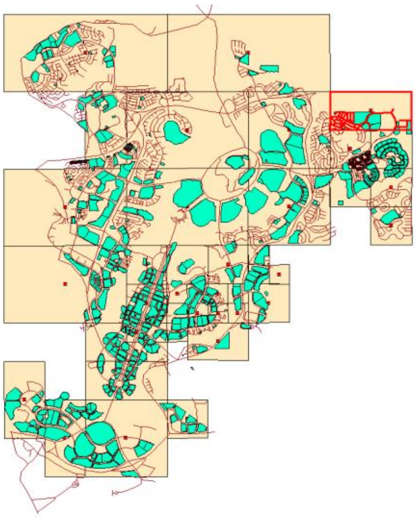

Figure 7 Example of waste distribution map

ii Layering the map over road-network map

Waste distribution map are built and then layered over road-network maps to estimate collection and transportation distance. Estimation of distance is carried out using Network Analysis function of GIS.

Calculation process is as follow

a. Moving distance 1

Distance travelled from collection truck parking area to the designated collection cell

b. Collection distance

Total distance travelled by collection car within the designated cell

c. Transportation distance

Distance travelled from designated cell to treatment facility and landfill site.

d. Moving distance 2

Distance travelled after waste unloading to collection truck parking area.

Main assumptions for the projection are:

a. Combination of two- and ten-tonne trucks is used

b. Besides truck capacity, waste generator and waste type are also considered

c. In the estimation process, it is assumed that collection distance in each designate cell is equal to the shortest collection route linking all waste sources within the cell. However, this is difficult to achieve due to external factors such as traffic jam and narrow road. Therefore, assumption coefficient of 1.2 is multiply to the collection distance.

(6) Pre-treatment

Recyclable material collected from community collection or separate collection in the CM scenarios are treated in pre-treatment facilities or known as materials recovery facility (MRF). Even though waste materials have been separated at source, additional separation and processing will usually be required before these material can be reused or recycled. **Table 13** summarized the typical examples of the materials and function of MRF used for the processing of source separated material. In this dissertation, a boundary for pre-treatment is limited to the input to MRFs without considering its output for further treatment.

(7) Final treatment

Two types of final treatment considered in this dissertation are as follow:

i Thermal treatment

The organic fraction of waste can be transformed by a variety of chemical and biological processes. The most commonly used chemical transformation process is thermal treatment (TT) or well-known as incineration. This method can be used to reduce the original volume of the combustible fraction of waste by 85 to 90 percent. In addition, the recovery of energy in the form of heat is another attractive feature of the thermal treatment. In this dissertation, waste after reduction at source and separate collection for material recovery is considered for thermal treatment.

Boundaries of estimation:

a. Type of thermal treatment technology used is not decided

b. Energy recovery from this method is not calculated ii Landfill

In the BaU scenario, landfilling is the only waste handling element applied in the SWM system. Even though six other elements are incorporated in the CM scenarios, landfill could never be avoided. In the CM scenarios, waste transported to landfill site included directly landfill waste, pre-treatment residual and thermal treatment residual.

Table 13 Material Recovery Facility requirement

Materials	Function/Operation	Equipment and facility requirements
Mixed paper and cardboard	Manual separation of old newspaper, old corrugated cardboard, and mixed paper from commingled mixture. Baling of separated materials for shipping. Storage of baled materials	Front-end loader, conveyors, enclosed picking station, baler, forklift
Mixed plastic	Manual separation of PET ad other plastic from commingled mixture. Baling of plastics for shipping. Storage of separated materials	Receiving hopper, picking conveyor, baler, forklift
Mixed glass	Manual separation of clear, green, and amber glass. Storage of separated materials	Receiving hopper, picking conveyor, glass crusher, storage bins, baler, forklift
Aluminium and tin cans	Magnetic separation of tin cans from commingled mixture of aluminium and tin cans. Baling of separated materials for shipping. Storage of baled materials	Receiving hopper, conveyor, overhead suspended magnet, magnet pulley, storage containers, baler or can crusher and pneumatic transport system, forklift

3.4.2 Greenhouse gases

The GHG baseline emission from waste is the amount of methane calculated in tons of carbon dioxide equivalent (tCO_2 *eq.*) that would be generated from disposal of waste at a solid waste disposal site in the absence of the project activity (UNFCCC, 2008). In this study, the baseline emission is calculated using inventory by The Japan Environmental Management Association for Industry (JEMAI). Calculation of GHG is amounts emitted from waste treatment facility and compare it with amount emitted from landfill; the only waste treatment selection at BaU scenario. The GHG effects involve the following releases: CO_2, CH4 and N2O. Emission in the CM scenarios and emission reduction in this dissertation is calculated as following equations:

$$GHG_{CM} = GHG_{BaU} - GHG_{ER} + GHG_{Tr} \quad (10)$$

$$GHG_{ER} = GHG_{L} - GHG_{T} \quad (11)$$

Where, GHG_{CM} and GHG_{ER} is total emission in the CM scenario and emission reduction of the CM scenario, respectively. GHG_{BaU} is emissions in the BaU scenario which represent all generated waste are directly landfill. GHG_{Tr} represents emission from collection and transportation. GHG_{L} and GHG_{T} is the amount of GHG reduces from landfill site based on waste reduction scenario and treatment facilities based on waste treatment scenario, respectively.

Details of GHG estimation for treatment selection are as follow:

(1) Composting

Inventory of centralized and decentralized composting are shown in **Appendix A**. Details of the treatment systems are as follow:

i. Application: Composting of food waste
ii. Boundary: Composting without including transportation of compost output
iii. Special remark:

a. Centralized compost: Capacity of 24t/d
b. Decentralized compost: Capacity of 32kg/d, gas typed water heater in apartment area.
c. Food waste condition: 80.93% (moisture), 2.84% (ash), 16.23% (combustible), 282 kcal/kg (low calorific value)

(2) Thermal treatment

Table for inventory of thermal treatment provided by NEDO is shown in **Appendix A**. Air pollutant substances are different based on the waste condition but shown in average value here. Based on regulation by Ministry of Environment, Japan, CO_2 for treatment of plastic is 3.64 kg-CO_2/kg. Details of the treatment system are as follow:

i. Application: Thermal treatment of MSW

ii. Boundary: Incinerator for general purpose thermal treatment

iii. Limit: CH_4 and N_2O from fuel are not included

(3) Landfill

Table for inventory of waste treatment in the final landfill provided by NEDO is shown in **Appendix A**. Details of the treatment system are as follow:

i. Application: Municipal solid waste management and thermal treatment ash

ii. Boundary: Operation and maintenance of landfill at final landfill site.

(4) Transportation

Estimation of GHG emission from waste transportation is carried out using generation rate from real data of waste transportation in Japan (Ishida, 2009). GHG emission rate from three types of truck is listed in **Table 14**

Table 14 GHG emission rate from waste collection truck

Truck capacity (Q) (ton)	A_Q (gCO_2/km)	Loading ratio(x) (%)	B_Q (gCO_2/km)	GHG_t
2	166	100	200	366
10	715	100	508	1223
15	1070	100	580	1650

Equation 12 shows the calculation method for per kilometre collection and transportation:

$$GHG_t = A_Q \times x + B_Q \tag{12}$$

A_Q and B_Q represent CO_2 emission based on loading capacity and x represents loading ratio per trip. x is calculated with **equation 13** and q and Q represents loading amount and truck loading capacity, respectively.

$$x = \frac{q}{Q} \tag{13}$$

Thus, total GHG emission from waste collection and transportation is:

$$GHG_T = \mathrm{D} \times GHG_t \tag{14}$$

D is total distance travelled in a trip.

3.5 Evaluation

Evaluation of quantification results is carried out for both waste and GHG amount. Comparison is carried out between the amount in BaU and CM in the target year. The **equation 15 and 17** below show the evaluation method for waste and GHG, respectively:

$$W_R = \frac{W_{CM}}{W_{BaU}} \tag{15}$$

W_R is the waste reduction rate, W_{CM} is total waste reduced from CM scenarios, and W_{BaU} is total waste generated in BaU scenario. With W_{CM} is calculated as follows:

$$W_{CM} = (W_{Pr} + W_{St} + W_{Ss} + W_{Tt}) + W_{Re} \tag{16}$$

W_{Pr}, W_{St}, W_{Ss}, W_{Tt} and W_{Re} each represents waste reduction from waste prevention, self-treatment, source separation, thermal treatment and residual from waste treatment facilities, respectively.

$$GHG_R = \frac{GHG_{CM}}{GHG_{BaU}} \tag{17}$$

GHG_R is the GHG reduction rate, GHG_{CM} is the total emission in the CM scenario and GHG_{BaU} is emission in the BaU scenario.

3.6 Reference for Chapter 3

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4 THE CASE STUDY OF FEDERAL GOVERNMENT CITY, PUTRAJAYA

4.1 Introduction of Putrajaya

4.1.1 Overview

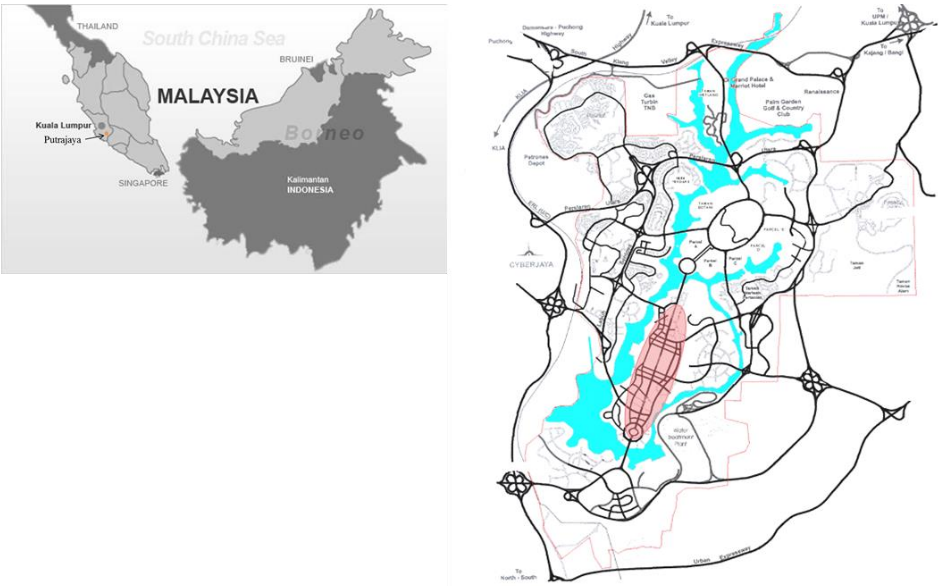

Figure 8 Map of Putrajaya

Putrajaya is a new planned city and the home of Malaysia's government since 1999 (although the formal capital remains Kuala Lumpur). It is an area of 5,000 hectares with 40% of its land dedicated to open space and park (**Figure 8**). The city plan is based on two underlying concepts: the 'city in a garden' and the 'intelligent city'. To date, after 14 years of development, 17 ministries and more than 50 government departments and agencies have been relocated to Putrajaya. The city at present has a population of approximately 70,000 people and is equipped with numerous community facilities, retail outlets, sport facilities, and recreational amenities. By 2012, the remaining four ministries still in Kuala Lumpur will also move to Putrajaya.

The creation of a new federal government administrative centre at Putrajaya marks a new chapter in the development history of modern Malaysia. The development of this city was prompted by the government's desire to balance development among regions and disperse it to areas outside the capital, improving the urban environment and quality of life.

4.1.2 Solid waste management in Putrajaya

Under the jurisdiction of PJC, waste generated in Putrajaya is collected and handle by Alam Flora. The main management of SWM planning in Putrajaya is handled by City Service Department of PJC. Up to date, The City Service Department together with Alam Flora has already came out with one-of its own program for Putrajaya such as Putrajaya Green Card, Buy-back Centre and Green Earth Campaign. Besides the two stake holder, JPSPN also carried out Pilot Project on waste separation in Putrajaya residential area to see the future of separate collection in Malaysia.

(1) Buy back centre

In August 2010, Putrajaya Buy Back Centre was launched and acting as the collecting center for Putrajaya recyclable waste collection. The center is the one and only daily operating permanent buy back center. Currently there are three permanent and two mobile centers that operating in Putrajaya. The permanent centers are located in Precincts 8, 9 and 16, and the mobile centers are in Precincts 11 and 16. All this centers are under both Putrajaya Cooperation and Alam Flora management. At the moment the type of waste accepted are newspaper, corrugated box, other paper, plastic, glass, metal and aluminum. However Alam Flora also accepted other type of recyclable waste such as bulky waste or e-waste according to the public request.

(2) Putrajaya Green Card

At the centers all the waste bring by the public are weighted according to its type and payment made according to the nation market value. The residents can choose from two different method of payment being cash and point system since the introduction of 'Putrajaya Green Card'. The Green Card is the first of its kind to be introduced in Malaysia and it is planned to be use nation widely.

(3) Green Earth Campaign

The implementation of the Green Earth Campaign (Planting Practices) was agreed upon by the Ministers' Council during its meeting on 19 October 2005. It was launched by Malaysia Prime Minister (PM) at the National Level on 3 March 2006. The program's main objective is to encourage the people to plant and produce daily food items such as vegetables and fruits for own consumption. This campaign will create awareness and interest among the people on agriculture especially among residents of urban residential areas. This campaign is also hoped to create awareness on the benefits of fresh, nutritious and safe foods as well as beautiful and attractive surroundings. This activity is able to foster close relationship among the residents and it is a step in creating a community that is ready to be accountable to take care of their own community's surroundings.

(4) Putrajaya Pilot Project

From September to March 2009, a six month pilot project on waste segregation was carried out in selected houses form 2 precinct of Putrajaya, and has been continuous to this day. During the period, the selected houses were asked to separate their waste into 3 categories being plastic, paper and other. The waste then collected accordingly and composition study were carried out. The outcome of this pilot project is the benchmark for separate waste collection in Putrajaya. **Table 15** shows us the composition percentage of waste generated within the six month period. All waste is generated in the same pattern for all three level of household income being low, middle and high, except for food and green waste. It is understand that as the income level increase, the garden waste also increase but the food waste decrease.

Table 15 Putrajaya Pilot Project

	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Average waste generation per house per day (Precinct 9) (kg/d)	2.6	2.4	2.3	2.3	2.6	2.7	2.5
Average waste generation per house per day (Precinct 10)(kg/d)	3.5	3.6	2.9	3	3	4.1	3.1
Recyclable collected (kg)	737	433	812	981	1188	855	971

As for their future plan, PJC allocated an amount of land in Precinct 10 to be turn in to Integrated Solid Waste Recycling Facility (ISWRF) area. ISWRF will be the home of waste pre-treatment plan such as sorting, bailing and compacting plant, and location of Putrajaya Incinerator for waste thermal treatment.

4.2 Background of Putrajaya Green City 2025 study

During the 2010 Budget Speech, Prime Minister Mohd Najib Abdul Razak announced to ‘develop Putrajaya and Cyberjaya as Pioneer Townships in Green Technology as a showcase for the development of other townships’. Based on this announcement, the LA in Putrajaya, known as the Putrajaya Corporation or PJC, came up with the idea to carry out a preliminary study on the theme of ‘Putrajaya Green City 2025’.

The study consists of three elements:

i Low-Carbon Putrajaya: 60% reduction of GHG emission intensity related to energy use

ii Cooler Putrajaya: minus 2°C peak temperature

iii 3R Putrajaya: 50% reduction of solid waste final disposal and 50% reduction of GHG emission per waste generation

Each element has its own targets, with the overall objective of building a LCS that consumes sustainable and relatively low-carbon energy as compared with present practices, to avoid adverse climate change. The target of ‘Low-Carbon Putrajaya’ is to reduce CO_2 emission intensity (CO_2 emission per economic activity) by 60% in 2025 compared to the levels in 2007. The target of ‘Cooler Putrajaya’ is to mitigate urban heat environment and lowering 2°C of peak temperature to a comfortable level for the residents and worker in Putrajaya. The lowering of the temperature will also assist in reducing the energy demand of cooling devices hence also contributing towards Low-Carbon Putrajaya. ‘3R Putrajaya’ sets two targets, one each for SWM and low-carbon action, respectively. The target for SWM is to reduce the volume of waste sent to landfills to half of total generated waste by the target year of 2025. The target for low-carbon action is to reduce total volume of GHGs to half of that emitted using conventional methods with the application of alternative methods by the target year of 2025.

A Dozen Actions were introduced towards realization of PGC2025. These actions are divided according to the three environmental targets. **Table 17** shows the detailed action names. The projection and modelling are carried out at base year and target year of 2007 and 2025, respectively.

4.2.2 Future socio-economic scenario assumption

The socioeconomic scenario is drawn up according to the setting of base year because of the availability data from Putrajaya Corporation (PJC). The base year information is obtained mostly from the Laporan Pemeriksaan Draf Rancangan Struktur Putrajaya, June 2009 (Perbandanan Putrajaya, 2009 REFERENCE). This document is development planning, and it enables us to use it to determine the base year information. As for some detailed figures which were not provided, some assumptions were made. The socio economic assumptions for base year are as seen in **Table 16**.

Table 17 Dozen action of Putrajaya Green City 2025

	Action name	Theme
Action 1	Integrated city planning and management	
Action 2	Low-carbon transportation	
Action 3	Cutting-edge sustainable building	Low-carbon
Action 4	Low-carbon lifestyle	Putrajaya
Action 5	More and more renewable energy	
Action 6	The green lung of Putrajaya	
Action 7	Cooler urban structures and buildings	
Action 8	Community & individual action to reduce urban temperature	Cooler Putrajaya
Action 9	Use less consume less	
Action 10	Think before you throw	3R Putrajaya
Action 11	Integrated waste treatment	
Action 12	Green incentives and capacity building	

Table 16 Socio-economic assumption

Socio-economic indicator	Assumption
Population	347,700 persons in year 2025
Household	79, 023 households in year 2025
In-coming person	67, 947 persons per day in year 2025
Out-going person	47, 672 persons per day in year 2025
Floor area	17, 229, 100m^2 in year 2025 (4.5 times compared to 007 level)
Employment	164, 500 employees in year 2025 (3.7 times compared to 2007 level)
Economy in Malaysia	Per capita GDP will grow approximately an average of 4.3% per year

4.3 Putrajaya Green City 2025 – 3R Putrajaya

4.3.1 Quantification flow

Two targets for 3R Putrajaya are:

1. To reduce the volume of waste sent to landfills to half of total generated waste by the target year of 2025.
2. To reduce total volume of GHGs to half of that emitted using conventional methods with the application of alternative methods by the target year of 2025.

Two achieve the two targets, Putrajaya case study waste flow as **Figure 9** is planned out.

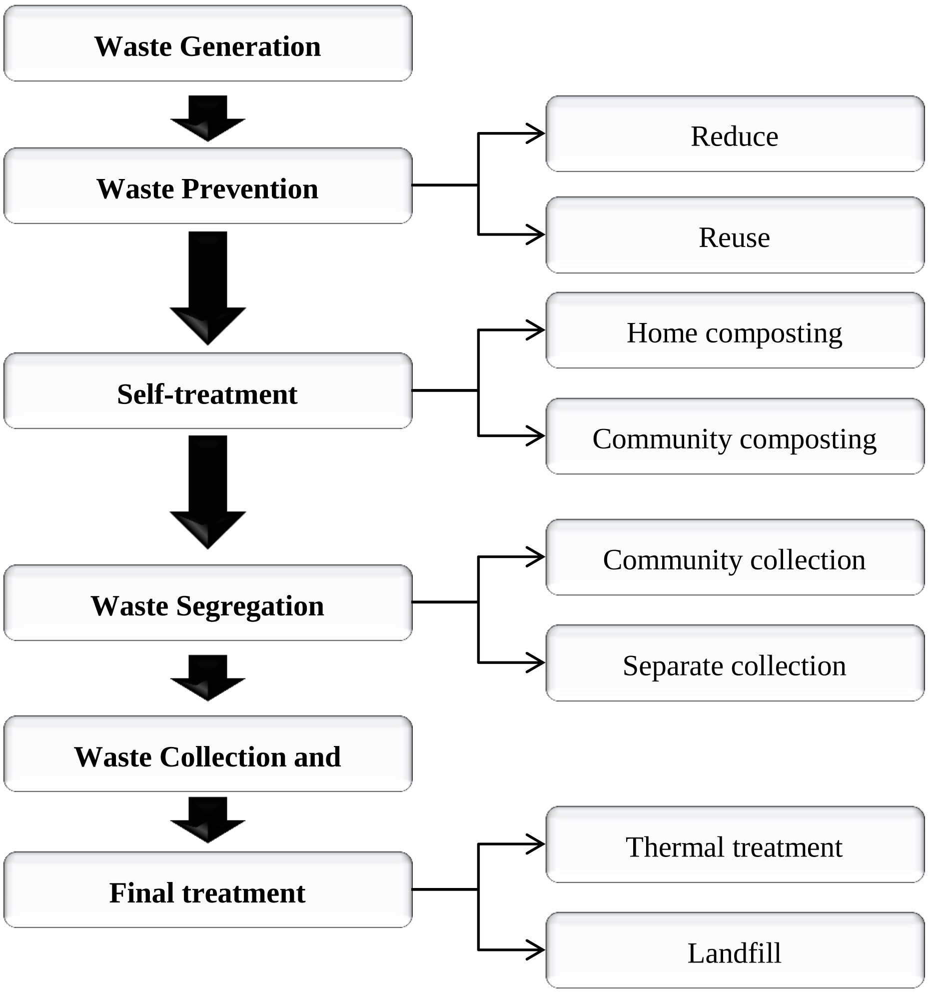

Figure 9 Estimation flow of 3R Putrajaya

4.3.2 Solid waste management action

From twelve actions introduced in PGC2025 study, three is allocated to achieve 3R Putrajaya targets. Under each action, sub-actions and programs are developed to support the projection process towards achievement of each element targets. The sub-actions are the general policy measures which can be identified to further detail out the action. These sub-actions were decided thru the workshop which was held in Putrajaya. The programs are a list of activities which can be conducted or implemented through each of sub-actions introduced. This programs function as a list of detailed activities which have direct or indirect effect towards the success of each Action. **Table 18**, **Table 19** and **Table 20** show the three actions for 3R Putrajaya – Action 9, Action 10 and Action 11, respectively.

Table 18 Sub-action 9: Use Less Consume Less

Sub-action			Programs
9-1	Implement Reduction of Waste at Source	1)	Reduction of household waste reduction
			a. Reduction in household consumption
			b. Increase public awareness in consumption reduction
		2)	Reduction of business waste reduction
			a. Intensify waste reduction programs in schools, offices and businesses
			b. Introduces and intensify paperless operations in businesses
			c. Shops and retail outlets, to restrict the usage of plastic bags
		3)	Reduction of construction waste
			a. Promote extensive use of IBS (Industrialized Building System) in building constructions
9-2	Introduce Regulatory Framework	1)	Make green accreditation mandatory
			a. Government offices to restrict/refrain from using PET bottles and Styrofoam utensils in events/functions
			b. Impose penalty for the disposal of reusable construction/renovation material

Table 19 Sub-action 10: Think Before You Throw

	Sub-action	Programs
10-1	Expansion of Products Lifespan	Encourage the reuse of household waste
10-2	Build More Facilities to Enhance Reuse	1) Introduce flea market where residents can resell their unused belonging. (Electrical items, furniture, books, etc.) 2) Provide locations for car boot sale (eg. At Park & Ride facilities, open space in residential areas, etc.) 3) Drop off point for reusable waste (e-waste, household waste, etc.) 4) Libraries to introduce books sharing activities
10-3	Introduce and Encourage Composting	1) Household - home composting 2) Conventional method
10-4	Recovery of Used Cooking Oil	1) Encourage household to separate used cooking oil for collection 2) Impose food and beverage outlets, school/office canteens to separate used cooking oil for collection
10-5	Introduce Regulatory Framework to Impose Waste Separation at Source	1) Residential area 2) Office 3) Commercial a. Recyclable b. Organic (food, used cooking oil, landscape) c. Others (e-waste, bulky, etc.)

