QUANTIFYING CARBON FOOTPRINT REDUCTION BY CONVERTING FOOD WASTE TO LIQUID COMPOST

HARSAHEB SINGH A/L SARJIT SINGH

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
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RESEARCH REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS IN SAFETY, HEALTH AND ENVIRONMENT ENGINEERING

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Matric No: KQD 170011

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ABSTRACT

Recently, Majlis Bandaraya Petaling Jaya (MBPJ) has developed a new facility called Smart Waste Solution Lab which is located at SS2. It was a pilot project and went fully operational in mid of May 2017. This facility uses the concept of circular economy where food waste is recycled to the benefit of the society. The aim of this study is to quantify the reduction of carbon footprint that can be achieved by recycling food waste. The purpose of this facility is to collect food waste from the nearby stalls and hawkers and hence convert it to liquid compost by the process of Anaerobic Digestion. This initiative has a lot of benefits which include carbon reduction, diverting waste from landfill and also generating income from the sales of liquid compost. However, this research will be focused on the quantification of carbon reduction based on waste reduction in this process. Basically, when food waste is diverted from landfills, emission such as carbon dioxide (CO_2) and methane (CH_4) can be avoided. Besides, since there will be less overall waste, number of trips to landfill site will also be reduced which will result in less carbon emission from dump trucks. All these carbon reductions will be quantified using a self-developed carbon calculator. This carbon calculator will measure and self-compute the carbon emission to the atmosphere taking into consideration the aspects of food waste, transportation and energy consumption. The method used in this study is giving out questionnaires to the waste operators in order to obtain information such as daily food waste collection and carbon emission from their daily operating process. Interview session were also carried out with MBPJ Authorities in order to gain more information. A period of six months is taken for data collection and the reduction of carbon recorded will be projected up to year 2030 to reflect the direction towards MBPJ Carbon Management Plan. All measurement will be done in accordance of carbon dioxide equivalent (CO_2 eq). Methane gas emission has a Global Warming Potential (GWP) of 28, meaning that 1kg of methane emitted to the atmosphere will be equivalent to 28kg of CO_2 emission. The results of the study show that a carbon reduction of almost 864 tonnes can be achieved for a period of one year. It is indeed a great initiative taken by MBPJ as it has set an example for other city councils to follow its footstep in contributing towards carbon reduction.

ABSTRAK

Baru-baru ini, Majlis Bandaraya Petaling Jaya (MBPJ) telah membangunkan kemudahan baru yang dikenali sebagai Smart Waste Solution Lab yang terletak di SS2. Ia merupakan projek perintis dan beroperasi sepenuhnya pada pertengahan Mei 2017. Kemudahan ini menggunakan konsep ekonomi pekeliling di mana sisa makanan dikitar semula untuk faedah masyarakat. Tujuan kajian ini adalah untuk mengukur pengurangan jejak karbon yang boleh dicapai dengan mengitar semula sisa makanan. Tujuan kemudahan ini adalah untuk mengumpul sisa makanan dari gerai dan penjaja yang berdekatan dan seterusnya mengubahnya menjadi kompos cecair dengan proses Penghadaman Anaerobic. Inisiatif ini mempunyai banyak faedah yang termasuk pengurangan karbon, mengalihkan sisa dari tapak pelupusan sampah dan juga menjana pendapatan daripada penjualan kompos cecair. Pada asasnya, apabila sisa makanan dialihkan dari tapak pelupusan, pelepasan seperti karbon dioksida (CO_2) dan metana (CH_4) boleh dielakkan. Selain itu, kerana terdapat kurang sisa keseluruhan, bilangan perjalanan ke tapak pelupusan juga akan dikurangkan yang akan mengakibatkan pelepasan karbon kurang dari lori sampah. Semua pengurangan karbon akan dikira menggunakan kalkulator karbon yang dibangunkan sendiri. Kalkulator karbon ini akan mengukur dan mengira sendiri pelepasan karbon ke atmosfera dengan mempertimbangkan aspek-aspek sisa makanan, pengangkutan dan penggunaan tenaga. Kaedah yang digunakan dalam kajian ini adalah menyediakan soal selidik kepada pengendali sisa untuk mendapatkan maklumat seperti pengumpulan sisa makanan harian dan pelepasan karbon dari proses operasi harian mereka. Sesi wawancara juga dijalankan dengan Pihak Berkuasa MBPJ untuk mendapatkan lebih banyak maklumat. Tempoh enam bulan diambil untuk pengumpulan data dan pengurangan karbon yang direkodkan akan dijangka sehingga tahun 2030 untuk menggambarkan arah ke arah Rancangan Pengurusan Karbon MBPJ. Semua pengukuran akan dilakukan mengikut setara karbon dioksida (CO_2 eq). Pembebasan gas metana mempunyai Potensi Pemanasan Global (GWP) dari 21, yang bermakna 1kg metana yang dipancarkan ke atmosfera akan bersamaan dengan 21kg pelepasan CO_2. Hasil kajian menunjukkan bahawa pengurangan karbon hampir 670 tan metrik dapat dicapai dalam tempoh satu tahun. Ini merupakan inisiatif yang hebat yang diambil oleh MBPJ kerana ia telah menetapkan contoh untuk majlis-majlis bandar lain untuk mengikuti jejak langkahnya dalam menyumbang kepada pengurangan karbon.