Table 20 Sub-action 11: Integrated Waste Treatment

	Sub-action	Programs	
11-1	Integrated Solid Waste Recovery Facility	1)	Mini thermal treatment plant for non- recyclable or compostable waste
		2)	Sorting centre for recyclable waste
		3)	Baling facility for recyclable waste before transported
		4)	Bio- diesel fuel plant for used cooking oil
		5)	Crushing facility for construction waste
		6)	Centralized composting centre for landscape waste and sewage sludge
		7)	Biogas plant for organic waste
		8)	Sewage treatment
11-2	Introduce Regulatory Framework	1)	To provide more composting facility a. Household - community composting - Provide common compost bins for garden waste in residential areas. - Provide common compost bins for garden waste in residential areas. b. Commercial - On-site composting machine for F&B outlets/markets/hotels - On- site composting machine for F&B outlets/markets/hotels * Impose regulations for landscape activities to use compost produced in Putrajaya
		2)	Provide more buy back centre a. Fixed facilities - Boutique for recycle product - Daily operation b. Mobile facilities - Vehicles that go around residential areas - Weekly operation
		3)	Introduce separate collection - Fixed schedule by Alam Flora
		4)	Study on “Pay As You Throw” system

4.4 Quantification of scenario

4.4.1 Waste

(1) Waste generation

In Putrajaya corporation (2009), population is planned to grow up to 347, 700 (7.03 times), so that assumptions is used in this study. Household size is assumed not to change from base year (4.4person/household). Projection of waste generation is based on documented data from "The Study on National Waste Minimisation in Malaysia" and data received from Putrajaya Corporation, City Service Department (**Table 21**).

Table 21 Total MSW collected in Putrajaya (Town Service, PJC) (t/d)

	2003	2004	2005	2006	2007	2008	2009	2010
Waste amount	22.96	32.88	32.83	38.69	35.33	39.39	47.00	50.00

(2) Waste prevention

On December 2010, FGD was held in Putrajaya with involvement of its Low-carbon Development Department and City Service Department. Rating process for 10 reduce and 5 reuse actions were carried out and the result of the FGD is as follows (**Table 22** and **Table 23**).

Table 22 Reuse

	Food and beverages	Clothing and footwear	Non-durable household goods	Printed materials	Leisure items	Personal grooming
Choose for durable items	0	3	0	3	3	1
Buy products from recycled materials	0	2	2	2	2	2
Repair broken items	0	3	0	0	3	0
Use reusable items	0	3	3	3	3	3
Use my bag for shopping	3	3	3	3	1	3

Table 23 Reduce

	Food and beverages	Clothing and footwear	Non-durable household goods	Printed materials	Leisure items	Personal grooming
Buy according to needs	3	3	3	3	3	3
Buy in bulk	1	2	3	0	0	2
Buy refill and concentrates	0	0	3	0	0	3
Buy local products	3	2	3	0	1	3
Not to buy over-packaged products	3	3	3	3	3	3
Don’t take plastic bag unless needed	3	3	3	3	3	3
Rent or borrow instead of buying	0	2	0	3	3	0
Digital service(On-Line)	0	0	0	0	3	0
My lunch pack/leftover	3	0	0	0	0	0
Sharing	0	3	3	3	3	1

(3) Self-treatment

PJC themselves have already come out with a ‘Green Earth Campaign’, a campaign that encourages residents to produce their own vegetables and farm poultry within their own living space. This shows PJC’s interest in building a nature-based community; thus we included composting in 3R Putrajaya self-treatment. The two type of composting projected are i Home composting

Composting activity carried out within personal house compound. Waste targeted in this sub-action is food left-over from the residential.

ii Community composting

Community composting is done in community gardens under the 'Green Earth Campaign'. Waste targeted in this sub-action is organic waste from the garden such as tree cutting and dried leaves.

In term of participation rate, home composting was set higher than community composting at 70% and 50%, respectively.

(4) Collection

i Community collection

All waste collected at mobile and permanent buy back centres in Putrajaya are calculated under this sub-action. In the case of Putrajaya, all recyclable materials collected under this method entitle the residents to redeem point under the program of Putrajaya Green Card. This 'bring' collection scheme, compared to the current 'kerbside' collection scheme, is likely to cause a decrease in participation rate. Thus, a 50% participation rate was assumed for this action.

ii Separate collection

All waste generated in Putrajaya area after community collection are considered under this sub-action. At present, waste is collected comingle in all residential area except in the Pilot Project area – Precinct 9 and 10. Separate collection is to be compulsory; therefore, a high participation was assumed of 90%.

(5) Transportation

Figure 10 is the result of waste collection and transportation planning for PGC2025 using GIS. The cells present capacity of waste collection for 2 ton truck for 2025CM scenarios. In the estimation for 2025BaU scenario, 10 ton waste collection truck was used as this is the only option in Malaysia currently. In 2025CM scenario, waste are collected door-to-door from the generation resource and transported to ISWMRF and the residual is transported to landfill located 35 km from Putrajaya.

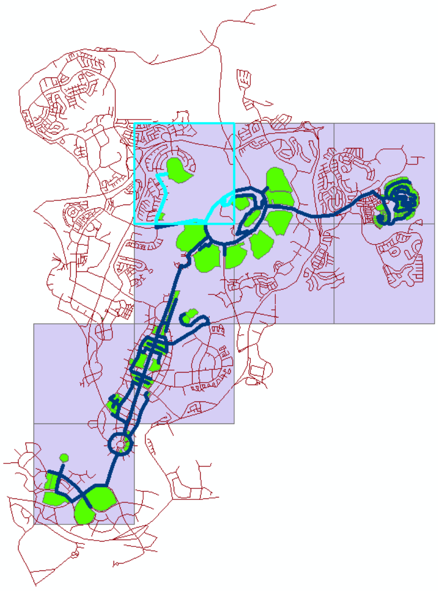

Figure 10 Waste collection and transportation cells in Putrajaya

(6) Final treatment

i Business as usual (BaU)

All waste generated is sent directly to the final landfill site without any kind of pre-treatment process. This is the current scenario for waste-handling in the study area.

ii Separate collection without thermal treatment (2025CM1)

After waste reduction at the source, recyclable waste is collected and treated separately and other waste is sent to landfill.

iii Thermal treatment without separate collection (2025CM2)

After waste reduction at source, commingled waste is sent for thermal treatment before being landfilled.

iv Separate collection with thermal treatment (2025CM3)

After waste reduction at source, recyclable waste is collected and treated separately. Other waste is sent for thermal treatment before being landfilled.

4.4.2 Greenhouse gases

GHG amount for 2025BaU and 2025CM are calculated as inventory listed in section 3.4.2 of this dissertation. The former are calculated for all generated waste being sent to final landfill site and the latter are calculated for waste treated at MRF and TT. GHG from waste collection and transportation were also projected using combination of 2 tons and 10tons collection truck.

4.4.3 Result

Table 24 summarized the parameter setting for 3R Putrajaya. The main results from the calculations are featured in this section.

Table 24 Parameter setting for 3R Putrajaya – Household Solid Waste

Scenario	**Waste type**	**Assumption**
Reduce	Product and packaging waste	70% product are recyclable
Reuse	Product waste	100% packaging are recyclable
Community collection	Product - Paper Packaging - Paper, Plastic, Glass, Metal	Segregation efficiency: 90% Participation rate:50%
Separate collection	Product - Paper and Plastic Packaging - Paper, Plastic, Glass, Metal	Segregation efficiency: 90% Participation rate: 90%

(1) Waste amount

Compared to 2007 (21 t/d), total waste generation in 2025 will achieved 149 (t/d). This is mainly lead by major increase of population especially from 2010 onwards. Under sub-actions Reduce and Reuse, 8 t/d of waste is reduced in 2025CM. Collection of recyclable materials at buy-back centres under sub-actions of Community Collection reduced 9t/d of waste. The remaining 132 t/d is then estimated for final treatment selections. The estimation result is shown in **Table 25**.

The most reduction achievable is 77% compared to 2025BaU under scenario of Separate Collection with Thermal Treatment (2025CM3), this is equivalent to reduction of 114 ton of waste daily from being sent to landfill site. The least reduction is from Separate Collection without Thermal Treatment (2025CM1) of 54t/d waste or equivalent to 36% from 2025BaU. 68% of waste reduction is expectable from Thermal treatment without Separate Collection scenario or equivalent to 102t/d waste amount.

Table 25 Waste amount based on treatment selection

	BaU	Separate collection	Separate collection with thermal treatment		Thermal treatment without separate collection	
			without self-treatment	with self-treatment	without self-treatment	with self-treatment
Food	59.17	55.83	16.749	5.583	16.749	5.583
Product	*5.95*	*0.84*	*0.25*	*0.25*	*0.84*	*0.84*
Packaging	*40.55*	*11.63*	*3.49*	*3.49*	*11.63*	*11.63*
Paper	46.50	12.46	3.74	3.74	12.46	12.46
Product	*3.11*	*0.91*	*0.27*	*0.27*	*0.91*	*0.91*
Packaging	*8.97*	*1.30*	*0.39*	*0.39*	*1.30*	*1.30*
Plastic	12.08	2.20	0.66	0.66	2.20	2.20
Product	*0.51*	*0.44*	*0.44*	*0.44*	*0.44*	*0.44*
Packaging	*4.71*	*0.65*	*0.65*	*0.65*	*2.16*	*2.16*
Glass	5.22	1.09	1.09	1.09	2.60	2.60
Product	*2.58*	*2.56*	*2.56*	*2.56*	*2.56*	*2.56*
Packaging	*0.70*	*0.11*	*0.11*	*0.11*	*0.35*	*0.35*
Metal	3.28	2.67	2.67	2.67	2.91	2.91
Other	22.8	20.94	20.94	20.94	20.94	20.94
Total	**149.05**	**95.19**	**45.84**	**34.67**	**57.86**	**46.69**

(2) GHG amount

GHG emission in 2025 is 1130 and 2 tCO_2/d from landfilling and transporting of total generated waste, respectively. Compared to 2025BaU the greatest reduction is seen from a combination of separate collection with thermal treatment at 67%, equivalent to 763tCO_2/d. For the other scenarios, CM1 and CM2 respectively show reductions of 62% (699 tCO_2/d) and 54% (613tCO_2/d). In the BaU scenario using 2-tonne trucks, 1.9tCO2/d of GHGs are emitted by waste collection. In the other scenarios, CM1, CM2, and CM3 respectively show 1.18, 1.27, and 0.96 tCO_2/d. Even though GHG emissions from the transportation sector are very small compared to other sectors, their value varies greatly between scenarios. The highest reduction is seen in CM3, at 50%, or 0.96tCO_2/d. GHG emitted from treatment options are 25.18, 115.43 and 45.94 CO_2/d, by CM scenarios, respectively. **Table 26** summarized the GHG estimation result of all scenarios.

Table 26 GHG amount based on treatment selection

	BaU	Separate collection	Separate collection with thermal treatment		Thermal treatment without separate collection	
			without self-treatment	with self-treatment	without self-treatment	with self-treatment
Landfill	1129.86	406.60	413.10	402.20	332.80	321.70
Treatment	0.00	25.18	122.49	115.43	53.00	45.94
Transportation	3.40	2.60	1.58	1.58	1.92	1.92
GHG emission	1133.26	434.38	537.17	519.21	387.72	369.56

4.5 Conclusion of Putrajaya Green City 2025

Putrajaya is the new city develops for federal government administrative centre. It is one of its kinds of city in the country and this special characteristic allowed the LA of Putrajaya, PJC to shape development of the city accordingly. Following PM announcement of the nation dedication to develop Putrajaya and Cyberjaya as Pioneer Townships in Green Technology as a showcase for the development of other townships, PJC agreed to collaborate with the study of PGC2025. As part of the study, follows are main finding of 3R Putrajaya which focus on SWM:

i Two targets for 3R Putrajaya are reduction of landfill waste by half and the reduction of GHGs by half using alternative waste treatment methods

ii Three treatment scenarios from combination of seven SWM elements were proposed to achieve these targets. The scenarios are 2025CM1 – Separate collection without thermal treatment; 2025CM2 – Thermal treatment without separate collection; and 2025CM3 – Separate collection with thermal treatment.

iii Both waste and GHG reduction targets are achievable under all scenarios tested; in order of reductions from most to least, 2025CM3, 2025CM2, and 2025CM1

The results from this study were presented to PJC including the President of Putrajaya. PJC appointed Japan Research Institute (JRI) to further study the proposed method to be implemented in Putrajaya.

4.6 Reference for Chapter 4

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5 THE CASE STUDY OF MULTIMEDIA SUPER CORRIDOR CITY, CYBERJAYA

5.1 Introduction of Cyberjaya

5.1.1 Overview

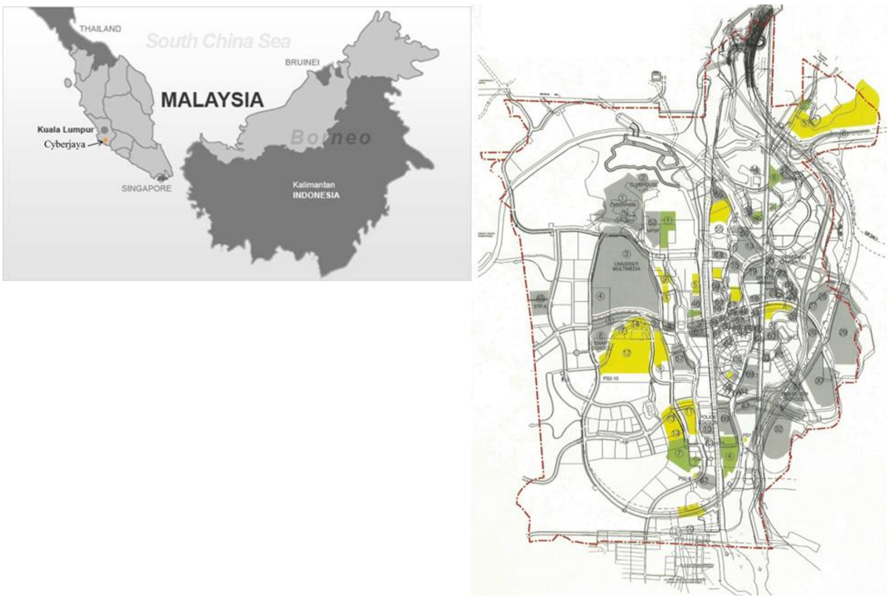

Figure 11 Location of Cyberjaya

Cyberjaya is a town with a science park as the core that forms a key part of the Multimedia Super Corridor (MSC) in Malaysia. The city aspires to be known as the Silicon Valley of Malaysia. The establishment of the MSC program was crucial to accelerate the objectives of Vision 2020 and to transform Malaysia into a modern state by the year 2020, with the adoption of a knowledge-based society framework. MSC Malaysia covers an area of approximately 750 km^2 stretching from the Petronas Twin Towers to the Kuala Lumpur International Airport, and including the towns of Putrajaya and Cyberjaya.

Cyberjaya the core of Malaysia MSC covers an area of 29 km^2 freehold land that consist four main zones known as enterprise, commercial, institutional and residential. It is now the home for over 500 MSC Status companies, several tertiary education institutes, and residential for both living in and commuting people of the city. By 2025, the city is also expected to see a large boom in population growth with residential developments to cater up to a target population of 210,000, business developments providing for up to 120,000 employees and institutional establishments for 30,000 students.

5.1.2 Solid waste management in Cyberjaya

Since 1997, responsibility of waste collection and treatment are transferred from LA to concession companies under the privatization of SWM in Malaysia. However, this is not applicable to Selangor, Pulau Pinang, and Perak, thus leave responsibility of SWM of Cyberjaya under jurisdiction of Sepang LA. Even though Cyberjaya is a newly develop city with special role in Malaysia MSC development, the different in SWM system make the gap between Cyberjaya and Putrajaya very distinct. There is no planning towards improvement of current practice of waste handling in the area. Besides, there is no available data for reference of designing new SWM system for Cyberjaya.

5.2 Background of Cyberjaya Digital Green City 2025 study

In October 2010 Putrajaya Corporation, LA of Putrajaya proposed a preliminary study of PGC2025 which was carried out under three elements of environment: 'Low-Carbon Putrajaya' 'Cooler Putrajaya' and '3R Putrajaya'. Each element presents its own target with the study target to achieve a LCS by the target year of 2025. Following the completion of PGC2025, Cyberjaya developer, Cyberview also proposed the interest in carrying out a preliminary study in Cyberjaya. For DGC2025, four themes were introduced:

i Low-carbon Cyberjaya
ii Smart 3R Cyberjaya
iii Liveable & Vibrant City
iv Smart Digital Network City

Towards realizing DGC2025 through the four themes, a 'Dozen Actions' table was formulated as a concrete vision for such society, shown in **Table 27**. Two out of the four actions are represented quantitatively; 'Low-carbon Cyberjaya' and 'Smart 3R Cyberjaya' and the other two themes; 'Liveable & vibrant city' and 'Smart digital network city' are indirectly contributing towards achieving the set targets. Two quantitative targets set are to reduce CO_2 emission by 50% and solid waste final disposal by 75%. The projection and modelling are carried out at base year and target year of 2010 and 2025, respectively.

Table 27 Dozen actions for Digital Green City 2025

	Action name	Theme
Action 1	Eco city planning	Low-carbon Cyberjaya
Action 2	Green transportation	
Action 3	Environment friendly buildings & houses	
Action 4	Local production & consumption of renewable energy	
Action 5	Urban energy system	
Action 6	Green incentive & education	
Action 7	Reduce, Reuse, Recycle and Smart management	Smart 3R Cyberjaya
Action 8	A liveable community and city	Livable & Vibrant City
Action 9	A vibrant urban space	
Action 10	Smart community	Smart Digital Network City
Action 11	Intra-city digital network	
Action 12	Innovative green business	

Table 28 Socio-economic assumption

Indicator	Sector	Unit	Value
Night-time population	-	person	13,353
Daytime population	-	person	41,759
Number of household	-	household	3,500
Household size	Family household	person/household	4
	Students residing	person/unit	6.25
Employment	Commercial		1,360
	Enterprise		9,478
	Institution		2,000
	Total		**12,838**
Student	-		20,221
In-coming persons	-		28,000
Economic activity	-		1,183

5.2.2 Future socio-economic scenario assumption

The socioeconomic scenario is drawn up according to the setting of base year because of the limited data in Cyberjaya. The base year information is obtained mostly from Cyberjaya City Survey “Outcome of Report”, 2010 (Cyberview, 2010). Cyberjaya doesn’t have any development plan, thus this survey had to be carried out for the purpose of this study and data projection was carried out for the non-collected data. The result is in **Table 28**.

5.3 Digital Green City 2025 – Smart 3R Cyberjaya

5.3.1 Quantification flow

Smart 3R Cyberjaya focuses on the study of SWM in Cyberjaya with the support of Action 7; Reduce, Reuse, Recycle and Smart management. Smart waste management in this study context is the focus of e-waste management in the ICT core city. However this paper discuss only on HSW management part.

(1) 75% reduction of solid waste amount sent to landfill by the year 2025 compared to BaU scenario

(2) 50% reduction of CO_2 emission from alternatives SWM method compared to 2025 BaU scenario

Figure 12 is the estimation flow for household solid waste in DGC2025.

5.4 Quantification of scenario

5.4.1 Waste

(1) Waste generation

Using socio-economic indicators provided by Cyberview (land owner of Cyberjaya) through their Cyberjaya City Survey 2010 “Outcome of Report” and The Study on National Waste Minimisation in Malaysia (TNS), we projected HSW generation for base year 2010. HSW generation for target year 2025 are projected using socio-economic indicators from Setia Haruman (master developer of Cyberjaya) and TNS. Combination of night time and student population for base and target year is 33,574 and 240,000, respectively. Total waste generation for Cyberjaya is calculated using urban per capita generation rate of 0.71 kg/d and the composition of 40% food, 31% paper, 8% plastic, 4% glass, 2% metal and 15% other. Product and packaging waste classification are projected as in PGC2025.

(2) Waste prevention

2R rating for DGC2025 was carried out using two methods – FGD and questionnaire. The former is carried out with officer of Sepang LA and the latter is carried out within other offices operating within Cyberjaya area especially MSC status companies. In the household sector, 11 sub-actions are group under three actions namely smart purchase, waste refuse and smart planning. Result of the rating is as **Table 29**.

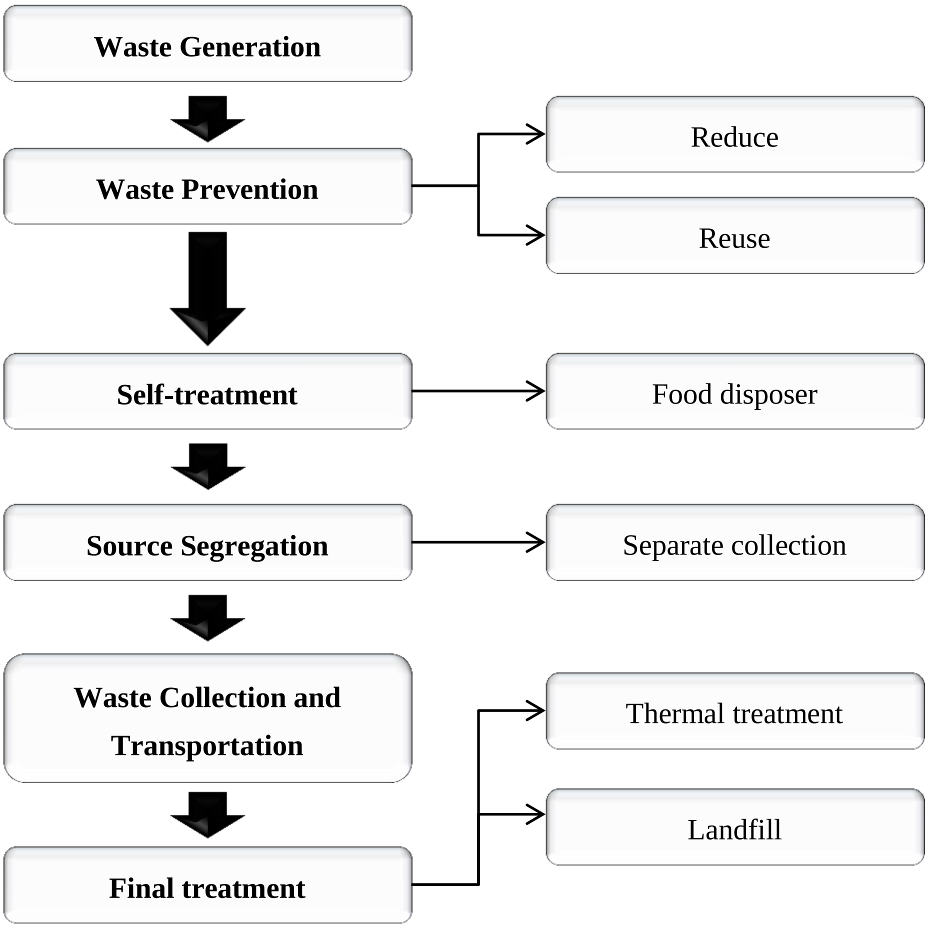

Figure 12 Estimation flow of Smart 3R Cyberjaya

Table 29 Reduce and reuse rating of DGC2025

Action	Sub-action	Food and beverages	Clothing and footwear	Non-durable household goods	Printed materials	Leisure items	Personal grooming
Smart purchase							
	Buy according to need	3	2	3	2	3	2
	Buy in bulk	1	1	1	1	1	1
	Buy refill and concentrates	3	0	1	0	0	3
	Buy local products	1	2	3	3	2	1
Waste refuse							
	Not to buy over packaged products	1	2	1	2	1	2
	Do not take plastic bag	2	2	2	2	2	2
	Use my shopping bag	1	2	2	2	2	1
Smart planning							
	Rent or borrow instead of buying	0	2	0	1	1	0
	Sharing	0	2	2	2	2	2
	Choose for durable items	0	1	2	3	2	1
	Choose for reusable items	0	2	2	1	1	2

(3) Self-treatment

Cyberjaya with its role as the core of Malaysia MSC is moving towards building a high-technology community. In line with this, we projected scenario of self-treatment using food disposer in each household compared to a more nature basis selection of composting that introduced in PGC2025. Under this action, disposer instalment is introduced to household depending on the enforcement level.

(4) Source segregation

In Malaysia generally waste collection and transportation is contracted to be handle by private concessionaire. However, this is not true for Cyberjaya that is under jurisdiction of Sepang Local Authority (LA). Waste collection is carried out by contractor appointed by Sepang LA. In term of waste separation, we proposed separate collection that meets the requirement of thermal treatment. Waste types estimated under this action are paper and plastic product waste, and paper, plastic, glass and metal packaging waste

(5) Final treatment

Four scenarios were proposed to evaluate the suitability of waste final treatment for DGC2025. The scenarios are:

i Business as usual (BaU)

All waste generated is sent directly to final landfill site without any pre-treatment process. This is the current scenario for waste handling in the study area.

ii Low level of enforcement (2025CM1)

Waste management with 3R actions are introduced and carried out. Both public participation and efficiency of carrying out actions are set at low level. In this scenario for MSW, except for thermal treatment, participation and efficiency are set at 50% level. In the thermal treatment action participation and efficiency are set at 90% and 50% respectively. At low level waste management scenario only Reduce and Reuse actions (2R) rated 3 will be calculated.

iii Moderate level of enforcement (2025CM2)

Waste management with 3R actions are introduced and carried out. Both public participation and efficiency of carrying out actions are set at moderate level. In this scenario for MSW, except for thermal treatment, participation and efficiency are set at 75%. In the thermal treatment action participation and efficiency are set at 90% and 75% respectively. At moderate level waste management scenario only 2R actions rated 3 and 1 will be calculated.

iv High level of enforcement (2025CM3)

Waste management with 3R actions are introduced and carried out. Both public participation and efficiency of carrying out actions are set at high level. In this scenario for MSW, for all actions, participation and efficiency are set at 100% and 90%, respectively. At high level waste management scenario all 2R actions will be calculated.

5.4.2 Greenhouse gases

GHG amount for 2025BaU and 2025CM are calculated as inventory listed in section 3.4.2 of this dissertation. The former are calculated for all generated waste being sent to final landfill site and the latter are calculated for waste treated at MRF and TT. Due to data limitation, GHG from waste collection and transportation could not be estimated for Smart 3R Cyberjaya.

5.4.3 Result

Table 30 summarized the parameter setting for Smart 3R Cyberjaya. The main results from the calculations are featured in this section.

Table 30 Parameter setting for Smart 3R Cyberjaya – Household Solid Waste (%)

		Disposer	Separate Collection	Thermal Treatment
CM1	Participation	50	50	90
	Segregation efficiency	90	50	50
CM2	Participation	75	75	90
	Segregation efficiency	90	75	75
CM3	Participation	100	100	100
	Segregation efficiency	90	90	90

(1) Waste amount

In 2025, total population in Cyberjaya will be X times 2005. Accordingly, waste will be generated as much as 170t/d, 7 times of 2010. From the three CM scenarios, the most waste reduction is achievable from 2025CM3 of high level enforcement of alternative waste handling method. Waste reduction from each CM scenarios is 44% (75 t/d), 65% (110 t/d) and 79% (135 t/d), respectively. Waste reduction from each elements of CM3 is 10, 61, 58 and 6 t/d from waste prevention, self-treatment, source segregation and thermal treatment, respectively. The estimation result from all there scenarios is shown in **Table 31**.

Table 31 Waste amount based on CM scenario (t/d)

	BaU	CM1	CM2	CM3
Landfill	170.40	95.34	60.02	35.25
2R		3.20	7.19	10.35
Disposer		30.44	45.66	60.88
Separate collection		17.78	37.77	57.61
Thermal treatment		23.64	19.75	6.30
Total	170.40	170.40	170.40	170.40

(2) GHG amount

In 2025BaU, GHG emitted from landfilling of total generated waste is 1638 tCO_2/d. Compared to 2025BaU, the greatest reduction is from 2025CM3 of 1446 tCO_2/d or equivalent to 88%. Reduction from 2025CM1 and 2025CM2 is 914 tCO_2/d (56%) and 1182tCO_2/d (72%), respectively. GHG emitted from waste treatment by scenario is 109, 70 and 41 tCO_2/d. **Table 32** shows the GHG estimation result of all scenarios.

Table 32 GHG amount based on treatment selection (tCO_2/d)

	BaU	CM1	CM2	CM3
Landfill	1638.28	832.41	526.99	232.00
Treatment		108.51	69.72	40.53

5.5 Conclusion of Cyberjaya Digital Green City 2025

Cyberjaya is developed to be the core of Malaysia Multimedia Super Corridor, to be the centre for ICT related companies. Cyberjaya DGC2025 was launched following the study of PGC2025. Smart 3R Cyberjaya is one of DGC2025 four themes with the target of building a zero emission society. Follows are main finding of Smart 3R Cyberjaya which focus on SWM:

i Two targets set for Smart 3R Cyberjaya are 75% reduction of waste sent to landfill site and 50% reduction of total GHG emission compare to 2025 BaU scenario.

ii From three CMs, the most waste to landfill and GHG emission reduction achievable in 2025CM3, 78% (172 t/d) and 84% (1459 t-CO_2/d)

iii Even though our target of 75% reduction waste amount sent to final landfill compare to 2025BaU is only achievable at 2025CM3, waste reduction from other scenarios are also significant

iv Target of 50% GHG reduction is achievable at all CM selection

5.6 Reference for Chapter 5

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6 THE CASE STUDY OF ISKANDAR MALAYSIA

6.1 Introduction of Iskandar Malaysia

6.1.1 Overview

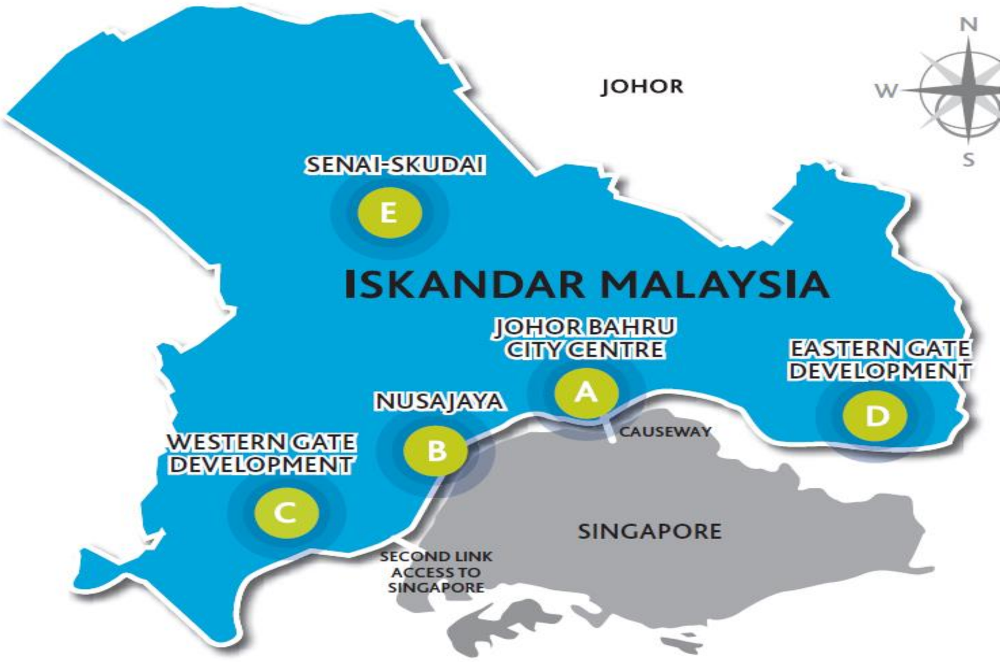


Figure 13 Five flagship of Iskandar Malaysia

IM is a newly develop economic region within Malaysia most southern state, Johor. IM was established on July 2006, under Ninth Malaysia Plan, to develop a zone that would be economically, socially and developmentally beneficial to the country. The development region encompasses an area of 2,217 square kilometres covering the city of Johor Bahru and the adjoining towns of Pontian, Senai, Pasir Gudang and the construction of a new administrative capital in Nusajaya. Johor Bahru District is included in its entirety, as are parts of the district of Pontian. Five local planning authorities have jurisdiction over the covered area, including Johor Bahru City Council, Johor Bahru Tengah Municipal Council, Pasir Gudang Municipal Council, Kulai Municipal Council, and Pontian District Council. Under the plan, five "Flagship Zones" are identified as developmental focal points which allocated under the management of Iskandar Regional Development Authority. The five flagships roles are as in **Table 33** below.

Table 33 Roles of Iskandar Malaysia's flagships

Flagship	Role
A - Johor Bahru	Service and business district
	Free Access Zone
B - Nusajaya	Johor State Administrative Centre
	New financial and business district
	MSC Cyber city and Nusajaya Cyber park
	Education hub
C - Western Gate Development	Port of Tanjung Pelepas (PTP)
	RAMSAR sites
	2nd Link Free Access Zone
D - Eastern Gate Development	Pasir Gudang Port and industrial zone
	Tanjung Langsat Technopolis
	Kim-Kim Regional Park
E - Senai - Skudai	Senai International Airport
	Integrated logistic hub
	Skudai knowledge centre
	Senai Multimodal Terminal Hub

Johor Bharu urbanization rate is 69.1% which is higher than the average national urbanization rate of 65.4% (National Physical Plan, 2005). This urbanization rate can be related to the economic development of IM as the area of concentration for investment and employment. This is reflected by IM covering 60% of Johor state's total GDP and 70% of Johor's manufacturing establishments are located. The development of IM is crucial due to the imbalanced in the current development practiced with focus is in main urban centres and along major roads and highways. Developments are also focused in areas with major industrial activities and these are mainly in the Flagship D areas. One of the key issues in the development of IM is balancing growth and in development with the protection of nature and the environment. The encroachment into such areas needs to be controlled and managed in a more sustainable manner. Development must capitalize upon the existing infrastructure available within IM, for example the second link highways and infrastructure available within is corridor. Prioritization of development must also be undertaken and the opening of new frontiers must be limited to Urbanization Promotion Areas to protect agriculture land that is categorized as Urbanization Control Areas.

To work out the development plan, IRDA came up with CDP for South Johor Economic Region. The CDP is a development roadmap for the next 20 years that is aimed at guiding decision makers, city planners, designers and builders in making decisions consistent with the overall plan. The CDP provides a strategic framework of visions, principles, development strategies, goals and key directions for a region that is liveable for its people, in which they can carry out daily activities with pleasure, pride and harmony.

The CDP will be guided by physical development strategies to ensure outcomes that reflect the vision and core principles outlined. These Physical Development Strategies (PDS) will be based on the potential of the area as well as the challenges faced by SJER in becoming a world class sustainable conurbation. These strategies will ensure that the required flexibility, to cater to the growing needs of the community, is not neglected. There are ten key PDS identified:

1. Ensure a balanced development within the SJER by reaffirming distribution and enhancing efficiency through focused development in certain corridors and nodes
2. Protect and conserve natural, historic and open space resources to improve the quality of life
3. Focus development in areas where existing and adequate infrastructure exists, build further enabling infrastructure
4. Promote in-fill and redevelopment in existing communities, including brownfield sites
5. Enhance accessibility by improving Regional and East-West linkages as well as provide alternative modes of public transportation
6. Promote key economic initiatives that will become focal points for growth within the region
7. Plan and develop SJER as one integrated global node consisting of Johor, Singapore and Indonesia
8. Manage Regional Growth Especially in the Periphery Areas of SJER
9. Plan for innovative and sustainable infrastructure and utilities
10. Promote Planned Communities that will produce quality neighbourhoods

In line with the desired vision, The Physical Plan of the CDP will adopt an optimum land use development-planning concept that will translate the ten development strategies from PDS 1 to PDS 10. These strategies promote sustainability and economic growth that will balance between environmental conservation and protection as well as meeting the needs and demand for social development.

6.1.2 Solid waste management in Iskandar Malaysia

In line with the CDP, IRDA came out with a comprehensive Integrated Solid Waste Management Blueprint for IM (IM-BP). The blueprint is part of an exercise to enhance the CDP and aims to provide a strategic framework for integrated SWM in IM. IM-BP is instrumental in establishing an advanced, environmentally sound, practical, long term sustainable SWM system for much of southern Johor. It covers the whole action and implementation plan for an integrated SWM in IM that will take place between 2010 and 2025. The whole process is divided into three terms – Short term (2010 – 2014); Medium term (2015 – 2019); and Long term (2020 – 2025). Towards fulfilment of the plans, current situation of waste in IM is also discussed in the IM-BP. **Table 34** Summarized the current waste flow and future proposal for waste handling in IM towards 2025.

Table 34 Current waste flow and proposal for waste disposal until 2015 for five Las in IM

Local authority	Waste amount (t/d)	Current landfill	Lifespan left	Proposal until 2015
Pontian	160	Pekan Nenas Landfill	0	Extended for 5 years (2008-2013), after that waste to be diverted to Seelong Landfill
Johor Bahru	621	Seelong Landfill	10 (2018)	Same landfill will be used. Part of waste from JB Tengah LA will be sent to Pekan Nenas landfill and Tanjung Langsat Landfill when scheme regulation is enforced
Kulai	155			
JB Tengah	362			
Pasir Gudang	300	Tanjung Langsat Landfill	8 (2016)	Same Landfill will be used. Currently using second cell untill 2011, third cell under planning until 2016 (5 years for each cell)

6.2 Background of Iskandar Malaysia 2025 study

From April 2010, research group from three institutions from Japan collaborating with UTM, Malaysia started a join study called “Development of Low Carbon Society Scenarios for Asian Regions” that aims at realizing a LCS in IM. This project design policy roadmaps to achieve a low-carbon city based on integrated scenario approach methods. Our main “Stakeholder” is Iskandar Regional Development Authority (IRDA) which is the main authority of IM.

In developing the area, IRDA came out with eight actions namely – walkable, liveable. Green

Table 35 Dozen actions for Iskandar Malaysia 2025

Green Economy	
Action 1	Integrated Green Transportation
Action 2	Green Industry
Action 3	Low Carbon Urban Governance
Action 4	Green Building and Construction
Action 5	Green Energy System and Renewable Energy
Green Community	
Action 6	Low Carbon Lifestyle
Action 7	Community Engagement and Consensus Building
Green Environment	
Action 8	Walkable, Safe and Livable City Design
Action 9	Smart Urban Growth
Action 10	Green and Blue Infrastructure and Rural Resources
Action 11	Sustainable Waste Management
Action 12	Clean Air Environment

city; low carbon lifestyle; a green economy; integrated transportation; energy-efficient buildings; land use planning; and securing funding. This project is to fill in the gaps in the existing IRDA actions. The twelve actions are - Integrated Green Transportation; Green Industry; Low Carbon Urban Governance; Green Building and Construction; Green Energy System and Renewable Energy; Low Carbon Lifestyle; Community Engagement and Consensus Building; Walkable, Safe and Liveable City Design; Smart Urban Growth; Green and Blue Infrastructure and Rural Resources; Sustainable Waste Management; Clean Air Environment (**Table 35**).

Table 36 Socio-economic assumption

	2005	2025	2025/2005
Population	1,353,000	3,000,000	2.2
Household	303,000	706,000	2.3
GDP (Billion RM)	35.7	141.4	4.0
Gross output (Billion RM)	121.4	438.9	3.6
Primary industry	1.5	2.4	1.6
Secondary industry	86.2	274	3.2
Tertiary industry	33.7	162.5	4.8
Passenger transport demand (Million passenger-km)	9,565	59,524	6.2
Freight transport demand (Million ton-km)	8,269	26,054	3.2

Table 37 Energy demand

	Unit	2005	2025BaU	2025CM	2025BaU /2005	2025CM/ 2005
Final energy demand	Mtoe	2.5	7.6	5.2	3.11	2.14
GHG emission	$MtCO_2eq$	11.4	31.5	18.9	2.64	1.66
Per capita CO_2 emission	tCO_2eq	8.4	10.4	6.3	1.24	0.75
GHG intensity	$kgCO_2eq/RM$	0.32	0.22	0.13	0.69	0.42

6.2.1 Future socio-economic scenario assumption

The CDP projected an economic growth of 8.0% per annual and population growth of 4.1% per annual for the 2005-2025 periods with significant investments in the infrastructure, industry and housing sectors. By using model simulation, a scenario of the future image of society and development of IM in 2025 as LCS is forecast based on socio-economic and technological potential variables. **Table 36** shows the projected main socioeconomic scenarios variables and **Table 37** shows the energy demand, GHG emission and intensity in year 2005 and 2025.

6.3 Iskandar Malaysia 2025 – Sustainable Waste Management

6.3.1 Quantification flow

Two targets for Sustainable Waste Management are:

(1) To reduce the volume of waste sent to landfills to half of total generated waste by the target year of 2025

(2) To reduce total volume of GHGs to half of that emitted using conventional methods with the application of CM methods by the target year of 2025

Figure 14 shows the estimation flow towards achieving the two targets.

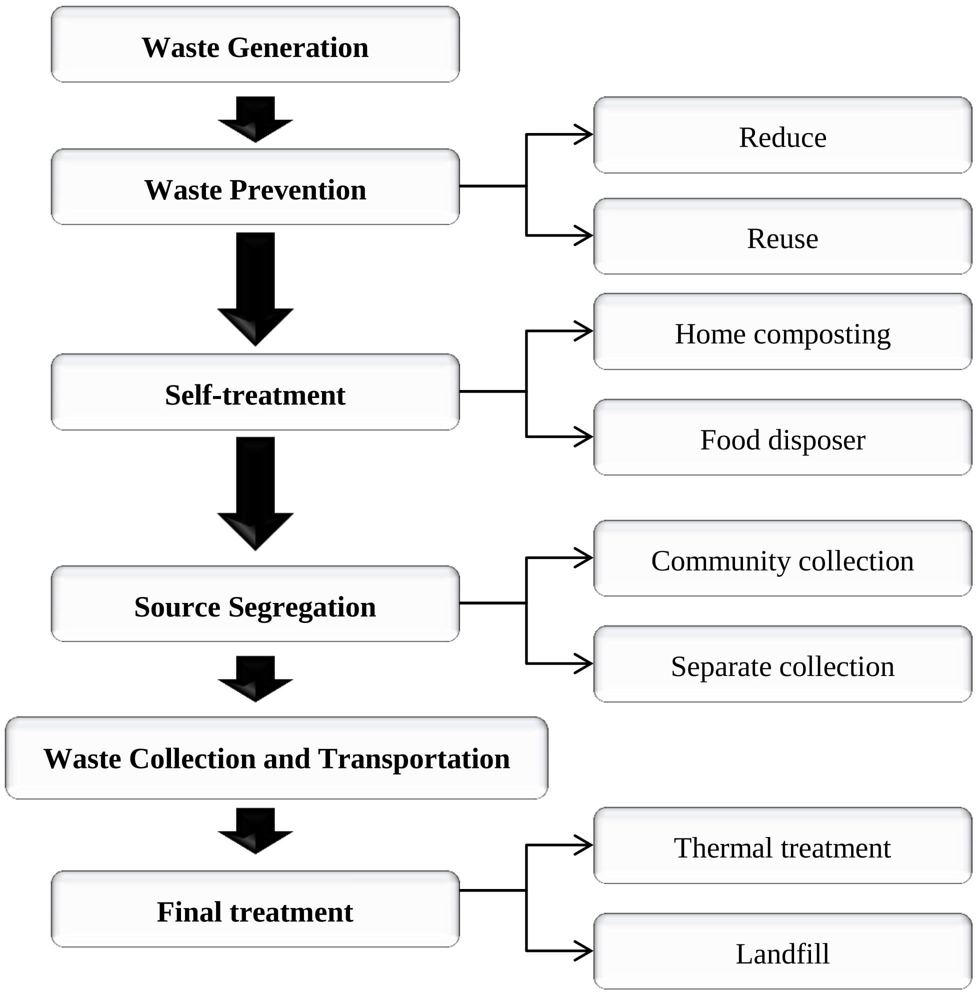


Figure 14 Estimation flow for Sustainable Waste Management

6.3.2 Solid waste management action

Under Action 12 of Sustainable Waste Management, five actions representing five categories of waste – municipal solid waste, agricultural waste, industrial waste, waste water, and construction and demolition waste. **Table 38** lists all this sub-actions and its measure. With regards to the methodology used for this dissertation, only HSW will be discussed in detail.

Table 38 Sub-actions and measures of Iskandar Malaysia Solid Waste Management actions

Sub-actions	Measures
Sustainable Municipal Solid Waste Management	Reduction at source
	Recycling of municipal solid waste
	Extended final disposal
	Effective waste transportation
Sustainable Agricultural Waste Management	Biomass to wealth
Sustainable Industrial Waste Management	Scheduled waste reduction and treatment
	Non-scheduled waste reduction, reuse and treatment
Sustainable Waste Water Management	Better waste treatment and sludge recycling
Sustainable Construction and Demolition Waste Management	Effective construction waste treatment

6.4 Quantification of scenario

6.4.1 Waste

(1) Waste generation

The population projections until the year 2025 were obtained from the Integrated Landuse Blueprint for IM by AJM Consultants for the LA areas of Majlis Bandaraya Johor Bahru (MBJB), Majlis Perbandaran Johor Bahru Tengah (MPJBT), Majlis Perbandaran Kulai (MPKu) and Majlis Perbandaran Pasir Gudang (MPPG). **Table 39** details the existing population and projections from 2010 until the year 2025.

Waste generation projection for IM2025 utilizes the population projections in **Table 39** and the waste generation rates from World Bank Generation Data and The Study of Waste

Minimization. In order to project the waste generated until 2025, the waste growth rates used were derived by averaging out the difference between 1.4kg/cap/d in 2025 and 0.81kg/cap/d in 1999 over a period of 26 years. The generation rates utilized to project the amount of solid waste generated in the IM region from 2008 to 2025 are detailed in **Table 40**. Projection result of household solid waste for IM from 2010 to 2025 is as **Table 41**.

Table 39 IM Population projection (2010-2025)

Local Authority	2010	2015	2020	2025
MPJBT	815,600	952,052	1,104,843	1,493,400
MBJB	156,900	173,518	192,545	260,200
MPPG	514,312	697,443	958,148	952,406
MPKu	211,900	240,916	252,130	340,800
MDP	33,078	35,269	37,412	40,085
TOTAL	1,731,790	2,099,198	2,545,078	3,086,891

Table 40 IM Household solid waste generation rates for 1999 - 2025 (kg/cap/d)

Year	1999	2010	2015	2020	2025
Generation rate	0.81	1.06	1.17	1.29	1.4

Table 41 IM Household solid waste generation projection (2010-2025) (t/y)

Local Authority	2010	2015	2020	2025
MPJBT	315,556	406,574	520,215	763,128
MBJB	198,987	297,843	451,144	486,680
MPPG	81,984	102,883	118,715	174,149
MPKu	60,705	74,101	90,660	132,962
MDP	12,796	15,062	17,615	20,484
TOTAL	670,028	896,463	1,198,349	1,577,403

(2) Waste prevention

Priority rating of 2R actions in IM is carried out through few series of FGC with IRDA representative from various sectors and divisions such as Integrated Planning, Economic Intelligence, Marketing and Investment, and Social Department. The rating result is shown in **Table 42** and **Table 43**.

Table 42 Reduce actions

	Food and beverages	Clothing and footwear	Non-durable household goods	Printed materials	Leisure items	Personal grooming
Buy according to need	2	3	3	3	2	3
Buy in bulk	2	2	2	1	2	2
Buy refills and concentrates	3	0	3	0	0	2
Buy local products	3	2	3	3	3	3
Do not buy over-packaged products	3	2	3	3	3	3
Don’t take plastic bags unless needed	3	3	3	3	3	3
Rent or borrow instead of buying	0	1	1	2	1	1
Use online service (bill statement,)	0	0	0	3	0	0
Pack meal from leftover	3	0	0	0	0	0
Share	0	0	0	3	3	0

Table 43 Reuse actions

	Food and beverages	Clothing and footwear	Non-durable household goods	Printed materials	Leisure items	Personal grooming
Choose durable items	0	2	0	0	2	0
Buy products made from recycled materials	0	2	2	2	2	2
Repair broken items	0	2	0	0	2	0
Use reusable items	0	0	0	0	2	1
Use own bag for shopping	3	3	3	3	3	3

(3) Self-treatment

IRDA Integrated Solid Waste Management Blueprint (IM-BP) stated that currently, there is very little incentive to pursue organic treatment or energy recovery from organic waste. One of the reasons is due to its difficulty to recycle and the sale of product –compost and fuel, is currently left to market forces. However, with almost half of waste generated in IM area is food waste, IRDA is willing to provide an incentive to local composting initiatives by buying their products to be used in the development of IM public parks, other green belts and even highway and road divider. Two selection of self-treatment projected in IM study are composting and instalment of food disposer.