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Praise to Almighty God for giving me the strength and motivation to complete my research project as part of my Masters in Safety, Health and Environment Engineering. First of all, I would like to extend my appreciation and gratitude to my supervisor, Assoc Prof. Sumiani Yusoff for her advices and patiently guiding me through while completing my research project. Her guidance and blessing are all that I needed to make this project a success. Her continuous encouragement makes me believe and not to give up while completing my research project. A million thanks for being a great and inspirational supervisor.

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LIST OF SYMBOLS AND ABREVIATIONS

AD	**: Anaerobic Digestion**
CH_4	**: Methane**
CO_2	**: Carbon Dioxide**
COP	**: Conference of Parties**
GDP	**: Gross Domestic Product**
GHG	**: Greenhouse Gases**
GWP	**: Global Warming Potential**
HFC	**: Hydrofluorocarbons**
ILC	**: Indigenous and local communities**
KeTTHA	**: Kementerian Tenaga, Teknologi Hijau dan Air**
LCA	**: Life Cycle Assessment**
LCC	**: Low Carbon City**
LCCF	**: Low Carbon City Framework**
LOS	**: Level of Service**
MBPJ	**: Majlis Bandaraya Petaling Jaya**
N_2O	**: Nitrous Oxide**
PFC	**: Perfluorocarbons**
SDG	**: Sustainable Development Goals**
SF_6	**: Sulphur Hexafluoride**
UNEP	**: United Nation Environment Programme**
UNFCCC	**: United Nation Framework Convention on Climate Change**
WCED	**: World Commission on Environment and Development**

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The purpose of this chapter is to give a brief understanding on the title "Quantifying Carbon Footprint Reduction by Converting Food Waste to Liquid Compost". This chapter will discuss about the project background, problem statement that arise from this topic, the main objectives, scope and significance of the study.

1.2 PROJECT BACKGROUND

As the threat of climate change becomes more acute, so does the need for adequate measures of impacts, management and mitigation. Although carbon footprints are increasingly being used by organizations in the public and private sectors, a number of challenges and questions need to be addressed (Wright, Kemp, & Williams, 2011). Among them, what does the term 'carbon footprint' actually mean? A carbon footprint is defined as the total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO_2) (Weidema, Thrane, Christensen, Schmidt, & Løkke, 2008). In other words, when we drive a car, the engine burns fuel which emits a certain amount of CO_2, depending on its fuel consumption and the

driving distance. When we use electricity in our house, the generation of the electrical power that we need will also have emitted a certain amount of CO_2.

Rees and Wackernagel developed the ecological footprint in the 1990s which is used to estimate the number of earths will be required to sustain current human behavior and energy resources consumption. Using the same concept, Anindita Mitra developed the carbon footprint which is used to measure the emission of carbon and keep track on the status of carbon emission. Carbon footprints are much more specific than ecological footprints since they measure direct emissions of gases that cause climate change into the atmosphere.