(4) Source segregation

i Community collection

Community collection in the concept of IM2025 represents collection of recyclable material with high market value. Waste concessioner of IM – Southern Waste Management, unlike Alam Flora in Putrajaya does not own any buy-back centres in IM. Community collection in IM is mostly conducted by residents committee through religious groups, non-government organizations and non-profit organizations.

ii Separate collection

Material Recovery Facilities (MRF) are to be sited at centres of high waste generation within IM five flagships to maximize the potential for waste to be recovered for recycling. IM-BP recommended separate collection of co-mingled, dry recyclables all packed together including paper, plastic bottles, metal cans, glass containers, and other materials. The collected materials will be sorted at the MRF for recycling or final treatment purpose.

(5) Final treatment

Building of Thermal Treatment plan t is already a confirmed matter in IM2025. Some of options considered include mass burn incineration using a grate-based furnace, refuse derived fuel (RDF) production followed by incineration either in a fluidized bed or grate-based furnace, and gasification or pyrolysis. Waste amount considered in this selection are total waste after “Waste prevention”, “Self-treatment”, and “Source segregation”.

6.4.2 Greenhouse gases

GHG amount for 2025BaU and 2025CM are calculated as inventory listed in section 3.X.X of this dissertation. The former are calculated for all generated waste being sent to final landfill site and the latter are calculated for waste treated at MRF and TT. Due to time limitation, GHG from waste collection and transportation were not carried out for IM2025.

6.4.3 Result

The main results from the calculations are featured in this section.

(1) Waste amount

IM total population in 2025 will increase 3 times 2005 from 1.3 million to 3 million people. Align with the population increase, HSW increases 5 times or equivalent to 4322(t/d). 42t/d is reduced from waste prevention which represent 1.4% of total waste reduction in 2025CM. Waste reduction from self-treatment is 543 and 623 t/d from composting and disposer, respectively. 527 and 1184 t/d of recyclable materials are recoverable from community collection and separate collection, equivalent to 40% of total waste reduction. Instalment of incinerator could reduce 132 t/d of generated waste from direct landfill. In total, 71% (3051 t/d) waste reduction from direct landfill is achievable in 2025CM scenario. The estimation result is summarized in **Table 44** and **Table 46**.

Table 44 Waste generation based on scenario (t/d)

	2005	2025BaU	2025CM
Food	**320.51**	**1,715.69**	**530.67**
Paper	**251.88**	**1,348.35**	**11.85**
Product	*32.24*	*172.59*	*0.17*
Packaging	*288.86*	*1,175.76*	*11.68*
Plastic	**65.39**	**350.05**	**1.15**
Product	*16.81*	*89.96*	*0.90*
Packaging	*48.59*	*260.09*	*0.26*
Glass	**28.26**	**151.26**	**1.61**
Product	*2.77*	*14.82*	*1.48*
Packaging	*25.49*	*136.43*	*0.14*
Metal	**17.76**	**95.08**	**74.48**
Product	*13.98*	*74.83*	*74.27*
Packaging	*3.78*	*20.25*	*0.20*
Other	**123.52**	**661.21**	**651.01**
Total	**807.32**	**4,321.65**	**1,270.77**

Table 46 Waste reduction based on action (t/d)

	Reduce	Reuse	Composting	Disposer	Community collection	Separate collection	Thermal Treatment
Food	**4.32**	**14.85**	**542.88**	**622.96**	**-**	**-**	**-**
Paper	**7.92**	**0.03**	**-**	**-**	**155.29**	**1,066.60**	**106.66**
Product	*0.02*	*0.03*	-	-	*155.29*	*15.53*	*1.55*
Packaging	*7.90*	-	-	-	-	*1,051.08*	*105.11*
Plastic	**3.71**	**0.21**	**-**	**-**	**230.92**	**103.70**	**10.37**
Product	*0.20*	*0.21*	-	-	-	*80.60*	*8.06*
Packaging	*3.51*	-	-	-	*230.92*	*23.09*	*2.31*
Glass	**0.55**	**0.02**	**-**	**-**	**122.31**	**12.23**	**14.53**
Product	*0.02*	*0.02*	-	-	-	-	*13.31*
Packaging	*0.54*	-	-	-	*122.31*	*12.23*	*1.22*
Metal	**0.32**	**0.28**	**-**	**-**	**18.18**	**1.82**	**-**
Product	*0.27*	*0.28*	-	-	-	-	-
Packaging	*0.05*	-	-	-	*18.18*	*1.82*	-
Other	**4.34**	**5.86**	**-**	**-**	**-**	**-**	**-**
Total	**21.17**	**21.25**	**542.88**	**622.96**	**526.70**	**1,184.35**	**131.56**

Table 45 GHG amount based on treatment selection

	2025	2025BaU	2025CM
Landfill	1439.81	7707.28	2864.28
Source separation			0
Self-treatment			87
MRF			5
Thermal treatment			28
Total	1439.81	7707.28	2985.01

(2) GHG amount

In 2005, total GHG emission from direct landfilling of generated waste is 1440 tCO_2/d. With the increase of generated waste in 2025BaU, GHG emission increased to 7707tCO_2/d, 5 times 2005 level. Under the CM scenario, 61% (4722 tCO_2/d) of reduction is achievable in 2025 which reduction from landfill alone is 4843 tCO_2/d. Reduction from waste prevention and self-treatment is 87t-CO_2/d but emission from recycling facility and incinerator is 5 and 28 tCO_2/d each. **Table 45** shows the GHG estimation result.

6.5 Field study

In order to implement the SWM methodology proposed in this dissertation, primary data on required parameter in the scenario building are very crucial. Three field studies were carried out to collect the data and discussed in this section.

6.5.1 Questionnaire survey

In June 2010, 1000 questionnaire were distributed to households in IM with the objective to understand waste generation pattern and public willingness (readiness) towards implementation of the new SWM system.

(1) Method

i Questionnaire survey

One thousands questionnaires, consisting of 47 questions, were randomly distributed over the 5 flagships of the IM area. They were distributed by hand to households of mixed race and varying income levels, picked by means of simple random sampling. The survey targeted 756 households, to obtain a 90% confidence level for an IM population of 900,000. The head of each household was asked to answer the questionnaire and return it by post within a one month. These 47 questions were divided into 4 categories: attribute, environmental awareness, waste generation, and participation. The attribute section inquired on demographic composition. The environmental awareness section was meant to elicit the respondent's awareness relating to three topics: living area waste handling situation, the 3R program, and the current waste situation in the country.

The waste generation section was the core of the questionnaire, containing 26 questions across 4 sub-sections. The first and second sub-sections consisted of 17 waste categories, as listed in **Table 47**, which were divided into weekly and monthly generated waste. The third sub-section had two questions related to household waste disposal. Respondents were to select an amount from ten levels of expected generated-waste amounts listed. The final sub-section concerned the possibility of introducing waste separation into the study area and comprised seven questions.

Final section of the questionnaire was made up of three questions, asking the respondent about their previous participation in environmental related movements. However, this paper focuses on the waste generation section’s first sub-section, as the main objective is to understand the relationship of waste generation and respondent socio-demographics.

ii Statistical data analysis

From the collected questionnaire survey results, two statistical data analyses are carried out to capture the data characteristic before modelling.

a. Measure of Variables Association

The first test studied the correlation between age, household size, and expenditure. The Pearson correlation test provided evidence of correlation between two random variables, suggesting a strong possibility for significance in the final model (George et al., 2001).

b. Analysis of Variance

The second test we carried out was an Analysis of Variance (ANOVA), to test for significant differences between means. The ANOVA was meant to verify the null hypothesis that age, household size and expenditure variables affect waste generation.

c. Modelling using Data Regression

Multiple linear regressions, using a stepwise method were applied for modelling. Multiple regressions were based on a correlation matrix of all the variables considered, which served in predicting a dependent variable from several independent variables (here age, household size and expenditure as the independent variables, and waste category as the dependent variable). Significance and validity were tested using t-statistics and F-statistics.

Table 47 Abbreviations for waste categories and components

Waste category	Component	Abbreviation
Food	Food waste, untouched food (excluded packaging)	Food
Paper	Book, magazine, newspaper	Paper
Other paper	Catalogue, pamphlet, calendar, card, envelope	Opaper
PET bottle	PET bottle (drinking water bottle, mineral water bottle)	PET
Other plastic and rubber	Wrapper, food container, pail, hose, tyre	Oplastic
Glass	Water bottle, dish, medicine bottle, cosmetic case	Glass
Metal	Food and drink container, spray bottle	Metal
Other metal	Cooking utensil, other metal	Ometal
Ceramic	Dish, vase	Ceramic
Other	Sports item, toys, unlisted wastes	Other
Textile	Shirt, blouse, suit, sweater, other clothing	Textile
Other textile	Bed linen, curtains, table cloth	Otextile
Garden waste	Dry leaves, branches	Garden
Furniture	Table, chair, cupboard	Furn
Floor covering	Carpet, rug	Floor
Electrical appliances	Television, radio, microwave	Electric
Other bulky waste	Unlisted bulky waste	Obulk

(2) Result and discussion

i Questionnaire survey

One thousand questionnaires were randomly distributed to households within the IM area by hand, and returned by post. The head of household was asked to answer the questionnaire. A total of 512 questionnaires were returned, giving a response rate of 51%. While our survey targeted 756 samples for 90% confidence level of a population of 900,000, the collection of 512 questionnaires gave us accuracy at 3.6% error level.

a. Attribute

The demographic distribution of collected questionnaires and the statistics of the Johor region show a similar pattern (DOS, 2000; 2004). Both the data show that the Malay were the most populous, followed by Chinese, Indians, and others. Race composition of our survey is 62% (Malay), 25% (Chinese), 11% (Indian), and 3% (Other), compared to the Johor state composition of 54% (Malay), 32% (Chinese), 7% (Indian), and 6% (Other). Survey results showed that respondents from the age groups 26 to 35 and 36 to 40 represented the majority of heads of household. Within the study area, most households consisted of three to six members. 16.4%, 27.3%, and 20.2% of the respondents spent between Ringgit (RM) 500 to RM1000, RM1001 to RM1500, and RM1501 to RM2000, respectively. Table 5 shows demographic distributions of the collected questionnaire.

b. Environmental awareness

This section consisted of 10 questions, and results showed that, at an average, 81% of the respondents were aware of the environmental situation both in their own surroundings and in general. However, the results from each sub-section show varying levels of awareness. From a total of 512 respondents, 73%, 86%, and 90% answered yes to questions regarding living area waste handling situation, 3R programs, and the current waste situation in the country, respectively. The results tells us that the residents were more aware of general issues regarding waste management compared to waste handling in their own surroundings.

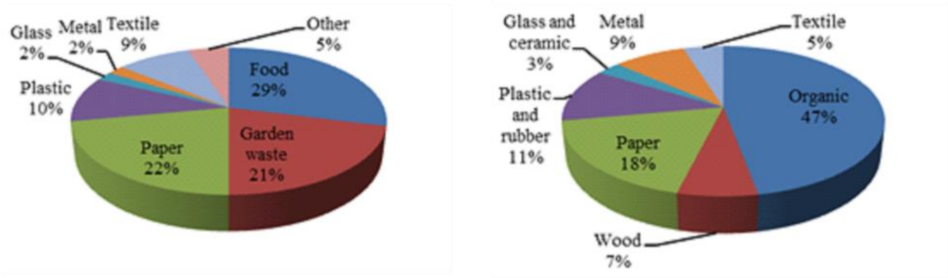
c. Participation

On average, 74% of respondents answered yes to this section, which can be interpreted as evidence of active participation of people in this study area in the campaign relating to waste management. However, compared to voluntary participation, a higher participations rate is shown for programs that involve acquiring incentives such as selling of used items.

In the fourth sub-section of the waste generation section, we asked respondents questions regarding the future possibility of introducing waste separation into the study area. Even though in average 68% answered yes to the seven questions, the pattern changed when the trends were further studied. Not only did the percentage of respondents willing to participate in waste separation drop from 78% to 62% in the questions relating to environmental concern compare to waste handling burden, the percentage of respondents unwilling to participate also rose from only 6% to 17%. This showed that respondents were willing to separate their waste owing to their concern for environmental problems, such as depleting natural resources. However, with regard to providing space and time to handle generated waste, the public in the study area appeared still unprepared. A study by Omran et al. (2009) also showed that most respondents did not participate in recycling activities stating inconveniences and the lack of time, compared to only 2.6% who indicated that they believed that recycling was a "waste of time."

d. Waste generation

While Error! Reference source not found.**(a)** shows results from returned questionnaires, Error! ference source not found.**(b)** shows results from the Study on National Strategic Plan on Waste Management (MHLG, 2005). While waste composition in Johor comprised 54% organic and wood waste, the questionnaire results showed a waste composition of 29% food waste and 21% garden waste, which are countable as organic waste. Paper and plastic waste also showed strong similarities, with 18% and 11% respectively in Johor, and 22% and 10% respectively from survey results. The Ministry of Housing and Local Government Landfill Inventory stated that in 2007 Johor state generated a daily waste of 2585 ton, with a waste generation rate of 1.12 kg per capita per day. While the National Strategic Plan (MHLG, 2005) stated that solid waste generated from residential urban areas was 0.4 kg per capita per day, results from the questionnaire survey showed a generation rate of 0.6 kg per capita per day. This is half of the Johor state waste generation rate, and 1.5 times of Johor residential urban waste generation rate.



(a) Results of questionnaire survey

(b) Study on National Strategic Plan on Waste Management (MHLG, 2005)

Figure 15 Waste compositions (%)

ii Statistical data analysis

a. Measure of variable association

Results of the Pearson correlation test showed that per capita waste generation is highly correlated with household size, with negative coefficients. 42% of the results were significant at 1% and 5% level, with the results of food and other textile waste significant at 10% level (**Table 48**). Results suggest that per capita waste generation decreases with an increase in household size. This result is consistent with other studies on relationships between household size and per capita waste generation rate. Thanh et al. (2010), Qu et al. (2009), and Ojida-Benitez et al. (2008), for instance, demonstrated an inverse influence of household size on per capita waste generation.

The age factor is also correlated with the generation of glass, metal, and other textile waste, at 5% level, and of textile waste at 1% level. The generation of this type of waste reduces with an increase in age of the head of household. This is probably related with the presence of durable items such as clothes and household textiles in these households.

Table 48 Pearson Correlation

	Age		Member		Expenditure	
	Correlation	Sig.	Correlation	Sig.	Correlation	Sig.
Food	–	–	–	–	–	–
Paper	–	–	−0.117**	0.009	–	–
Opaper	–	–	−0.106*	0.018	0.097*	0.03
PET	–	–	−0.106*	0.017	–	–
Oplastic	–	–	−0.122**	0.006	–	–
Glass	−0.114*	0.01	−0.144**	0.001	–	–
Metal	−0.110*	0.013	−0.163**	0	–	–
Ometal	–	–	−0.101*	0.023	–	–
Ceramic	–	–	−0.097*	0.029	–	–
Other	–	–	−0.142**	0.001	–	–
Textile	−0.135**	0.002	−0.100*	0.024	–	–
Otextile	−0.091*	0.042	−0.068	0.125	0.087*	0.051

Other paper and other textile are also correlated with the expenditure factor at a 5% level. Households with higher income levels, which have a bigger buying power, appear to have enough resources to spend on optional items such as household textiles. Thanh et al. (2010) and Qu et al. (2009) also studied the effect of waste generation incorporating an income factor, and found positive relationships.

b. Analysis of variance

Table 49 shows results of the ANOVA test using age, household size, and expenditure. "**" and "*" denote parameter estimate significance at 1% and 5% levels, respectively. Results of the one-way ANOVA show that age affects generation of food, other paper, and other plastic waste. The same test using household size and expenditure shows that waste generation is affected by all these factors, with the exception of other paper, metals, and other textile for household size, and food, paper and metal for expenditure. A two-way ANOVA test shows that a combination of age with household size or expenditure provides us unfavorable results. However, a combination of household size and expenditure shows significant results for all waste types, except ceramic. All waste types, except other and other textile are significant at the 1% level.

Table 49 Results of ANOVA test

	Age	Member	Expenditure	Age*Member	Age* Expenditure	Member* Expenditure
Food	2.931**	4.452**	–	–	–	2.018**
Paper	–	4.385**	–	–	–	1.825**
Opaper	1.986*	–	3.749**	–	–	2.089**
PET	–	3.555**	5.071**	1.897**	–	1.869**
Oplastic	4.114**	3.02**	4.721**	–	–	3.482**
Glass	–	3.167**	5.287**	1.994**	–	2.895**
Metal	–	–	–	–	–	2.331**
Ometal	–	–	2.32**	–	–	1.639**
Ceramic	–	–	2.885**	–	–	–
Other	–	–	2.914**	–	–	1.538*
Textile	–	2.822**	4.328**	–	–	2.79**
Otextile	–	–	3.562**	–	–	1.541*

Table 50 Household waste generation model

	Constant	Household Size	Expenditure	*F-test*
Food	0.215	-0.008	–	4.066
	(-9.369)	(-2.016)		(0.044)
Paper	0.094	-0.005	0.002	7.193
	(-9.831)	(-2.682)	(1.641)	(0.008)
Opaper	0.072	0.004	-0.005	5.881
	(-7.041)	(-2.485)	(-2.621)	(0.003)
PET	0.037	-0.002	0.001	6.032
	(-9.557)	(-2.456)	(1.650)	(0.014)
Oplastic	0.045	-0.003	–	7.847
	(-8.553)	(-2.801)		(0.005)
Glass	0.015	-0.001	–	10.351
	(-8.116)	(-3.217)		(0.001)
Metal	0.019	-0.002	–	13.906
	(-8.119)	(-3.729)		(0.000)
Ometal	0.008	-0.005	–	5.631
	(-7.031)	(-2.373)		(0.018)
Ceramic	0.008	-0.002	–	5.300
	(-7.582)	(-2.302)		(0.022)
Other	0.046	-0.003	–	10.537
	(-9.728)	(-3.246)		(0.001)
Textile	0.008	0.094	-0.109	4.708
	(-6.181)	(-2.108)	(-2.447)	(0.009)
Otextile	0.007	0.096	-0.078	3.454
	(-5.104)	(-2.145)	(-1.745)	(0.032)

c. Data regression

Based on statistical tests and ANOVA results, a waste model was then developed. The results of the linear regression model using a stepwise method are shown in **Table 50**. Model significance and validity were tested using t-statistics and F-statistics. Figures in parentheses depict t-ratios for the estimated coefficients. All waste types correspond with household size, except for paper, other paper, PET, textile and other textile, which show better correspondence when expenditure is included as an additional factor in the model. F-values are acceptably high with all being significant at 1% and 10% levels; this confirming good model performance.

The results of the modelling show that household size has inverse impacts on waste generation. Per capita waste generation by larger households is smaller than by smaller households. Expenditure level is seen to affect paper and PET waste generation positively, with reverse effects for other paper, textile, and other textile waste generation.

iii Discussion

Even though the IM administration has not come out with future plans and targets for SWM, the national target for 2020 has already been spelt out in the National Strategic Plan for Solid Waste Management (MHLG, 2005) to achieve 100% source separation and 17% reduction and recovery. The Study on National Waste Minimisation projected that Johor would generate 3037 tonnes of household waste in 2020 or 0.96 kg/cap/d (MHLG, 2006). After a 17% reduction, the total waste sent to Seelong landfill would be 2521 tonnes per day. From our study, an average of 70% respondents states that they would be willing to participate in source separation and waste reduction, giving a figure of 0.24 kg of waste reduction per capita per day. This can be achieved by adopting waste solution alternatives currently in use in other countries, such as the well-known method of recycling.

With a large proportion of organic waste generated in IM, recycling by means of composting emerges as a practical option. Composting not only reduces amount of landfill waste but also provides products that can be used as new resources. In fact, composting at a small scale can be carried out even by households themselves. In Japan, in cities such as Kyoto (Kyoto cityhall, 2006), Fujieda city in Shizuoka prefecture (Fujieda cityhall, 2009), and Kamakura city in Kanagawa prefecture (Kamakura cityhall, 2011), purchasing composting machines by households attracts subsidies from the city hall. Such incentives can encourage the public to take part in these activities.

Second, the main proportion of IM waste, at around 18%, is paper. Even though Europe and United States recycle 64% and 53% of their paper waste, respectively, the trend is yet to emerge in Malaysia (Abu Qdais et al., 1997; PIAC, 2006). Not only does paper recycling help save natural resources, using 1 ton of recycled paper also helps save 2.5m3 of landfill space. Therefore, recycling 17% of IM's paper waste can save 120m3 of landfill space daily. Even though plastic waste constitutes another large proportion of total waste generated, plastic recycling activities lag far behind. IM should take serious interest in plastic recycling, especially recycling of PET, which constitutes 47 % of total plastic waste.

Malaysia is relatively less densely populated compared to other countries that lead in recycling and SWM. Malaysia is placed 96 among 192 countries, which is low compared to Netherlands, Japan, Germany, and even its neighbor Singapore (placed at 14, 17, 33, and 2 respectively). This means that space for landfill will not pose as a constraint in IM, or in Malaysia in general. Nevertheless, waste generation within IM is proposed to sharply increase owing to rapid development. Sole dependency on Seelong landfill will no longer be practical. Alternative solutions for IM's SWM are essential, and proposing an integrated SWM, with well-documented data, is very important.

(3) Conclusion

This study aimed to identify and grasp current HSW amounts and composition, as such data, although important for future SWM planning, are deficient in Malaysia.

i One thousand questionnaires were distributed by hand among the residents of IM, a new economic region within Malaysia's most southern state, Johor, and 51% were returned by post

ii Solid waste mainly constitutes food waste and paper waste, at 29% and 22% respectively

iii Statistical data analyses showed household size to be the most influential factor in per capita waste generation

iv In the waste generation model, household size and expenditure level were seen to influence waste generation

Analysis of waste generation based on a questionnaire study provides only aggregate or intermediate results. A more detailed micro-level study on household expenditure and consumption should be carried out to support these results.

6.5.2 Landfill survey

Currently 70 percent of collected MSW in IM are transported to Seelong Landfill, the biggest landfill site in IM run by Southern Waste Management. It is relevance to carry out details characterization of composition and characteristic of waste transported to this landfill site.

(1) Materials and method

Manual segregation of 100 kg of HSW was carried out at the Seelong Waste Treatment Facility in June 2012. Using the "coning and quartering" method, 1000 kg of waste were taken randomly from the transfer station dumpsite. The selected waste was transported by collection truck from residential areas within 24 hours prior to our study. After the selection, waste was transferred to a pre-cleaned flat surface for the manual segregation and physical analyses. Based on its identifiable characteristics, the waste was sorted into 27 groups according to waste and expenditure categories (**Table 52**). Samples from each group were brought back to the laboratory to perform proximate analysis, and elemental composition and calorific value analyses.

i Waste composition and characteristic

In the laboratory analyses, we first dried the samples at 100°C for 3 days to determine its moisture contents (**equation 18**). When the weight of the samples had reached a constant value after drying, measurement of the combustible content was carried out by burning them at 800°C for 2 hours (**equation 19**) using a Muffle Furnace FO3000. The higher calorific value of the samples was determined using a bomb calorimeter, and the lower calorific value was calculated using **equation 20**. The equations are as follows:

$$\text{Moisture content} \equiv \text{amount of evaporated waste} / \text{amount of wet based waste} \times 100 \qquad (18)$$

$$\text{Combustible content} \equiv \text{burn away solid particle} / \text{amount of wet based} \times 100 \qquad (19)$$

$$\text{Ash content} \equiv \text{remaining solid particle after burning/wet based waste} \times 100 \qquad (20)$$

Based on the test results, we assessed the suitability of the generated waste for other treatment options based on the following list of waste conditions that are suitable for each treatment type:

a. Direct landfill

Two conditions for landfilling are shown in **equations 21** and **22**. The former is that excessive water contents could disrupt the landfilling condition and the latter is that small amounts of organic matter are desired for early landfill stability.

$$W<85 \tag{21}$$

$$B/(100-W)<0.1 \tag{22}$$

b. Composting

In order for microbes to work in compost generation, sufficient oxygen is required and this is achievable with water contents between 50% and 70% (**equation 23**). **Equation 24** is the balance of combustible and water contents required for the aerobic reaction to occur.

$$50<W<70 \tag{23}$$

$$40B\times0.5>6W \tag{24}$$

c. Refused-derived fuel (RDF) generation

RDF is the name given to the combustible waste fraction recovered from MSW. The composition of the recovered combustible fraction has higher concentrations of combustible materials such as paper and plastic than those present in the collected MSW, and thus, the recovered fuel fraction is of a higher fuel quality than the collected MSW (NETL, 2012). The standard requirements are shown in equations 25 and 26, and specify that the water content must be less than 20% so that no drying is required and the total calorific value should be more than 3000 kcal/kg.

$$W<20 \tag{25}$$

$$50B>3000 \tag{26}$$

d. Gasification with melting

Gasification with melting involves the pyrolysis of waste and generation of combustible gas and incombustible materials. High-temperature combustion then melts the ash contained in the waste. Thus, combustion and melting takes place using the energy from the waste itself (Kobelco, 2012). In order to achieve a self-sustaining combustion and melting process, the lower calorific value of the treated waste material should be more than 1700 kcal/kg, as shown in equation 27.

$$H_L=50\times B-6\times W>1700 \tag{27}$$

e. Incineration

Waste incineration is the thermal conversion of waste with a surplus of air to generate heat and potentially power (Thomas, 2011). Two conditions for incineration are considered here. Equation 28 concerns a type of treatment that is self-sustaining and does not require an auxiliary fuel if the lower calorific value is more than 800kcal/kg. For waste with a lower calorific value exceeding 1500 kcal/kg, thermal treatment with power generation can be used (equation 29).

$$H_L = 50 \times B - 6 \times W > 800 \tag{28}$$

$$H_L = 50 \times B - 6 \times W > 1500 \tag{29}$$

where W is the water content, B is the combustible content, and HL is lower calorific value.