Apart from understanding the term of carbon footprint, it is more important to understand why we need to measure or calculate carbon footprint. First of all is to manage the footprint and reduce emissions over time. Calculating and quantifying a nation's carbon footprint can be an effective tool for ongoing energy and environmental management. In this case, Majlis Bandaraya Petaling Jaya (MBPJ) has started a new Smart Waste Solution Lab in Petaling Jaya (PJ) SS2 which begin around May 2017. This initiative is to turn green food waste such as discarded vegetables from the markets into liquid fertilizer called enzymes and biogas. The sales of the composts products will then be used to cover the operational cost of the project. A close-loop concept is being opted for this Living Lab whereby food waste is returned to nature as fertilizers and nothing from the composting process goes to waste.

1.3 PROBLEM STATEMENT

Over the past decade, several issues regarding climate change has been the headlines of the environment sector. A rise temperature of 0.5 ^{o}C may not sound high, but

actually this rise of temperature has a global impact which may cause massive natural disasters and extinction if not well controlled in the early stages. All these issues are due to excessive carbon emission (Peters et al., 2013). This is where United Nation Framework Convention on Climate Change (UNFCCC) came up with an international cooperation on how much each country should reduce their carbon dioxide emission under the Kyoto Protocol in order to save the world from further global warming effects.

With regard to waste, improper waste management may lead to soil contamination, climate pollution, air and water contamination which may lead to outbreak of diseases, harm towards animal and marine life and finally harm towards human (Cheng & Hu, 2010). Moreover, wastes that are being dumped to landfills releases methane, CH_4 gas which has an equivalent Global Warming Potential (GWP) 22 times of Carbon Dioxide, CO_2.

1.4 OBJECTIVE

The main objective of this project is to come up with a systematic method that is able to quantify the reduction of carbon footprint that can be achieved based on the effort by Majlis Bandaraya Petaling Jaya (MBPJ) to convert food waste to liquid compost. In order to understand and come up with this quantifying method, several sub objectives have been identified which includes:

i) To identify the sources and effects of ineffective waste management to the nation

ii) To quantify reduction of carbon footprint based on initiative done by MBPJ

1.5 PROJECT SCOPE

There are two major scopes involved in this project. First of all, carbon footprint measures the meission of carbon based on the daily activities done by humans or industries. All of greenhouse gas emissions are converted to carbon equivalent (CO_2e). A carbon

footprint accounts for all six Greenhouse Gas emissions that are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6). But in this project, only carbon dioxide and methane emission is going to be focused as it accounts more than 80% of the overall Greenhouse gas emission.

As we concentrate more on the emission of CO_2 and CH_4, there are many sources that contributes to its emission. There are both natural and human sources. Natural sources include decomposition, ocean release and respiration. Human sources come from activities like cement production, transportation, deforestation as well as the burning of fossil fuels like coal, oil and natural gas. However, in this project, it is only limited to quantify sources from waste.

1.6 SIGNIFICANCE OF STUDY

The issue of waste keeps gaining attention due to its improper management. The amount of waste generated is constantly increasing because increasing population means there are more people on the planet to create waste. Moreover, amount of food waste generated is nearly 50% of the total household waste being produced. Converting this food waste into something useful can indirectly reduce carbon emission, reduce the amount of waste at landfill site, reduce financial expenditure in the economy and finally saving a huge amount of energy.

Efforts and initiatives by MBPJ is also in line with the nation’s aspiration to reduce carbon emission as stated by our Prime Minister, Dato' Sri Haji Mohammad Najib bin Tun Haji Abdul Razak during the Conference of Parties 15 (COP 15) which was held in Copenhagen. During that conference, he said "I would like to announce here in

Copenhagen that Malaysia is adopting an indicator of a voluntary reduction of up to 40 per cent in terms of emissions intensity of GDP (gross domestic product) by the year 2020 compared to 2005 levels," [Utusan Online 2009]. This percentage was then further improved to reduction of 45% by the year 2030 compared to 2005 levels.

1.7 THESIS OUTLINE

In Chapter 1, the project background, problem statement, objectives and scope were defined to set the boundaries of the study. The significance of conduction this study was explained in detail.

In Chapter 2, a detail literature review will be done on sustainability development, Low Carbon City Framework (LCCF), waste management system in Malaysia, impact and ways to reduce Greenhouse Gas emission and countries with good waste management system.