We used Tanner's diagram (**Figure 15**) to show the suitability of generated waste for alternative treatment. Trapezoid BDEC and OLMN represent the waste suitability for landfilling and composting, respectively. Triangle BFG and BHI represents the suitability for incineration without power generation (HL≺800kcal/kg) and incineration with power generation (HL≻1500kcal/kg). Triangle BJK and trapezoid BPQR indicates suitability for gasification with melting, and RDF.

The summary of waste treatment option is as **Table 51**.

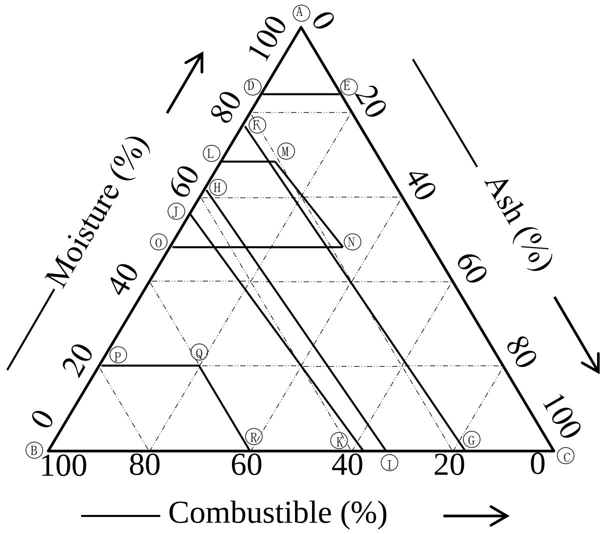


Figure 15 Tanner's diagram of waste suitability for treatment selections

Table 51 Waste treatment option

Treatment	Condition	Remark
Direct landfill	$W < 85$	Too high water contents could interfere landfill operation
	$B/(100 - W) < 0.1$	Small amount of organic matter is desirable for early stability
Composting	$50 < W < 70$	Activation of microbe, enough amount of oxygen
	$40B \times 0.5 > 6W$	Evaporation of water via energy from aerobic reaction
Refuse-derived fuel	$W < 20$	No necessity of drying
generation	$50B > 3000$	Total energy more than 3000
Gasification and melting	$H_L = 50B - 6W > 1700$	Self-sustain combustion and melting
Thermal treatment	$H_L = 50B - 6W > 800$	Self-sustain combustion and no
Thermal treatment with power generation	$H_L = 50B - 6W > 1500$	need of supplement fuel

ii CM scenarios

Furthermore, three waste treatment scenarios for IM in 2025 were also projected: separation of biodegradable materials including food and garden waste (Scenario 1), separation of recyclable material including paper, plastic, glass, metal and textile (Scenario 2), and combination separation of both biodegradable and recyclable material (Scenario 3). Public participation rate and segregation efficiency were set from 50% up to 100%. In this study, public participation is the ratio of the public taking part in the introduced scenario, and segregation efficiency is the rate at which waste is segregated appropriately for each of the introduced scenario.

(2) Result and discussion

i Waste composition and characteristic

Table 52 shows the results of physical composition analysis. The total waste composition on a wet basis was food (47.29 kg, 41.06%), plastic (25.60 kg, 22.23%), paper (24.10 kg, 20.93%), textiles (8.92 kg, 7.74%), glass (4.10 kg, 3.56%), garden waste (2.82 kg, 2.45%), metal (2.26 kg, 1.96%), ceramic (0.08%), and rubber (0.01%). In terms of physical composition, both our result and Malaysia's national waste generation shows that food, paper, and plastic are the main components of generated waste, even though a larger proportion of plastic than paper was found in our study (. From the total 100 kg of waste sampled at the site, product and packaging materials accounted for 19.8% and 28.9%, respectively. Removing food waste, garden waste, and single-use items, 34.6% of the total waste is appropriate for materials recycling. Additionally, 11.4% of the waste could be reduced directly, as the proportions of pamphlets and shopping bags were 4.1% and 7.3%, respectively.

Table 52 Result of waste characterization based on physical composition

Waste type		Composition (%)		Waste type		Composition (%)	
Food	Leftover	18.61		Glass	Product	0.03	
	Food preparing	22.42			Packaging	3.53	3.56
	Untouched food	0.03	41.06	Metal	Product	1.85	
Paper	Product	4.91			Packaging	0.11	1.96
	Single-use item	7.11		Textile	Product	7.74	
	Pamphlet	4.09			Packaging	0.00	7.74
	Packaging	4.63		Rubber	Product	0.01	
	Shopping bag	0.17			Packaging	0.00	0.01
	Waste bag	0.00	20.93	Leather	Product	0.00	
Plastic	Product	1.52			Packaging	0.00	0.00
	Single-use item	0.27		Ceramic	Product	0.07	
	Packaging	10.19			Packaging	0.00	0.07
	Shopping bag	7.12		Garden Waste		2.45	2.45
	Waste bag	3.13	22.23				
				Total		100.00	100.00

Table 53 Result of waste characteristic analysis

Proximate analysis	Weight (%)
Moisture	56.9
Combustible	34.9
Ash	8.2
Elemental analysis	
Carbon	45.08
Hydrogen	6.44
Nitrogen	1.12
Others	47.36
Calorific value (kcal/kg)	
Measured	1591
Calculated using three component value	1236

Proximate analysis and calorific values are shown in **Table 53**. The moisture content, combustible content, and measured calorific values were 57%, 35%, and 1591 kcal/kg, respectively. This shows that the generated waste is very wet. The same situation was also found by other researcher at other locations in Malaysia (Sivapalan, 2003a; Agamuthu, 2011). Besides the fact that current waste handling in households involves dumping the waste into uncovered waste bins, which exposes the waste to rainfall (IM receives average rainfall of 250 mm annually), dumping mixed waste without removing water will also contribute to the high water content. In terms of calorific value, we could not find any reference or previous study on HSW in the IM area. However, we compared our results with a study of Japan waste characteristics and found similarities with the waste generated in 1975 in Osaka and in 1976 in Kyoto (Osaka, 2012, Kyoto 2012). This means that there is a 36-year gap in the waste trends of IM and Japan. This finding could be used to predict future generation characteristics of IM waste, assuming that the economic level and consumption pattern of IM residents approaches those of these cities within its development term.

Figure 17 shows the suitability of the waste for alternative treatments using Tanner's diagram. Our sample from this study (W = 56.9%, A = 8.2%, B = 34.9%) falls into trapezoid BDEC, JLMN and triangle BFG. It is indicated that waste generated in IM is not only suitable for landfill, as it is being handled at the moment, but also for the composting and the incineration without power generation.

ii CM scenarios

Result for future possibility of waste treatment in IM2025 is shown in **Figure 16** with square, circle, and triangle marks indicated the composition of residual waste after separation in Scenario 1, 2 and 3, respectively. In Scenario 1, at participation and segregation rate between 50% and 80%, generated waste is suitable for incineration without power generation. Participation and segregation rate exceeding 80% enable the waste to be incinerated with power generation and for more than 90% rate, composting is no longer suitable. In Scenario 2, at participation and segregation rate lower than 90% generated waste is suitable for composting and incineration without power generation, however exceeding 90% rate, waste is only suitable for landfilling. Combination separation of biodegradable and recyclable material (Scenario 3) indicated that between 50% and 90% level, generated waste is suitable for the composting and the incineration without power generation and at 100% rate is waste suitable for incineration with power generation.

From the waste characterization and projected scenarios, we have demonstrated that final landfill is not the only waste-handling method suitable for IM. Alternative waste treatment such as composting and incineration without power generation is also applicable in this area if separated collection is implemented. Even though a high level of waste separation participation and segregation efficiency is required (at more than 80%, incineration with power generation could be achievable), the current national recycling rate is only 5%, so achieving this scenario will be difficult (Fauziah, 2004). However, the need to reduce the amount of waste sent directly to landfill is crucial, especially with the development of the new economic region in IM. Currently, three landfills operating in the IM area are facing closure before the year 2025, at which point the economic region will be fully developed (Khazanah, 2006). Further study on implementing alternative waste-treatment strategies is needed, especially from the viewpoint of cost and sustainability.

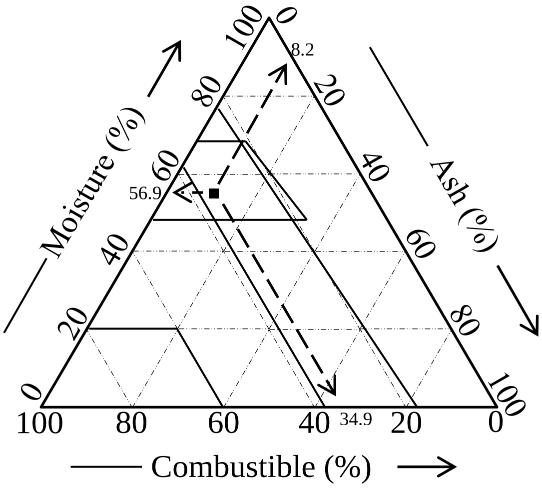


Figure 17 Result of waste characteristic analysis

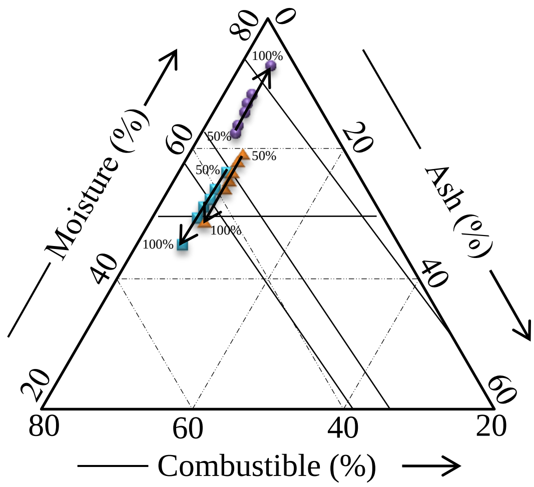


Figure 16 Changes in waste characteristic through changes in participation and segregation rates

(3) Conclusion

A detailed characterization of HSW generated in the IM area was carried out at the Seelong Waste Treatment Facility. The objective of this study was to assess alternative SWM appropriate for a LCS in IM by 2025 to improve the current situation of open landfill dumping.

One hundred kilograms of HSW, which had been collected within 24 hours prior to our study, were classified into 27 physical groups and samples were taken back to the laboratory for a more detailed analysis. Our main findings are as follows:

i Food (47.29kg, 41.06%), plastic (25.60kg, 22.23%), and paper (24.10kg, 20.93%), are the primary components of the generated waste, with product and packaging materials are 48% and 52% respectively, with the most generators being paper for product and plastic for packaging materials.

ii Food waste were further separated into leftover, cooking scrap, and untouched food with composition of 25%, 75% and 0.1%, respectively. Composition of plastic waste is plastic film (40%), shopping plastic bag (32%), waste plastic bag (14%), dense plastic (13%) and non-recyclable plastic (1.3%). 65% of paper waste is from recyclable material and the rest are non-recyclable paper such as tissue and diaper

iii In term of waste generation from consumption expenditure, waste is most generated from food (64%) and followed by miscellaneous goods (personal grooming) (13%), printed material (6%), beverages (6%) and durable household goods (5%).

iv The moisture content, combustible content, and measured calorific values were 57%, 35%, and 1591 kcal/kg, respectively. Waste characterization and assessment of alternative waste treatment shows that if waste separation were implement, composting and incineration would be suitable in the study area.

With the rapid development of the IM area, serious efforts toward the implementation of alternative SWM are crucial in order to face the impending burden of massive waste generation.

6.6 Conclusion of Iskandar Malaysia 2025

Currently, there are five economic regions being develop in Malaysia and IM is the fastest growing region. Total development area of IM covers jurisdiction of five LAs with 70% of total Johor state population. IM CDP is backed up with IRDA SWM-BP to address IM needs of an alternative SWM substituting the current situation of total dependence on final landfill site. Sustainable Waste Management, part of the study on Low-carbon Society Iskandar Malaysia is to support the planning quantitatively. Main findings of Sustainable Waste Management in term of HSW are:

i Both waste and GHG in 2025 will be generated 5 times of 2005 level

ii The combination of waste prevention, self-treatment, source segregation and thermal treatment is able to reduce waste and GHG to achieve the study targets of half reduction of landfill waste and GHG from CM scenario

iii Based on data collected from questionnaire survey, in the waste generation model, household size and expenditure level were seen to influence waste generation

iv Waste characterization and assessment of alternative waste treatment shows that if waste separation were implement, composting and incineration would be suitable in the study area. The moisture content, combustible content, and measured calorific values were 57%, 35%, and 1591 kcal/kg, respectively

The results from this study were presented to both IRDA and SWM Environment. IRDA is coming out with their 10 Actions towards implementation of the actions and SWM Environment is in their final stage of allocating MRF and incinerator in IM with reference to our survey result.

6.7 Reference for Chapter 6

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7 DISCUSSION AND CONCLUSION

This study introduced a methodology to implement a SWM that incorporated SMCS within LCS in a Malaysia Green Cities. It addresses the common issues face by these countries – lack of reliable documented data, and clear policy and necessary enforcement. This study introduced the approach of 3R in the SWM system to move from the conventional system that centralized on open dumping landfill. This chapter will present a summary of major findings in this dissertation focusing on the three case studies and recommendation for future research.

7.1 Discussion

In the pass years, we have seen that there is a trend to decentralized SWM from central to local government. However, government of Malaysia is taking opposite approach of SWM in the country to centralize the SWM through NSWMD and NSWMC. Accordingly, Malaysia is one of its kinds to fully privatize its SWM responsibility to private companies. The main objective of the centralization and privatization is to ensure all 48 LAs in the country to receive equal SWM service despite its economic situation. This aid is crucial especially to the LAs in the rural area with low income level. The issue of funding for implementing a better SWM system is a common issue in the developing countries. However, we believe that the national legislation needs to leave enough autonomy to LAs to address their most pressing issues and make their own decision. Our methodology of involving stake holders in shaping their own 2R concepts through FGD is one example of flexibility achievable even under the centralization of SWM system. This is important because although national governments are important for setting the direction, they can also have competing priorities or do not always understand the nuances of local needs.

Secondly, in order to achieve an integrated SWM system, it is important to take a holistic approach. It is very important to have a structured communication and joint target setting between departments with different responsibilities. In the context of LCS study, this joint responsibility is seen between transportation, building, energy, air and waste. In the context of SWM it could include a number of departments that related to city planning for facilities planning, road networking for collection and transportation, and housing for bins and buy-back centres placement. The study of Green City Index introduces cities like Singapore and Copenhagen that practice holistically planning. Singapore has the Inter-Ministerial Committee on Sustainable Development, which brings together many different departments to set an integrated strategy on sustainable development. Copenhagen has coordinators in each environmental department who meet regularly to exchange information. *REFERENCE

Even though it is mentioned earlier that economic situation of the area plays important roles in shaping the SWM system, at the early stages of development, the right policies matter more than financial ability. In the case of our study areas, due to the high composition of organic waste, introduction of self-treatment like composting could reduce waste largely in a very short time without huge cost. The case study of Surabaya, Indonesia already proves the successful of waste reduction in a low income level city. However, the waste manager should also be prepared to handle changes in waste composition through the developing period. Our modeling result based on questionnaire study in IM shows that consumption preferences changes with changes in income level. Within the developing period of the cities, especially IM, major changes in waste composition could be foreseen. The right technology to handle waste treatment demand due to the changes should be well chosen. Besides the technology, waste handling method should also be well planned. The situation of "recycling impoverishment" is one example of failing to properly plan of SWM at early stages of development. "Recycling impoverishment" represent the situation in which separate collection is not organized in a reasonable way that caused increased costs required for the collection and transportation, pre-treatment and overall management of waste (SWAPI, 2010).

In 1972, Rene Dubos, an advisor to the United Nation Conference on The Human Environment used the phrase "Think globally, Act locally" to express the urge for people to consider the health of the entire planet and to take actions in their own communities and cities. The expression suits this study that focuses on supporting stake holders at the city level to shape their own SWM system that works with the concept of LCS. Even though, Malaysia as a nation is moving towards centralization of its SWM, LAs at city level should also take part in the process as they are the one that under stands the situation at the root. This doesn't stop to the management level but should also involve cooperation and understanding of local community.

7.2 Summary of key points and main findings

Chapter 1, "Introduction" is the introductory chapter where issues related to global warming, and term of low-carbon society, SMCS and green city in the global context is introduced. There are three major environmental crises facing mankind – global warming, resources depletion, and ecosystem crisis. These crises are all closely related to waste and waste management. The working definition of Japan-UK Joint research project on LCS defines LCS as a society that demonstrates high levels of energy efficiency and uses low-carbon energy sources and production technologies; a society that makes an equitable contribution towards the global effort to stabilize atmospheric concentration of CO_2 and other GHG at a level that will avoid dangerous climate change through deep cuts in global emissions; and a society that takes actions that are compatible with the principles of a sustainable development, ensuring that the development needs of all groups within society are met. Sound material-cycle society is defined by Ministry of Environmental Japan as a society in which the amount of resources to be extracted is minimize at all stages of social and economic activities, from resource extraction through production, distribution, consumption and disposal, through a range of measures such as reduction of waste generation and use of circulate resources, thereby minimizing environmental loads. In order to overcome the three major environmental crises, finding a balance symbiosis between the two societies is a crucial agenda. Building or transforming cities into Green City is an example of effort by LAs and other stake holders to face the challenge.

Chapter 2, entitled "Overview of solid waste management" provides a throughout description of elements in an integrated SWM system at global level and in the context of Malaysia as a nation. SWM in this dissertation represent seven elements of the system: (1) Waste generation – amount of material discarded at source; (2) Waste prevention – amount of discarded items that could be recovered at source without going through any treatment process under reduce and reuse actions; (3) Self-treatment – treatment of waste at source using method such as composting; (4) Source segregation – segregation of recyclable material at source for separate collection purpose to enhanced recycling; (5) Collection and transportation – process of collection waste from waste generation source and transporting the collected waste to allocated waste treatment facility; (6) Pre-treatment – the act of handling recyclable material before going through final treatment such as incineration or landfilling and (7) Final treatment – end-cycle of generated waste both from generation source and residual of treatment. Integrated SWM represents a management system that includes 3R – Reduce, Reuse and Recycle that included in the combination of the seven elements. SWM in Malaysia is one-of its-kind as it is being centralized under the jurisdiction of federal government by NSWMD. On top of that, from 1998, the management of SWM is being privatized to shift the burden from the LA to the waste consortium. In term of waste generation, urban waste generation increased 3% annually due to urban migration, affluences and rapid development. In 2008, approximately 31,000 tons of waste were disposed of into 260 landfills in Malaysia and estimated to be doubled by 2020. Level of per capita solid waste generation changed accordingly with the rate in the 1980's was 0.5kg/d and had increased to range from 1.5 to 2.0 kg/d in most cities currently.

Chapter 3, "Methodology", explains how the whole process of designing the alternative SWM for Malaysia Green Cities are carried out. The whole process is divided into four main steps namely – target setting, scenario building, quantification, scenario evaluation. The concept of back casting was applied in which the desired future condition is envisioned and later steps towards achieving the target are figured out. Two targets representing two indicators were set for this purpose; (1) Waste amount - amount of total waste sent to final landfill after reduction through alternatives waste handling and pre-treatment; (2) GHG amount - amount of GHG emitted from each alternative method. Scenario of system structure and scenario of parameter setting are two aspect considered in developing the CM scenarios. The former represents selection of SWM elements in the CM scenario and the latter represents selection of level to implement system structure that incorporates stake holder's preference in shaping the future of their jurisdiction area. Quantification for all seven elements was carried out using available documented data and projection based on the data. The main challenge in carrying out study on solid waste in a developing country is the lack of documented and reliable data. In the case study of IM2025, with the time and budget allocation, three field studies were conducted to support the study process. Finally evaluation of the calculation was carried out for both waste and GHG amount to figure out the potential of implementing suggested CM scenario in the study area.

Chapter 4 to 6 covers three case studies of implementation our recommended system to Malaysia Green Cities. **Chapter 4** discussed application of this study method in Putrajaya under PGC2025 preliminary study. Main findings from the projection are:

1. Total waste and GHG generation in 2025BaU is 149t/d and 1,132tCO_2/d, respectively. Both are 5 times of 2005 level.
2. Both waste and GHG reduction targets are achievable under all scenarios we tested; in order of reductions from most to least, the scenarios were separate collection with thermal treatment (2025CM3), thermal treatment without separate collection (2025CM2), and separate collection without thermal treatment (2025CM1)
3. From three CMs, the most waste to landfill and GHG emission reduction achievable in 2025CM3, 77% (114 t/d) and 67% (763t-CO_2/d)
4. Waste reduction from each action is 5% (8t/d), 26% (42t/d), and 69 %(114t/d) for waste prevention, source segregation, and thermal treatment with self-treatment, respectively.
5. Waste collection and transportation using 2-ton trucks shows inverse impacts in the CM scenarios with the most emission is from CM1 follows by CM 2 and CM3 at 1.18, 1.27 and 0.96tCO2/d, respectively.

Chapter 5 discussed application of this study method in Cyberjaya under Cyberjaya DGC2025 preliminary study. Main findings from the projection are:

1. Total waste and GHG generation in 2025BaU is 170t/d and 1,638tCO_2/d, respectively.
2. From three CMs, the most waste to landfill and GHG emission reduction achievable in

2025CM3, 78% (172 t/d) and 84% (1459 t-CO_2/d)

3. In order of reductions from most to least, the scenarios were 2025CM3 – high level of enforcement, 2025CM2 – moderate level of enforcement, 2025CM1 – low level of enforcement

4. Waste reduction from each action is 8% (10t/d), 45% (61t/d), 43% (58t/d), and 5 %(6.3t/d) for waste prevention, self-treatment, source segregation, and thermal treatment, respectively.

5. Even though our target of 75% reduction waste amount sent to final landfill compare to 2025BaU is only achievable at 2025CM3, waste reduction from other scenarios are also significant. Target of 50% GHG reduction is achievable at all CM selection.

Chapter 6 discussed application of this study method in IM under study of Project for Development of Low Carbon Society Scenarios for Asian Regions. Main findings from the projection are:

1. Total waste and GHG generation in 2025BaU is 4321t/d and 7,707tCO_2/d, respectively. Both are 5 times of 2005 level.

2. From the CMs, waste to landfill and GHG emission reduction achievable in 2025CM is 78% (172 t/d) and 84% (1459 t-CO_2/d), respectively

4. Waste reduction from each action is 1% (42t/d), 38% (1166t/d), 56% (1711t/d), and 4 %(132t/d) for waste prevention, self-treatment, source segregation, and thermal treatment, respectively.

Main findings from questionnaire survey are:

1. One thousand questionnaires were distributed by hand among the residents of IM, a new economic region within Malaysia's most southern state, Johor, and 51% were returned by post.

2. Solid waste mainly constitutes food waste, paper waste and garden waste, at 29%, 22% and 21%, respectively.

3. The results of the modelling show that household size has inverse impacts on waste generation. Per capita waste generation by larger households is smaller than by smaller households. Expenditure level is seen to affect paper and PET waste generation positively, with reverse effects for other paper, textile, and other textile waste generation.

4. The age factor is correlated with the generation of glass, metal, and other textile waste, at 5% level, and of textile waste at 1% level. The generation of this type of waste reduces with an increase in age of the head of household.

5. In the waste generation model, household size and expenditure level were seen to influence waste generation

6. Other paper and other textile are also correlated with the expenditure factor at a 5% level. Households with higher income levels, which have a bigger buying power, appear to have

enough resources to spend on optional items such as household textiles.

Main findings from landfill survey are:

1. One hundred kilograms of HSW, which had been collected within 24 hours prior to our study, were classified into 27 physical groups and samples were taken back to the laboratory for a more detailed analysis.
2. Food, paper, and plastic are the primary components of the generated waste, with product and packaging material accounting for 19.8% and 28.9%, respectively. Our results show similar patterns to those seen in the national data on waste composition
3. The total waste composition on a wet basis was food (47.29 kg, 41.06%), plastic (25.60 kg, 22.23%), paper (24.10 kg, 20.93%), textiles (8.92 kg, 7.74%), glass (4.10 kg, 3.56%), garden waste (2.82 kg, 2.45%), metal (2.26 kg, 1.96%), ceramic (0.08%), and rubber (0.01%).
3. More than 40% of the generated waste could be reduced and recycled if 3R programs were implemented due to the waste are from packaging waste and shopping bags
4. Waste characterization and assessment of alternative waste treatment shows that if waste separation were implement, composting and incineration would be suitable in the study area. The moisture content, combustible content, and measured calorific values were 57%, 35%, and 1591 kcal/kg, respectively.

Application of our study method to the three cities with different characteristics shows that both the targets of waste and GHG reduction are achievable using the CM scenarios. Nevertheless, there is dissimilarity between the three cities. The biggest difference is in waste prevention which is influenced by rating of 2R actions by the stakeholders from each city. Stakeholders in PGC2025 and IM 2025 rate more than half of the actions with high priority level while DGC2025 with moderate priority level. The rating percentage from high to low priority respectively shows PGC2025 (77%, 15%, and 8%), DGC2025 (14%, 51%, and 35%) and IM2025 (54%, 36%, and 10%). Even though all three cities play an important role in the development of modern Malaysia, there is a distinct different interest in the management in each city. Putrajaya as the federal government city need to be ahead of other cities in the country give more reason for PJC to actively promote 2R besides the fact that compared to other cities residents in Putrajaya is well exposed and higher educated. As for IM, it is built with the vision to become a world class city. Therefore stakeholders are very well motivated to achieve the vision. Compared to the two cities, SWM in Cyberjaya is still under LA – Sepang LA and not being privatized. As previously stated, one of the biggest challenge of SWM faced by LAs is funding shortage. With the pressure of fulfilling basic needs such as waste collection and transportation, priority on 2R campaign and promotion become less important in the city.

Therefore it can be concluded that the methodology proposed in this dissertation is consistent and feasible and it can be implemented in other cities even with difference in income level and SWM ability.

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Appendix

Appendix A Methodology

Table 1 National Input Output table for 1987, 1991, and 2000

	Food			Paper			Plastic			Glass			Metal			Other (leather, rubber)		
	1987	1991	2000	1987	1991	2000	1987	1991	2000	1987	1991	2000	1987	1991	2000	1987	1991	2000
Food	4,852,038	8,362,091	20,543,931	91,859	181,591	919,770	85,677	219,996	345,636	34,311	58,095	268,427	253,260	363,612	540,636	–	–	–
Beverages				11,183	35,155	102,981	4,636	14,919	69,506	40,115	131,162	106,552	47,399	104,307	214,277	–	–	–
Clothing and footwear	–	–	–	38,903	48,220	162,664	20,574	100,610	2,279,143							733,867	1,200,964	1,928,328
Household goods	–	–	–	10,425	21,839	107,932	4,178	17,793	96,221	19,921	78,981	391,953	3,962	6,024	19,975	–	–	–
Leisure items	–	–	–				2,106	10,735	126,964	–	–	–	–	–	–	–	–	–
Printed materials				251,828	772,878	1,648,581												
Personal grooming	–	–	–	–	–	–		42,393	54,030	–	–	–	–	–	–	–	–	–

Table 2 Extrapolation result for 2005 Input Output

	Food	Paper	Plastic	Glass	Metal	Other (leather, rubber)
Food	52,140,838	2,408,251	889,474	697,119	1,288,249	–
Beverages	–	271,798	184,296	224666	550136	–
Clothing and footwear	–	408808	6,083,301			4,727,673
Non-durable household goods	–	283024	256,567	1,043,819	50952	–
Leisure items	–		339048	–	–	–
Printed materials		4327857				
Personal grooming	–	–	152,657	–	–	–

Table 3 Reduce (Product) based on action selection and implementation level

	Food and beverages	Clothing and footwear	Non-durable household goods	Printed materials	Leisure items	Personal grooming
Buy according to needs	0.90	0.90	0.90	0.90	0.90	0.90
Buy in bulk	1.00	1.00	1.00	1.00	1.00	1.00
Buy refill and concentrates	1.00	1.00	1.00	1.00	1.00	1.00
Buy local products	1.00	1.00	1.00	1.00	1.00	1.00
Not to buy over-packaged products	1.00	1.00	1.00	1.00	1.00	1.00
Don’t take plastic bag unless needed	1.00	1.00	1.00	1.00	1.00	1.00
Online bill paying	1.00	1.00	1.00	1.00	0.75	1.00
Rent or borrow instead of buying	1.00	1.00	1.00	0.50	0.50	1.00
Digital service (On-Line)	1.00	1.00	1.00	1.00	0.25	1.00
My lunch pack/leftover	0.80	1.00	1.00	1.00	1.00	1.00
Sharing	1.00	0.90	0.90	0.90	0.90	1.00
	0.72	**0.81**	**0.81**	**0.41**	**0.08**	**0.90**
Waste reduction	0.28	0.19	0.19	0.60	0.92	0.10

Table 4 Reduce (Packaging) based on action selection and implementation level

	Food and beverage	Clothing and footwear	Non-durable household goods	Printed material	Leisure items	Personal grooming
Buy according to needs	1.00	1.00	1.00	1.00	1.00	1.00
Buy in bulk	1.00	1.00	0.79	1.00	1.00	1.00
Buy refill and concentrates	1.00	1.00	0.33	1.00	1.00	0.33
Buy local products	0.50	1.00	0.50	1.00	1.00	0.50
Not to buy over-packaged products	0.75	0.75	0.75	0.75	0.75	0.75
Don't take plastic bag unless needed	0.75	0.75	0.75	0.75	0.75	0.75
Online bill paying	1.00	1.00	1.00	1.00	1.00	1.00
Rent or borrow instead of buying	1.00	1.00	1.00	1.00	1.00	1.00
Digital service (On-Line)	1.00	1.00	1.00	1.00	1.00	1.00
My lunch pack/leftover	1.00	1.00	1.00	1.00	1.00	1.00
Sharing	1.00	1.00	1.00	1.00	1.00	1.00
	0.28	**0.56**	**0.07**	**0.56**	**0.56**	**0.09**
Waste reduction	0.71875	0.43750	0.92627	0.43750	0.43750	0.90710

Table 5 based on action selection and implementation level

	Food and beverages	Clothing and footwear	Non-durable household goods	Printed materials	Leisure items	Personal grooming
Choose for durable items	1.00	0.67	1.00	0.67	0.67	1.00
Buy products from recycled materials	1.00	1.00	1.00	1.00	1.00	1.00
Repair broken items	1.00	0.67	1.00	1.00	0.75	1.00
	1.00	**0.44**	**1.00**	**0.67**	**0.50**	**1.00**
Waste reduction	0.00	0.56	0.00	0.33	0.50	0.00

Table 6 Composting inventory

		Name	Value		Unit
			Centralized	Decentralized	
Input	Raw material	Food waste	1.000	1.000	kg
	Sub-material	-			kg
	Utility	Electricity	0.0497	0.5398	kWh
		Diesel fuel	0.0003		L
		Gas		0.1235	m3
		Clean water	0.1	6.7	kg
		Sewage water		6.7	kg
Output	Product	Compost	0.293	0.125	kg
	Sub-product/residue	-			kg
	Air pollution substance	CO2			kg
		Nox			kg
		Sox			kg
		Smoke dust			kg
	Water pollution susbstance	BOD			kg
		COD			kg
		SS			kg
	Soil pollution substance				

Table 7 Thermal treatment inventory

		Name	Value	Unit
Input	Raw material	Municipal Solid Waste	1.000	kg
	Sub-material	Hydrated lime	0.00831	kg
		Caustic soda	0.0002	kg
		Hydrochloric acid	0.0000881	kg
		Deoxidizing agent	0.000016	kg
		Clean water	0.000148	kg
		Industrial water	0.000428	kg
		Underground water	0.000151	kg
	Utility	Electricity	0.0248	kWh
		A Diesel Fuel	0.000645	L
Output	Product	Incinerated ash + Fly ash	0.155	kg
	Sub-product/residue	Electricity	0.0406	kWh
	Air pollution substance	CO2		kg
		CH4	0.00001175	kg
		N2O	0.00005394	kg
		Nox	0.00122	kg
		Sox	0.000544	kg
		Smoke dust	0.000106	kg
	Water pollution susbstance	P-total		kg
		N-total		kg
		BOD		kg
		COD		kg
		SS		kg
	Soil pollution substance			

Table 8 Landfill inventory

		Name	Value	Unit
Input	Raw material	Municipal Solid Waste	1.000	kg
	Sub-material	Ferric chloride	0.00209	kg
		Caustic soda	0.00534	kg
	Utility	Electricity	0.0586	kWh
		Diesel fuel	0.00062	L
Output	Product			
	Sub-product/residue			
	Air pollution substance	CO2		kg
		CH4		kg
		N2O		kg
		NOx		kg
		SOx		kg
		Smoke dust		kg
	Water pollution substance	P-total	0.000000206	kg
		N-total	0.0000111	kg
		BOD	0.0000216	kg
		COD	0.0000929	kg
		SS	0.0000332	kg
	Soil pollution substance			

Appendix B The Case Study of Federal Government City, Putrajaya

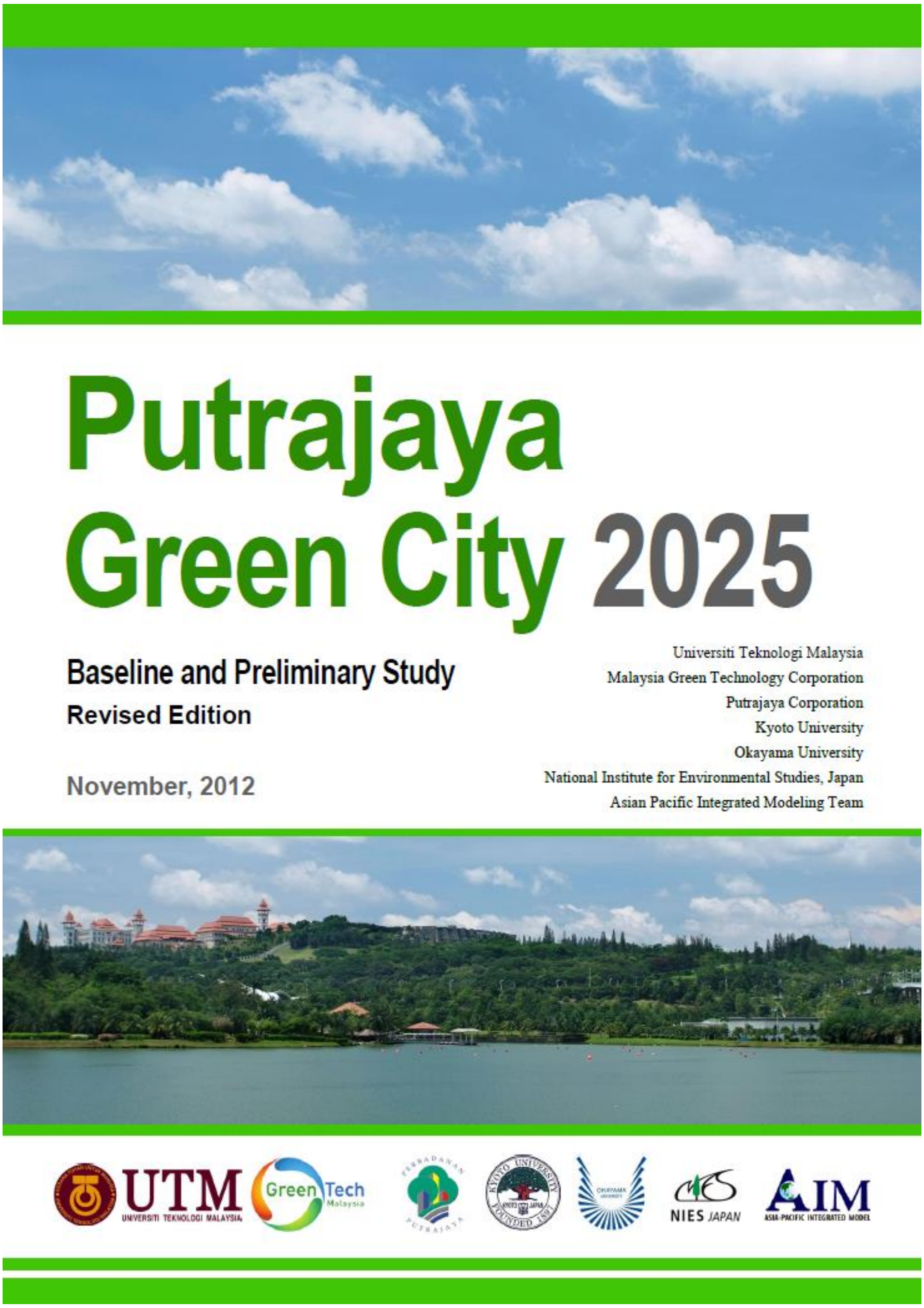

Figure 1 Brochure of Putrajaya Green City 2025 study

Use Less Consume Less

Action 9

Our daily consumption preference influences our waste generation. In order to balance the economic growth and the natural resource saving with our concern towards sustainable development, it is important to reduce consumed goods, as a result, this consumption lifestyle depresses GHG emission as well as waste reduction.

"Reduce" is the first pillar of 3R in Solid Waste Management (SWM). It is defined as "reducing the amount of waste by increasing the efficiency of resource use and extending the useful life of products". Efforts of reduction activities save money not only of household but also of authority's waste treatment cost.

By practice of "reduce" activities in home, GHG emission from household waste can be reduced by 2.85ktCO_2eq, which contributes 93% of the reduction by this action. Remaining 6% and 1% are carried out by restriction of plastic bag use in business sector and promotion of IBS (Industrialized Building System) which should be applied in 70% of future building construction (See also pages 42-43).

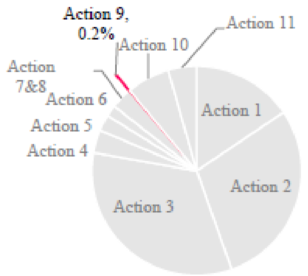

Figure 29: Contribution to GHG emission reduction of Action 9

Table 15: Sub-actions & Programmes in Action 9

Sub-action	Programmes	GHG emission reduction [ktCO_2eq]	Contri-bution in the Action [%]	Contri-bution in total reduction [%]
9-1 **Implement Reduction of Waste at Source**	1) Reduction of household waste reduction a. Reduction in household consumption b. Increase public awareness in consumption reduction	2.85	93	0.142
	2) Reduction of business waste reduction a. Intensify waste reduction programs in schools, offices and businesses b. Introduces and intensify paperless operations in businesses	-	-	-
	c. Shops and retail outlets, to restrict the usage of plastic bags	0.18	6	0.009
	3) Reduction of construction waste a. Promote extensive use of IBS (Industrialized Building System) in building constructions	0.04	1	0.002
9-2 **Introduce Regulatory Framework**	1) Make green accreditation mandatory a. Government offices to restrict/refrain from using PET bottles and Styrofoam utensils in events/functions b. Impose penalty for the disposal of reusable construction/renovation material	-	-	-
Total		**3.07**	**100**	**0.153**

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Figure 2 Action 9 of PGC2025 – Use Less Consume Less

Think Before You Throw

Action 10

Before we throw useless things, we should think of "reuse" and "recycle" to reduce GHG emission as well as waste. "Reuse" and "Recycle" are the second and third pillars of 3R in SWM, and respectively mean to repair for longer use, to use in other manner or to pass to who desires and to process it in order to get back to the products or their materials.

This action contributes to reduction of 134ktCO_2eq in 2025. The biggest reduction is from waste separation at source with 72% from office and commercial, and 24% from household sector. Implementation of waste sorting at source should work together with separate collection and both selections are based on waste treatment.

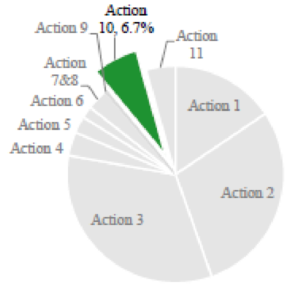

Figure 30: Contribution to GHG emission reduction of Action 10

Build More Facilities to Enhance Reuse

However, before waste products are sent to the final treatment, some can be reused after going through minor pre-treatment. Introduction of medium such as Flea market, car boot sale and drop off point is one way to enhance reuse by household. In 2025, Putrajaya will have 7 Park and Ride facilities, that serve as parking area, these facilities can be transformed into open space to enhance reuse. Park and Ride area can be the location for car boot sale during the weekend. Other open spaces in residential area or government office can also play the same role.

Putrajaya Buy Back Centre

Buy back centers in Putrajaya provide the public opportunity to sell their unneeded items. The centre was launched in August 2010, and it is the only one daily operating permanent buy back centre. Currently there are two permanent and three mobile centres that are operating in Putrajaya. The residents can choose from two different methods of payment; by cash or point system, since the introduction of "Putrajaya Green Card".

Encourage of Composting at Source

Natural circulation of biomass waste is essential countermeasure for waste and GHG reduction. For reduction at source, composting of food waste should be the main focus. Four levels of composting were introduced in the estimation, which are home, community, on-site and centralized composting. While conventional composting at home is very easy to carry out, farming in community garden will give extra benefit of socializing and enjoyment. Community farming is one of PJC on-going program known as "Kempen Bumi Hijau". Large amount of food waste from school/office/restaurant is treated using composting machine efficiently at the on-side facility, and landscape waste and sewage sludge is treated in centralized composting facility located in Putrajaya Integrated Solid Waste Recovery Facility.

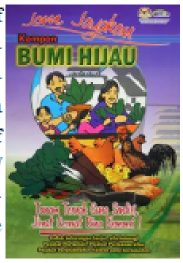

Figure 31: Kempen Bumi Hijau by PJC

Waste Separation at Source

PJC together with Alam Flora, provide household and offices garbage bins for waste separation. Commercial sectors such as restaurants, cafeterias and hotels are also provided with organic-waste bin for composting purpose. It is targeted by 2025 that waste separation, recycling and composting center allocation become mandatory in Putrajaya.

Introduce IBS to Building Construction

Industrial building system suppresses waste generation at construction site by prefabrication of construction materials.

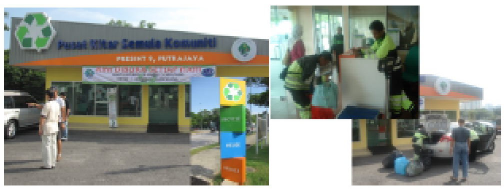

Figure 32: Putrajaya Buy Back Centre in Precint 8

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Figure 3 Action 10 of PGC2025 – Think Before You Throw

Table 16: Sub-actions & Programmes in Action 10

Sub-action		Programmes	GHG emission reduction [ktCO$_2$eq]	Contri-bution in the Action [%]	Contri-bution in total reduction [%]
10-1	Expansion of Products Lifespan	Encourage the reuse of household waste	1.2	0.9	0.06
10-2	Build More Facilities to Enhance Reuse	1) Introduce flea market where residents can resell their unused belonging. (electrical items, furniture, books, etc.)	-	-	-
		2) Provide locations for car boot sale (eg. At Park & Ride facilities, open space in residential areas, etc.)			
		3) Drop off point for reusable waste (e-waste, household waste, etc.)			
		4) Libraries to introduce books sharing activities			
10-3	Introduce and Encourage Composting	1) Household - home composting	3.7	2.8	0.19
		2) Conventional method			
10-4	Recovery of Used Cooking Oil	1) Encourage household to separate used cooking oil for collection	0.2	0.1	0.01
		2) Impose food and beverage outlets, school/office canteens to separate used cooking oil for collection	0.1	0.1	0.01
10-5	Introduce Regulatory Framework to Impose Waste Separation at Source	1) Residential area	128.4	96.1	6.40
		a. Recyclable			
		b. Organic (food, used cooking oil, garden waste)			
		c. Others (e-waste, bulky, etc.)			
		* Impose mandatory waste separation in all government quarters			
		2) Office			
		a. Recyclable			
		b. Others (e-waste, bulky, etc.)			
		* Mandatory allocation of recycling center in buildings			
		3) Commercial			
		a. Recyclable			
		b. Organic (food, used cooking oil, landscape)			
		c. Others (e-waste, bulky, etc.)			
		* Mandatory allocation of recycling/composting center in facilities/parks			
Total			133.5	100	6.66

(May not sum to total due to rounding error.)

Figure 33: Night market as reuse promotion venue

Figure 34: Waste separation bins

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Figure 4 Calculation result for Action 10 PGC2025

Integrated Waste Treatment

Action 11

Recycle, treatment, and disposal facilities support to the robust solid waste management. There are several options for waste treatment in order to recover all the valuable resources and to minimize the needs to use virgin materials.

This action reduce GHG emission by 88ktCO_2eq or 4.4% of total emission reduction. Composting contributes to 88% of GHG reduction in this action. Especially composting by commercial sector is important.

In order to enhance recycling activities in Putrajaya, in 2025 more buy back center should be provided. From the estimation, this program reduce 5ktCO_2eq.

The model estimation includes not only GHG emission from waste treatment but also waste handling stage: GHG from waste collection and transportation. Introduction of Integrated Solid Waste Recovery Facility in Putrajaya reduces GHG emission from waste handling itself.

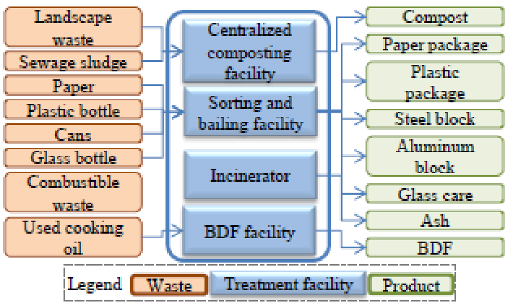


Figure 35: Process of waste treatment

Integrated Solid Waste Recovery Facility

To save energy and cost, an integrated solid waste recovery facility will necessary to be constructed as a recycle home base.

Thermal Treatment

This is a treatment process that involves the combustion of organic substances contained in waste materials. It can significantly reduces the necessary volume for final disposal up to roughly 90% in volume. Another benefit is that this treatment produces power in the process of waste burning.

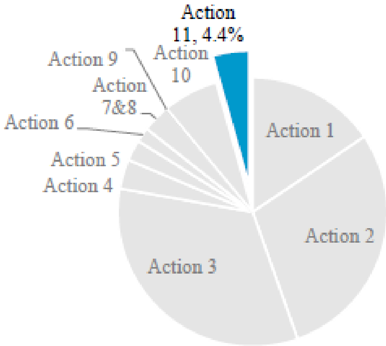


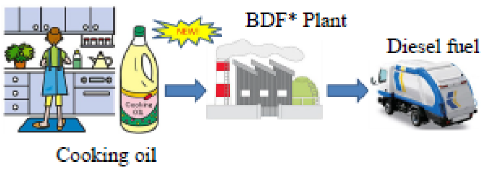
Figure 36: Contribution to GHG emission reduction of Action 11

Utilization of Bio-Diesel Fuel

Waste cooking oil is collected and utilized as fuel. Bio-diesel fuel generated from treatment of used cooking oil has similar quality to the diesel oil. Therefore it can be directly used in conventional transportation engine. Usage of generated bio-diesel fuel in waste transportation truck is the most applicable option. The recovery of used cooking oil not only reduces amount of waste sent to landfill but also reduces GHG emission because cooking oil belongs to "carbon natural" by regarding the nature of cooking oil as "carbon neutral".

Pay As You Throw

"Pay As You Throw" system is known as unit pricing or variable-rate pricing. Due to the introduction of this system, household in Putrajaya will be charged according to the amount of their discharged waste. This program will create direct incentive to recycle more and generate less waste.