Moving forward in Chapter 3, the methodology will be discussed focusing on Majlis Bandaraya Petaling Jaya (MBPJ) efforts and initiatives to convert food waste to liquid compost. Method to quantify carbon and methane reduction will also be discussed.

In Chapter 4, result and discussion will be focused on the amount of CO_2 and CH_4 can be reduced over a timeframe period of six months. Based on the obtained results, a 12-year period will be extrapolated to predict reduction in emission by year 2030.

Finally, in Chapter 5, a summary of obtained results will be done and hence recommendations will be suggested for future improvements.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Climate change and global warming are worldwide issue now. It requires the cooperation of all nations and parties to overcome this issue. Saying that, if only a certain group are against climate change, it may be too late until these effects may not be reversible. A close problem related to climate change and global warming is carbon footprint. Carbon footprint is the carbon emission of each people on the planet. In this chapter, topics such as sustainability development, Low Carbon City Framework (LCCF), waste management system, impact of Greenhouse gases and ways to reduce Greenhouse gas emission will be explained.

2.2 SUSTAINABILITY DEVELOPMENT

Sustainable cities are described as urban communities where communities would love to live. It is an environment where the urban areas coexist with the natural environment and its utilizations don't antagonistically influence the earth, save their normal nature and add to a high caliber of life. Practical urban areas are protected, well managed and provide a wide range of services. Increasing empirical evidence indicates that city sustainability is not just related to technical issues, such as carbon emissions, energy

consumption and waste management, or on the economic aspects of urban regeneration and growth, but also it covers social well-being of different groups living within increasingly cosmopolitan towns and cities (Rostami, Khoshnava, & Lamit, 2014).

In 1983, the World Commission on Environment and Development (WCED) came up with a report called “Our Common Future “more commonly knew as Brundtland Report 1987. This report gives a summary on the environmental problems happening around the world and also providing solutions to solve these problems.

The Brundtland Report and the concept of sustainability can be seen as an attempt to create awareness of the disturbing relations between human society and the natural environment, focusing on institutional, economic, ecological and social aspects. Sustainability is, however, not a clear cut homogeneous concept. It is a complex concept apart from the overall and quite broad principles. However, this report has able to create influence regarding environmental planning (Keeble, 1988). The rise of Brundtland Report has brought awareness on the establishment of sustainable development and sustainability energy development. **Figure 2.1** shows the concept to be adapted with regard to sustainable development.

Figure 2.1: Sustainable Development

Sources: United Nation Brundtland Report 1987

Sustainable development is a process of developing land, cities, business, communities and others without affecting the natural environmental condition just to for their own satisfaction. During this development, resources are maintained at minimum to ensure there are enough needs for the future generation. It is a continuous development process without disturbing the resources of environment and natural environment of the system (Pearce, Barbier, & Markandya, 2013).

There is a saying "you cannot make an omelette without breaking an egg". In other means, if there is a need of development, economic growth and social needs such as electricity and comfortable livings, certain sacrifice to the environment must be made. But referring to this, moderation and environmental protection is needed so that irresponsible developers does not take any advantage towards the environment. If everyone is committed and responsible towards the environment, the idea of sustainable development can be

achieved easily. **Figure 2.2** shows the concept to be adapted for sustainable energy development.

Figure 2.2: Sustainable Energy Development

Sources: United Nation Brundtland Report 1987

Sustainable energy development is a process of developing and utilising energy resources that meets the needs of the present without compromising the ability of future generations to meet their own needs. Some of the elements of sustainable energy are conservation of resources, energy diversification, alternative renewable sources.

There are also several protocol established to assist the United Nation Environment Programme (UNEP) in this matter. First is the Montreal Protocol. The Montreal Protocol is an international agreement designed to reduce the production and consumption of ozone depleting substances in order to reduce their abundance in the atmosphere, and thereby protect the earth's fragile ozone layer (Velders, Andersen, Daniel, Fahey, & McFarland,

2007). The original Montreal Protocol was agreed on 16 September 1987 and entered into force on 1 January 1989.