*BDF: Bio Diesel Fuel

Figure 37: Process of bio-diesel fuel utilization

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Figure 5 Action 11 of PGC2025 – Integrated Waste Treatment

Table 17: Sub-actions & Programmes in Action 11

Sub-action		Programmes	GHG emission reduction [$ktCO_2eq$]	Contri-bution in the Action [%]	Contri-bution in total reduction [%]
11-1	Integrated Solid Waste Recovery Facility	1) Mini thermal treatment plant for non- recyclable or compostable waste	Contribution of these pro-grammes are included in Sub-action 10-5.		
		2) Sorting center for recyclable waste			
		3) Baling facility for recyclable waste before transported			
		4) Bio- diesel fuel plant for used cooking oil	Contribution of this program is included in Sub-action 10-4.		
		5) Crushing facility for construction waste	Contribution of this program is included in Sub-action 9-1, pro-gram 3.		
		6) Centralized composting center for landscape waste and sewage sludge	75.87	86.65	3.8
		7) Biogas plant for organic waste			
		8) Sewage treatment			
11-2	Introduce Regulatory Framework	1) To provide more composting facility	-	-	-
		a. Household - community composting - Provide com-mon compost bins for garden waste in residential are-as.	1.46	1.67	0.07
		- Provide common compost bins for garden waste in residential areas.			
		b. Commercial - On-site composting machine for F&B outlets/markets/hotels	4.75	5.42	0.24
		- On- site composting machine for F&B outlets/ markets/hotels			
		* Impose regulations for landscape activities to use compost produced in Putrajaya			
		2) Provide more buy back center	5.48	6.26	0.27
		a. Fixed facilities			
		- Boutique for recycle product			
		- Daily operation			
		b. Mobile facilities			
		- Vehicles that go around residential areas			
		- Weekly operation			
		3) Introduce separate collection	-	-	
		- Fixed schedule by Alam Flora			
		4) Study on “Pay As You Throw” system	-	-	-
Total			88	100	4.37

(May not sum to total due to rounding error.)

Figure 38: Thermal treatment facility
(Picture of Eastern Clean Centre, Okayama, Japan)

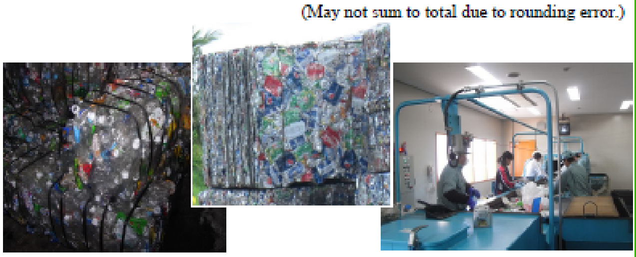

Figure 39: Bailing and sorting at Material Recovery Facility

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Figure 6 Calculation result for Action 11 PGC2025

3R Putrajaya

GHG emission from waste treatment

The two main targets of 3R Putrajaya are, to reduce 50% of the solid waste volume which is land filled from the 2025 (BaU) case, and to reduce 50% of GHG emission from the 2025 (BaU) case. Waste amount is estimated at three levels as mentioned below:

1. From waste collected after reduction at source
2. From Waste after it is treated at selected treatment facilities
3. At landfill site for final disposal

The GHG emission are estimated from waste treatment including final disposal, and transportation of waste from source to treatment facilities to landfill site. GHG emission from waste collection and transportation are estimated from travel distance of collection truck. GIS estimates the trip distance of waste transportation among locations of waste source, treatment facilities and landfill site, using road networks as well as waste generation and location.

Countermeasures for reduce, reuse and recycle

"3R" means Reuse, Reduce and Recycle. Tables 21 and 22 show some example of countermeasures which can be practiced in order to "reduce" and "reuse" household waste. These activities should be enhanced by the programs in Action 9 to 11. As for "recycle", separate collection is the most important practice. It requires integrated collection systems and facilities.

All 3R practices can reduce waste landfill, hence methane emission from landfill site. 3R, as well as thermal treatment, can contribute to reduce overall GHG emission significantly, since methane has stronger greenhouse effect than CO_2 .

Future simulations

The future simulation was conducted in four different cases (Table 21). In 2025BaU, all waste go to landfill as in the base year. The other three countermeasure cases, 2025CM, simulate combination of two groups of countermeasures: (1) Separate collection, (2) Thermal treatment, and (3) The both. In all three 2025CM cases, "reduction at source" (= home composting and other "reduce" activities) is considered. GHG calculation from waste transportation is calculated in this study using road network which is shown in Figure 64.

Figure 66 shows the result of waste treatment in the four cases. In BaU case, amount of landfilled waste will be increased more than 4 times than 2005. In 2025CM cases, reduction of landfill is the most in the case 2025CM(3), which shows 73% of reduction. However, from the view point of GHG emission reduction, 2025CM(1) emits least GHG, and therefore thermal treatment is not the best choice. Considering the balance of two targets, we decided to adopt 2025CM(3) for the proposal of Actions 9 to 11.

In addition, waste reduction at source and home composting are the best solutions for SWM since it is an effective for both GHG emission reduction and landfill reduction. More detailed results are shown in Tables 28 and 29 in page 50.

Table 21: Combination of treatment option and collection waste type

Cases	Treatment option
2025BaU	Landfill
2025CM(1) Separate collection	Landfill, home composting, recycling, and Bio Diesel Fuel (BDF)
2025CM(2) Thermal treatment	Landfill, home composting, BDF, and thermal treatment
2025CM(3) Thermal treatment with separate collection	Landfill, home composting, recycling, BDF and thermal treatment

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Figure 7 Calculation methodology of PGC2025

Methodology

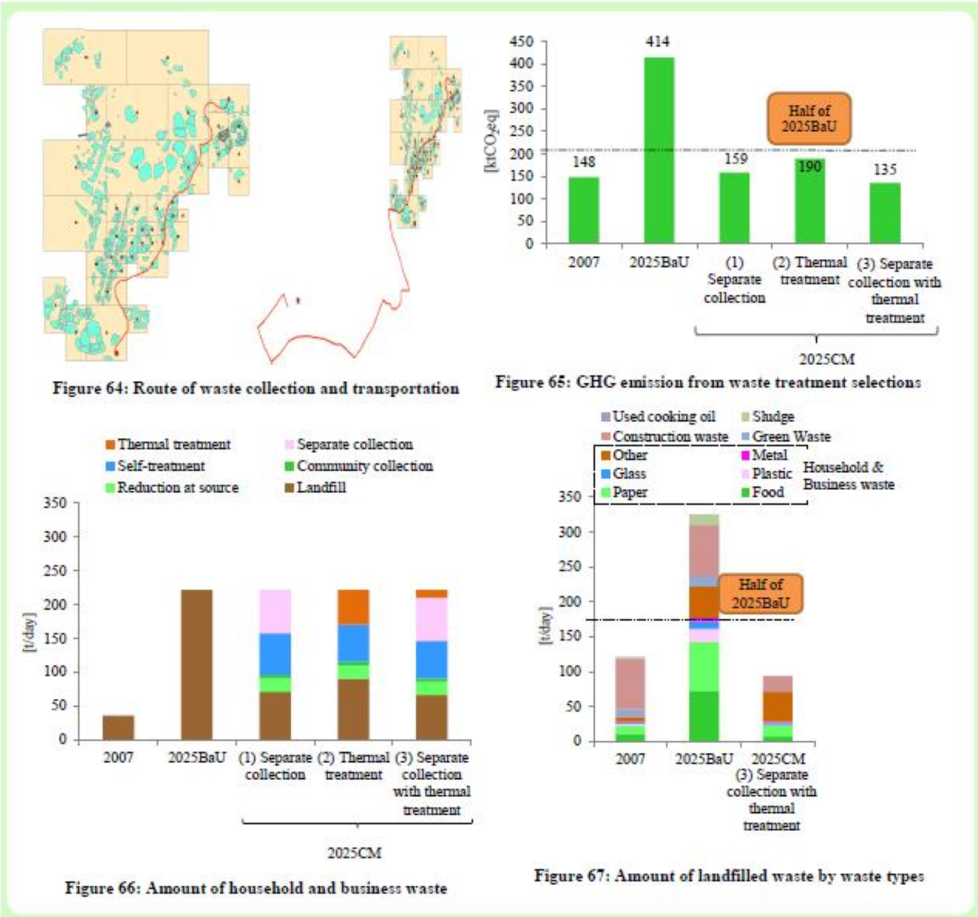

Figure 64: Route of waste collection and transportation

Figure 65: GHG emission from waste treatment selections

Figure 66: Amount of household and business waste

Figure 67: Amount of landfilled waste by waste types

Figure 68: Scenery in Putrajaya

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Figure 8 Calculation methodology of PGC2025

Table 26: Waste amount by waste types

[t/day]	2007	2025BaU	2025CM(3) (Thermal treatment with separate collection)		
	Waste to Landfill	Waste to Landfill	Waste to Landfill	Reduction at source	Waste to treatment
Food	10.98	72.34	6.90	3.34	62.09
Paper	11.19	70.06	15.83	4.12	50.11
Plastic	2.96	18.47	0.88	11.28	6.31
Glass	1.83	10.82	2.66	2.62	5.54
Metal	1.01	6.04	1.42	2.78	1.84
Other	7.37	44.04	43.22	0.82	0.00
Green waste	10.67	15.19	0.00	0.00	15.19
Construction waste	72.57	72.57	22.64	22.88	27.05
Sludge	2.08	14.67	0.00	0.00	14.67
Used cooking oil	0.10	0.74	0.00	0.00	0.74
Total	**120.75**	**324.94**	**93.54**	**47.85**	**183.54**

(May not sum to total due to rounding error.)

Table 27: Waste amount by treatment selections

[t/day]	2007	2025BaU	2025CM		
			(1)Separate collection	(2)Thermal treatment	(3)Thermal treatment with separate collection
Reduction at source	0.0	0.0	19.6	19.6	19.6
Community collection	0.0	0.0	5.4	5.4	5.4
Separate collection	0.0	0.0	63.8	0.0	63.8
Self-treatment (Composting)	0.0	0.0	62.1	55.2	55.2
Thermal treatment	0.0	0.0	0.0	51.2	11.7
Landfill	35.3	221.8	70.9	90.4	66.1

Table 28: Reduce: ten good practices towards household waste reduction

Practice	Explanation
Buy according to needs	Excessive expenditure will leads to excessive waste generation.
Buy in bulk	Buy a bigger quantity of product, instead of buying the same product in a few smaller packaging.
Buy refill and concentrated products	Refills and concentrated products mostly comes in simple packaging and large amount
Buy local product	1. Most local products are sold directly before packaging is done. 2. Local products usually have shorter transport distance and require minimum packaging
Not to buy over-packaged product	Choosing products with simple packaging to prevent the generation of packaging waste.
Decline packaging bag unless necessary	Choose to decline the use of packaging bags when buying in small amounts.
Rent or borrow instead of buying	Opt to rent or borrow products that are rarely used. It saves money, storage space, and reducees the amount of waste generated.
Use online services	This apply to all service than can be obtained online such as, online music, newspaper, magazines and etc.
Pack left over food.	This reduces the amount of food waste and the needs to buy food.
Sharing	Big items such as party supplies or big machines (grass cutter, gardening tools) can be shared within the community

Table 29: Reuse: five good practices towards household reuse

Practice	Explanation
Buy durable items	Durable items are longer lasting.
Buy products from recycled material	This will encourage the recycling activities and also reduce the use raw materials.
Repair broken items	Exchanging partly broken item prevent excess generation of waste.
Use reusable items	Choose reusable containers helps prevent the generation of containers waste.
Use "my bag"	The use of personal bags - "my bag" prevents generation of plastic bag waste and promotes "reuse" of textile waste for hand-made bag.

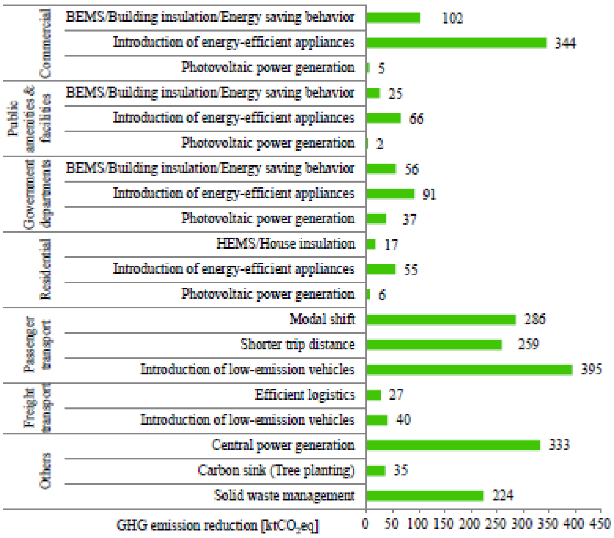

Figure 69: GHG emission reduction by countermeasure types

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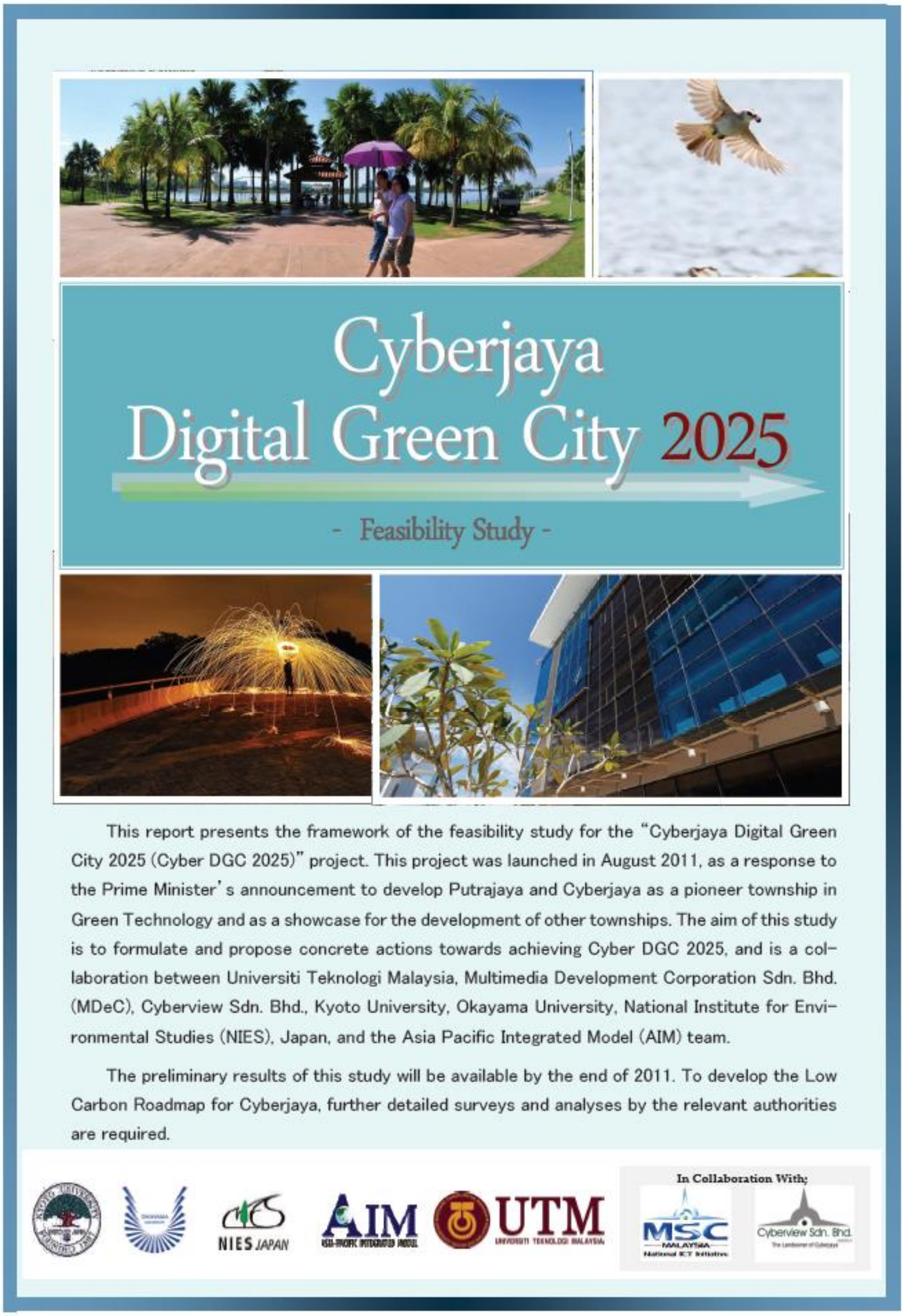
Figure 9 Details result of PGC2025

Appendix C Case Study of Multimedia Super Corridor City, Cyberjaya



Cyberjaya
Digital Green City 2025

- Feasibility Study -

This report presents the framework of the feasibility study for the "Cyberjaya Digital Green City 2025 (Cyber DGC 2025)" project. This project was launched in August 2011, as a response to the Prime Minister's announcement to develop Putrajaya and Cyberjaya as a pioneer township in Green Technology and as a showcase for the development of other townships. The aim of this study is to formulate and propose concrete actions towards achieving Cyber DGC 2025, and is a collaboration between Universiti Teknologi Malaysia, Multimedia Development Corporation Sdn. Bhd. (MDeC), Cyberview Sdn. Bhd., Kyoto University, Okayama University, National Institute for Environmental Studies (NIES), Japan, and the Asia Pacific Integrated Model (AIM) team.

The preliminary results of this study will be available by the end of 2011. To develop the Low Carbon Roadmap for Cyberjaya, further detailed surveys and analyses by the relevant authorities are required.

In Collaboration With;

Figure 1 Brochure of Cyberjaya Digital Green City 2025 study

Cyberjaya
Digital Green City 2025

- Smart 3R Cyberjaya -

"Cyberjaya Digital Green City 2025 (Cyber DGC 2025) was launched in August 2011, as a response to the Prime Minister's announcement to develop Putrajaya and Cyberjaya as a pioneer township in Green Technology and as a showcase for the development of other townships. The aim of this study is to formulate and propose concrete actions towards achieving Cyber DGC 2025, and is collaboration between University Teknologi Malaysia, Multimedia Development Corporation Sdn. Bhd. (MDec), Cyberview Sdn. Bhd., Kyoto University, Okayama University, National Institute for Environmental Studies (NIES), Japan, and the Asia Pacific Integrated Model (AIM) team.

As part of the team, Okayama University is responsible to carry out modelling for "Smart 3R Cyberjaya", an alternative Solid Waste Management dedicated for the special characteristic of Cyberjaya as the core of Malaysia's Multimedia Super Corridor.

For the modelling purpose, we distributed this questionnaire survey to capture the current condition of solid waste in Cyberjaya. Both household and business sector are included in this survey. The preliminary results of the whole study will be available by the end of 2011. To develop the Low Carbon Roadmap for Cyberjaya, further detailed surveys and analyses by the relevant authorities are required.

Thank you for your kind cooperation.

In Collaboration With;

Figure 2 Cover letter of questionnaire survey to household and business entities in Cyberjaya

Please answer the following question regarding respondent background. Fill your answer in the blank box

Age		1: below 20 2: 20 to 24 3: 25 to 29 4: 30 to 34 5: 35 to 39 6: 40 to 44 7: 44 to 49 8: 50 and above (please state)
Occupation		1: Businessman 2: Desk Worker 3: Administration 4: Professional 5: Student 6: Other (please state)
Household member		1: 1 2: 2 3: 3 4: 4 5: 5 6: 6 7: 7 8: more than 8 (please state)
Living condition		1: Living alone 2: Living with family 3: Living outside Cyberjaya 4: Other (please state)

Please rate the following 2R (Reduce・Reuse) actions of solid waste management based on possibility of consumption reduction (**1: Low 2: Moderate 3: High**)

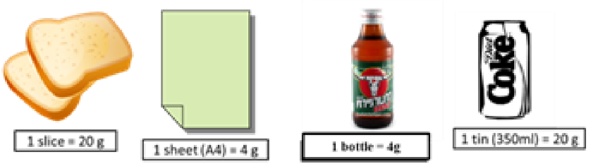
Example:

	Food and beverage	Clothing and footwear	Household maintenance	Recreation and culture (Printed materials)	Recreation and culture (Toys, sports and hobbies)	Misc. (Personal care: hair dressing, jewellery)
Smart purchase	1	2	3	1	3	3

	Food and beverage	Clothing and footwear	Household maintenance	Recreation and culture (Printed materials)	Recreation and culture (Toys, sports and hobbies)	Misc. (Personal care: hair dressing, jewellery)
Smart purchase						
Example: Buy according to needs Buy in bulk Buy refill and concentrates Buy local products						
Waste refuse						
Example: Not to buy over-packaged products Don't take plastic bag unless needed Use my bag for shopping						
Smart planning						
Example: Rent or borrow instead of buying Sharing Choose for durable items Choose for reusable items						

The following table is to be filled if respondent is responsible of household waste handling
How much waste does your household member generate in a day?

	1	2	3	4	5	6	7
Food	0g	25g	50 g	100 g	150 g	200 g	more than 200 g
Paper	0g	2g	5 g	10 g	15 g	20 g	more than 20 gram
Plastic	0g	2g	5 g	10 g	15 g	20 g	more than 20 gram
Plastic bottle	0g	1	2	4	4	5	More than 5 bottles
Glass	0g	50g	100 g	200 g	300 g	400 g	more than 400 g
Metal	0g	10g	20 g	40 g	60 g	80 g	more than 80 g
Other (____________)	0g	50g	100 g	200 g	300 g	400 g	more than 400 g



Thank you for your kind cooperation

Figure 3 Questionnaire distributed to households in Cyberjaya

Please answer the following question regarding respondent background. Fill your answer in the blank box

Age		1: below 20 2: 21 to 25 3: 26 to 30 4: 31 to 35 5: 36 to 40 6: 41 to 45 7: 46 to 50 8: more than 50
Occupation		1: Businessman 2: Desk Worker 3: Administration 4: Professional 5: Student 6: Other (please state)
Working position		1: High-level management 2: Management 3: Clerical 4: Other (please state)
Company type		1: ICT based 2: Education 3: Service 4: Food and Beverage 4: Other (please state)
Living condition		1: Living alone 2: Living with family 3: Living outside Cyberjaya 4: Other (please state)

Please rate the following 2R (Reduce・ Reuse) actions of solid waste based on possibility to carry it out in your daily working operations. **(1: Low 2: Moderate 3: High)**

Example:

General		Paper	
Plan purchase to avoid leftover	3	Limit printout number per employee	1

General	
Plan purchase to avoid leftover	
Choose refillable stationery	
Choose multi-purpose stationery	
Use rechargeable battery	
Use rewritable computer media	
Buy recycled product	
Use rental and lease service	
Paper	
Priority to digital documentation - paperless classroom/meeting	
Limit printout number per employee	
Set printer to double-sided printing mode	
Set a one-sided paper corner	
Use central filing system	
Refuse junk mail	

Break room	
Use reusable utensil	
Bring lunches in reusable container	
Set-up a food waste composting program	
Building maintenance	
Use a multipurpose product	
Use metered dispenser	
Use concentrate and refillable applicator	
Use cloth roll towel / air dryer in the restrooms instead of paper product	
Shipping, receiving and distribution	
Buy supplies in bulk or economy size packaging	
Ask for minimal packaging option	
Ship product in returnable, reusable container	
Reuse incoming packaging material	
Use shredded office paper or discarded material for packaging	

The following table is to be filled if respondent is responsible with stock keeping of the office

	Currently available Please write the correct number (item)	Discarded in the past five years Please write the correct number (item)	Discard method Choose from the following options: 1) Discard together with other municipal solid waste 2) Give/sell to recyclable material collector 3) Pay to the collector 6) Other: (please specify)
1 Television set			
1.1 Color CRT			
1.2 LCD			
2 Computer			
2.1 Desktop			
2.2 Notebook			
2.3 Other (______)			
3 Audio Video (AV) set			
4 Mobile phone			
5 Refrigerator			
6 Air conditioner			
7 Washing machine			
8 Other (________)			

Thank you for your cooperation

Figure 3 Questionnaire distributed to business entities in Cyberjaya

Appendix D Case Study of Iskandar Malaysia

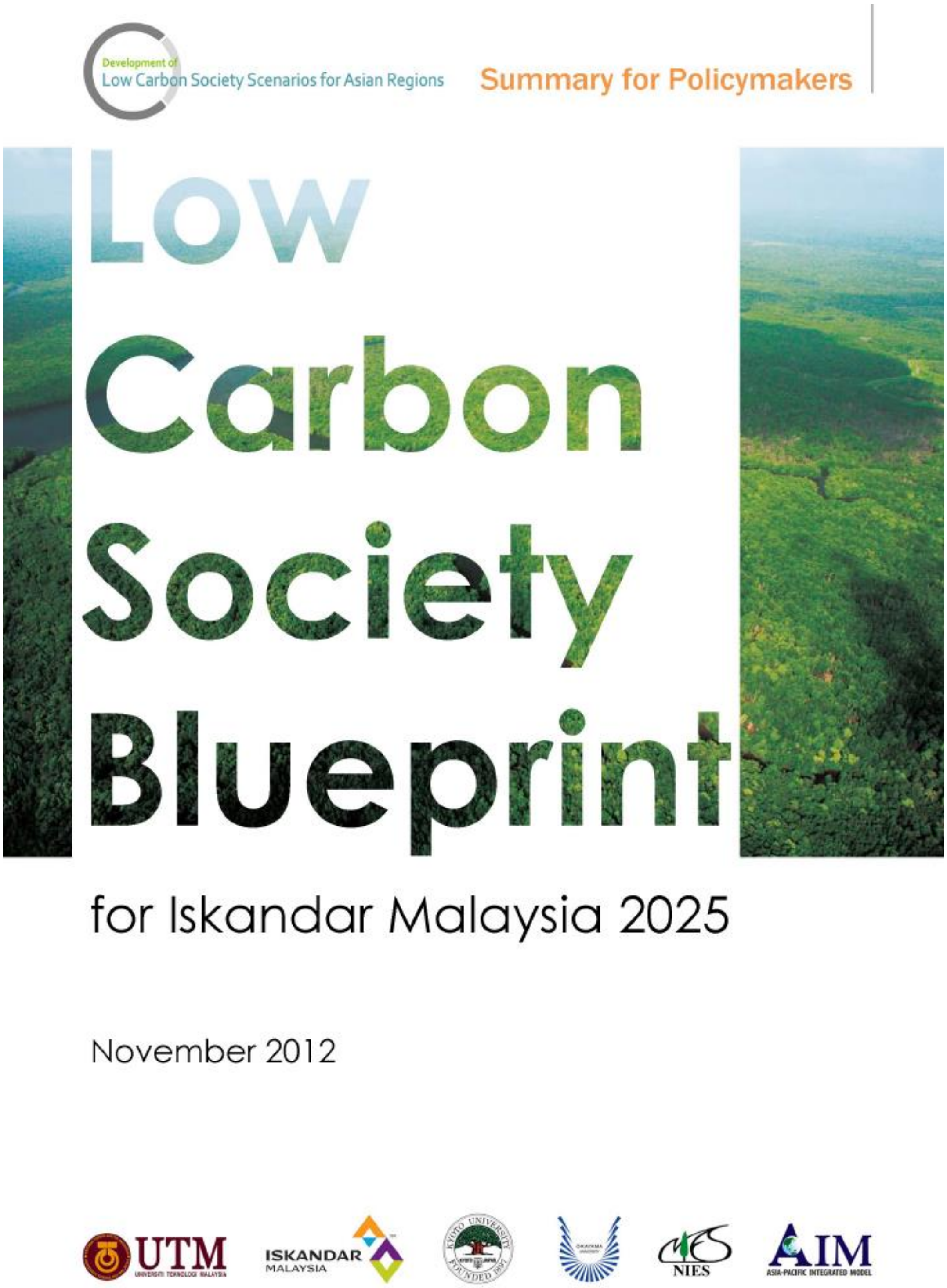
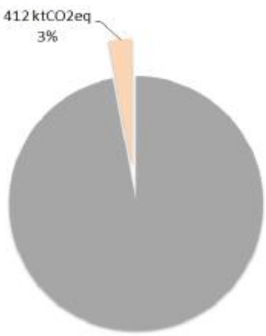


Figure 1 Brochure of Iskandar Malaysia Green City 2025 study

11 Sustainable Waste Management

Greenhouse Gases Reduction



Main objective of Sustainable Waste Management is to figure out alternatives solid waste management (SWM) system that can prevent waste generation and enhance material and energy recovery – SWM that fulfill the challenge of building both low-carbon and sound material cycle society. Four sub-actions were considered in the model of Sustainable Waste Management to achieve the target of half reduction of final waste sent to landfill site and half GHG emission from alternative methods, compare to business as usual (BaU) scenario. The actions are (1) Sustainable municipal solid waste management, (2) Sustainable agricultural waste management, (3) Sustainable industrial waste management, (4) Sustainable waste water management and (5) Sustainable construction and demolition waste management. Implementation of measures and programs under these sub-actions projected to reduce carbon emission in Iskandar Malaysia by 412ktCO2 equivalent (3% of total emission reduction) in 2025. Total reduction of final waste to landfill is 2500kton/year.

	Sub-actions	Measures
1	Sustainable Municipal Solid Waste Management	Reduction at source
		Recycling of municipal solid waste
		Extended final disposal
		Effective waste transportation
2	Sustainable Agricultural Waste Management	Biomass to wealth
3	Sustainable Industrial Waste Management	Scheduled waste reduction and treatment
		Non-scheduled waste reduction, reuse and treatment
4	Sustainable Waste Water Management	Better waste treatment and sludge recycling
5	Sustainable Construction and Demolition Waste Management	Effective construction waste treatment

Figure 2 Action 11 – Sustainable Waste Management of IM2025

Sustainable Municipal Waste Management

In general waste composition of developing country is mainly of organic waste and in Iskandar Malaysia 40% of its MSW is food waste. Implementation of household composting and decentralized composting for business sector is the best solution for this type of waste. Anyhow, the most effective alternative waste treatment towards reduction of final landfill amount and GHG emission is incineration.

Measure 1: Reduction at source

Programs:
- Smart consumption (buy in bulk, refill & concentrate local product)
- Choose durable and reusable item
- Restrict of using non-recyclable packaging
- Encourage culture of sharing, borrowing or renting instead of buying
- Choose online digital services, paperless services
- Buy product from recyclable material
- Pay-as-you-throw" system by 2015
- Scheduled waste collection for bulky waste

Measure 2: Recycling of municipal solid waste

Programs:
- Composting at home
- Decentralized composting plant
- Centralized organic waste recycle center
- Establishment of material recycling facilities (MRF)
- Incineration for energy recovery
- Recycling of e-waste

Measure 3: Extended final disposal

Programs:
- Sanitary landfill with methane gas capture to energy

Measure 4: Effective waste transportation

Programs:
- Separate waste collection at source
- Effective use of transfer station
- Optimization of waste collection routes
- Selection of appropriate size of collection vehicle
- Use of collection vehicle driven by biodiesel fuel (BDF) or Natural Gas Vehicle (NGV)

Sustainable Agricultural Waste Management

Agricultural waste included all major crops residue and public green waste, but waste from palm oil plantation covers more than 90% of total generated agriculture waste and it is 8 times of municipal solid waste. Thus, programs on reducing and treatment of palm oil mill effluent (POME), empty fruit bunch, and palm kernel shell are focus of this sub-actions. All the programs focus on utilizing Clean Development Mechanism to crude palm oil and oil palm biomass factory.

Measure 1: Biomass to wealth

Programs:
- POME to biogas
- Onsite co-composting
- Centralized organic waste centers
- Formulation of biomass into animal feed

Sustainable Industrial Waste Management

In Malaysia as general, another major challenge in industrial waste management besides its massive generation amount is centralization of schedule waste into one treatment plant for Peninsular Malaysia. With two flagships focusing on industrial development, the management of industrial waste treatment is crucial. Besides improvement in production process through cleaner production, improvement of reusable waste cycle through industrial symbiosis within Iskandar Malaysia industrial area is also another option in reducing amount of total waste generation.

Measure 1: Scheduled waste reduction and treatment

Programs:
- Encourage cleaner production initiative
- Select of treatment method with less energy and less material
- Decentralized scheduled waste treatment plant
- Smelting of inorganic wastes

Measure 2: Non-scheduled waste reduction, reuse and treatment

Programs:
- Encourage cleaner production initiative
- Introduce industrial symbiosis for waste reusing system
- Waste to fuel and production of bio-diesel fuel
- Incineration for energy recovery

Sustainable Waste Water Management

Sewage sludge massive generation is inevitable due to the major increase in population within Iskandar Malaysia. With better management of sewage sludge could improve GHG emission from this sector such as anaerobic digestion for methane gas production. Shifting from individual septic tank to centralized mechanical sewerage system is also another option.

Measure 1: Better waste water treatment and sludge recycling

Programs:
- Design of better wastewater treatment
- Sewage sludge recycling & recovery (Anaerobic digestion for methane recovery)

Sustainable Construction and Demolition Waste Management

As cities within Iskandar Malaysia expand rapidly, waste from building and facilities construction also generated massively. In term of waste reduction, 70% (2025) from 35% (2005) IBS implementation is set for newly constructed building in Iskandar Malaysia. As for material recovery almost 90% of waste from construction area is reuse and recyclable.

Measure 1: Effective construction and demolition waste treatment

Programs:
- Recycling of construction and demolition waste

Figure 3 Action 11 – Sustainable Waste Management of IM2025

1 A. Attribute of head of household

1.1 Age

①18 – 24 ②25 – 34 ③ 35 – 39 ④ 40 – 44 ⑤ 45 – 49 ⑥50 – 54 ⑦ 55 – 59

⑧ 60 – 64 ⑨ 65 – 69 ⑩over 70

1.2 Gender

① Male ②Female

1.3 Race

①Malay ②Chinese ③Indian ④Other

1.4 Religion

①Islam ②Christian ③Hindu ④Buddha ⑤Other

1.5 Occupation

①Professional ② Administrative ③ Clerical ④ Sales ⑤ Services ⑥ Agricultural

⑦ Production ⑧ Other

B. Household characteristic

1.6 Household size including respondent

① 1 person ②2 person ③3 person ④4person

⑤5 person ⑥6 person ⑦7 person ⑧ 8 person ⑨ 9 person ⑩ 10 and more

1.7 Average monthly household expenditure

① below than RM500 ② RM 500 – RM 999 ③ RM 1000 – RM 1499 ④RM 1500 – RM 1999

⑤ RM 2000 – RM 2499 ⑥ RM 2500 – RM 2499 ⑥ RM 3000 – RM 3499

⑦ RM 3500 – RM 3999 ⑧ RM 4000 – RM 4499 ⑨ RM 4500 – RM 4999 ⑩ more than 5000

1.8 Are you hiring housekeeper?

① Yes ② No

2 Awareness

2.1 Do you know waste collection days of your area?

① Yes ② No

2.2 Do you know where the collected waste is being sent?

① Yes ② No

2.3 Have you ever seen the 3 different colour recycling bins?

① Yes ② No

If your answer is yes, answer the next question. If your answer is no, proceed to question 2.5

2.4 Do you know what does the colour represent?

① Yes ② No

2.5 Have you ever heard of "3R"?

① Yes ② No

If your answer is yes, answer the next question. If your answer is no, proceed to question 2.7

2.6 Do you know what does the "3R" represent?

① Yes ② No

2.7 Do you know that most of waste generated can be Recycle, and will reduced the amount of waste in the landfill area thus help lengthen the landfill lifespan?

① Yes ② No

Figure 4 Questionnaire distributed to household in IM – Page 1

2.8 Do you know that by Recycling we are not only helping to conserves our country natural resources but also helping to conserves world natural resources?

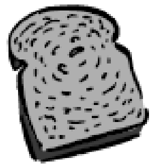
① Yes ② No

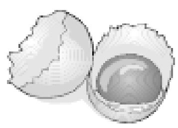
3 Waste generation and separation

Currently, in Europe and Japan, household wastes are being collected by segregation. The wastes are first separated into several groups according to its types such as paper, plastic and glass by the households' members before being collected by the waste collector. Later, the collected wastes are being treated to be used as a new products, this process is called Recycle. Some of the benefits of Recycling are that besides conserving natural resources such as timber, water, and minerals, it helps to reduce the amount of wastes sent to the landfill area. Recycling also prevents pollution caused by the manufacturing of products from virgin materials, saves energy and decreases emissions of greenhouse gases that contribute to global climate change. In a nutshell, segregation and recycling helps sustain the environment for future generations.

3.1 How much of the following waste type is generated in your household in weekly basis


Epal = 200 gram


Sekeping roti = 20 gram


Sebiji telur = 80gram


Sehelai kertas A4= 4 gram

	1	2	3	4	5	6	7	8	9	10
Food (gram)	0	1 - 49	50 - 99	100 - 149	150 - 199	200 - 249	250 - 299	300 - 349	350 - 399	More than 400
	Food residual and untouched food excluding the packaging and wrapping									
Paper (gram)	0	1 - 49	50 - 99	100 - 149	150 - 199	200 - 249	250 - 299	300 - 349	350 - 399	More than 400
	Book, magazines,newspaper, wrapping paper, paper box									
Other paper (gram)	0	1 - 49	50 - 99	100 - 149	150 - 199	200 - 249	250 - 299	300 - 349	350 - 399	More than 400
	Tissue, phamplet, paper bag,									
Plastic and rubber	0	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	11 - 12	13 - 14	14 - 15	More than 15
	PET bottle (mineral water, coca-cola, cooking oil, etc)									
Other plastic and rubber (gram)	0	1 - 49	50 - 99	100 - 149	150 - 199	200 - 249	250 - 299	300 - 349	350 - 399	More than 400
	Wrapping plastic,egg shell, pail,rubber (sandle, ball, pipe hose, tyres, tubes)									
Glass (gram)	0	1 - 49	50 - 99	100 - 149	150 - 199	200 - 249	250 - 299	300 - 349	350 - 399	More than 400
	Beverages, alchohol,perfume, seasoning bottle									
Metal (item)	0	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	11 - 12	13 - 14	14 - 15	More than 15
	Canned food, drinks, spray and cookies can									
Other metal (item)	0	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	11 - 12	13 - 14	14 - 15	More than 15
	Cooking appliances (frying pan, pot, etc), etc									
Ceramics (item)	0	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	11 - 12	13 - 14	14 - 15	More than 15
	Tableware, pasu bunga									
Other (item)	0	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	11 - 12	13 - 14	14 - 15	More than 15
	Sports equipment, toys, stationery,									

Figure 5 Questionnaire distributed to household in IM – Page 2

3.2 How much of the following waste type is generated in your household in monthly basis

	1	2	3	4	5	6	7	8	9	10
Textile (gram)	0	1 - 49	50 - 99	100 - 149	150 - 199	200 - 249	250 - 299	300 - 349	350 - 399	More than 400
	Shirt, pants, dress, underwear, bedlinen									
Other textile (gram)	0	1 - 49	50 - 99	100 - 149	150 - 199	200 - 249	250 - 299	300 - 349	350 - 399	More than 400
	Household textile (curtain, bedlinen), etc									
Garden waste (gram)	0	1 - 49	50 - 99	100 - 149	150 - 199	200 - 249	250 - 299	300 - 349	350 - 399	More than 400
Bulk waste (item)	0	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	11 - 12	13 - 14	14 - 15	More than 15
	Furniture									
	0	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	11 - 12	13 - 14	14 - 15	More than 15
	Floor coverings									
	0	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	11 - 12	13 - 14	14 - 15	More than 15
	Electrical appliances									
Other bulk waste (item)	0	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	11 - 12	13 - 14	14 - 15	More than 15

3.3 How many times do you throw away your household waste?

① Twice a day ② Once a day ③ Every other day (once in 2 days)

④ Once a week ④ Twice a week ⑤ Depends on the amount

3.4 How much time do you spend in a day handling your household waste?

①less than 5 minutes ② 5 to 10 minutes ③ 11 to 15 minutes

④16 to 20 minutes ⑤ 21 to 25 minutes ⑥ 26 to 30 minutes

⑦more than 30 minutes

3.5 Do you try to minimize waste amount generated in your household?

① Yes ② No

3.6 Base on the following statement, if waste segregation is being introduced in your area, will you separate your household waste?

	Yes	No	Not Sure
Separating our waste is essential as the amount of waste being generated today causes immense problem. Segregation of municipal solid waste can be clearly understood by daily separating of household waste into different bags for the different categories of waste. Certain items are not biodegradable but can be reused or recycled. In fact, it is believed that a larger portion can be recycled, a part of it can be converted to compost, and only a smaller portion of it is real waste that has no use and has to be discarded.			
The separated waste have be kept in the house for some amounts of times before it is being collected by its category. For example, in Japan, biodegradable waste is being collected twice a week but not biodegradable waste is only being collected once or twice a month.			
Longer time have to be spend on waste handling. This is because you have to separate the waste into its category. For example, before u can throw one carbonated drink bottle, you have to clean it with water, take out the label and cap because both are plastic waste but the bottle is PET waste.			
Segragation helps to reduce the amount of waste that have to be sent to landfill			

Figure 6 Questionnaire distributed to household in IM – Page 3

Table 1 Result of Head of household information

	n	%		n	%
Q1. Age			Q4. Religion		
18 - 25	32	6.3	Islam	325	64.0
26 - 35	169	33.3	Christian	37	7.3
36 - 40	82	16.2	Tamil	25	4.9
41 - 45	41	8.1	Buddha	118	23.2
46 - 50	71	14.0	Other	3	0.6
51 - 55	59	11.6			
56 - 60	45	8.9	Q5. Job		
61 - 65	6	1.2	Professional	41	8.1
66- 70	2	0.4	Administration	32	6.3
over 70	0	0.0	Clerical	39	7.7
			Marketing	80	15.7
Q2. Gender			Services	147	28.9
Male	335	66.1	Agricultural	15	3.0
Female	172	33.9	Assemblers	14	2.8
			Other	139	27.4
Q3. Race					
Malay	315	62.1			
Chinese	125	24.7			
Indian	54	10.7			
Other	13	2.6			

Table 2 Result of Household information

	n	%		n	%
Q6. Number of household member			Q7. Average monthly expenditure		
1	0	0	less than RM500	33	6.5
2	18	3.5	RM500 - RM 1000	83	16.4
3	37	7.3	RM1001 - RM1500	138	27.3
4	117	23	RM1501- RM2000	102	20.2
5	126	24.8	RM2001-RM2500	55	10.9
6	114	22.4	RM2501-RM3000	24	4.8
7	36	7.1	RM3001-RM3500	5	1
8	37	7.3	RM3501-RM4000	13	2.6
9	18	3.5	RM4001-RM5000	15	3
more than 10	5	1	more than RM5000	37	7.3
			Q8. Maid hiring		
			Yes		23
			No		77

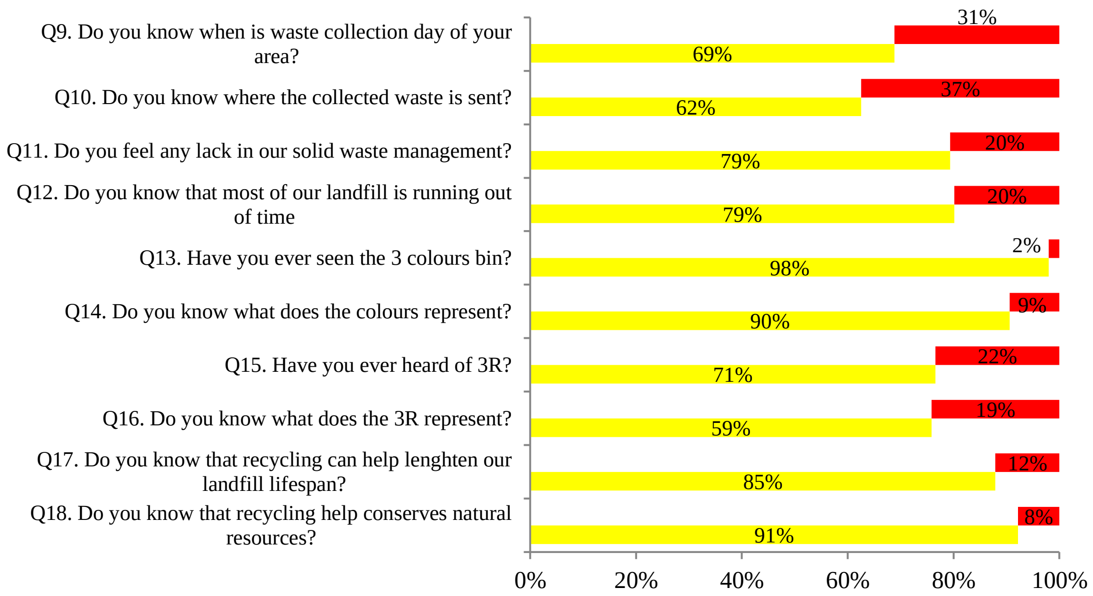


Figure 7 Result of awareness section *(Yellow: Yes, Red: No)*

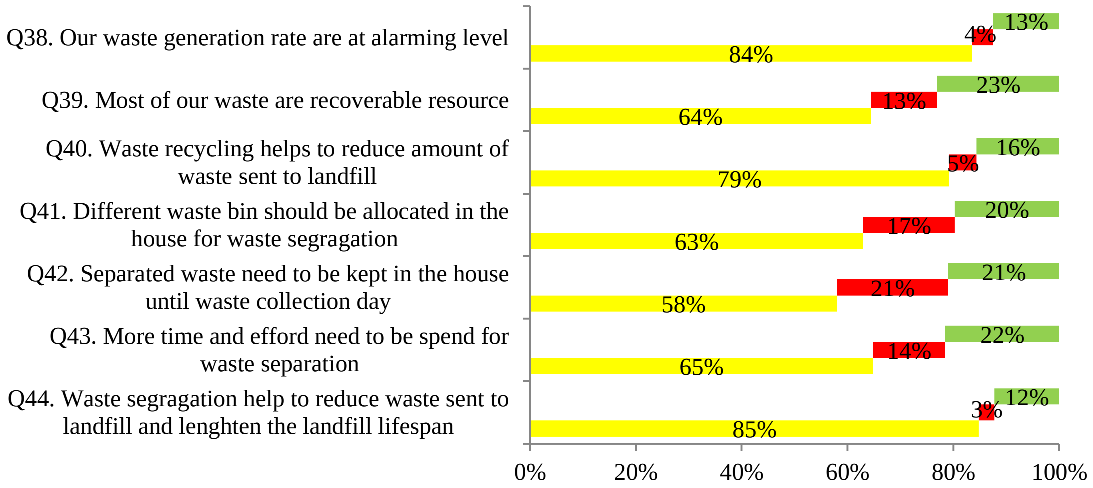


Figure 8 Result of willingness section *(Yellow: Yes, Red: No, Green: Not sure)*

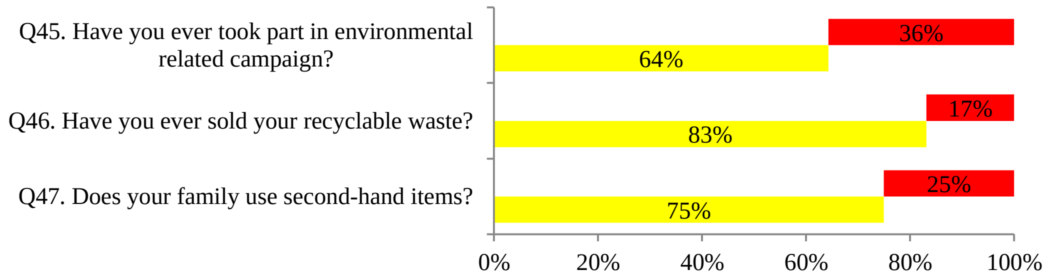


Figure 9 Result of participation section *(Yellow: Yes, Red: No)*

Table 3 Table for waste characterization in Seelong Landfill

		Food	Beverages	Clothing and footwear	Durable goods	Non-durable goods	Printed materials	Leisure items	Misc.
Food	Residual								
	Food preparing								
Paper	Recyclable								
	Other recyclable paper								
	Non-recyclable paper								
Plastic	Dense plastic								
	Plastic film								
	Non-recyclable plastic								
Glass	Bottles and jars								
	Other glass product								
Metal	Packaging								
	Product								
Textile	Clothing								
	Household textile								
	Non-recyclable								
Rubber	Packaging								
	Product								
Leather	Packaging								
	Product								
Garden waste	Grass, branch								
Ceramic	Packaging								
	Product								
Shopping bag	Paper								
	Plastic								
Other	Product								
	Packaging								