Next is the Kyoto Protocol. It is an international agreement within United Nation Framework on Climate Change Convention (UNFCCC) to address & delay global climate change by reducing greenhouse gas emissions. The Kyoto Protocol was adopted at COP3 (Conference of Parties) of the UNFCCC, in Dec 1997. Its first commitment period was from 2008 until 2012. Its primary aim is to legally bind Annex 1 countries (developed countries) to reduce their greenhouse gas emission by 5% - 8% with respect to year 1990 level. Annex 1 countries are industrialized countries while non Annex 1 countries are mostly developing countries (Grubb, Vrolijk, & Brack, 1997). As of June 2013, there are a total of 192 members. Unfortunately, Canada withdrew at end of December 2012. Malaysia signed UNFCCC on July 1994 making it Non-Annex 1 Member. Malaysia also signed the Kyoto Protocol in March 1999. In December 2009, in Copenhagen at COP15, Malaysian Prime Minister made a voluntary pledge for Malaysia to cut down our CO_2 emission by 40% of 2005 level. This number is then further improved and Malaysia pledge to cut down CO_2 emission to 45% by 2030. **Figure 2.3** below shows the parties of the Kyoto Protocol.

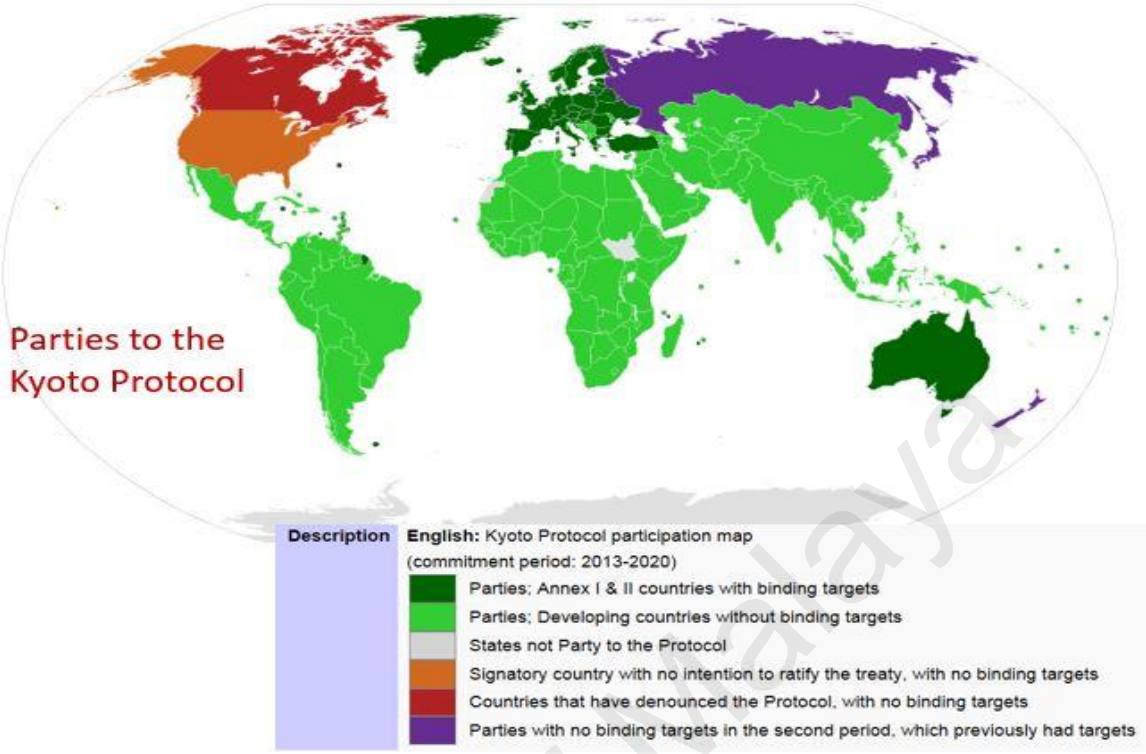

Figure 2.3: Parties to the Kyoto Protocol

Sources: Kyoto Protocol Participation Map for the commitment period of 2013 – 2020

2.2.1 11th Malaysia Plan

One of the major focus in the Eleventh Malaysia Plan, 2016-2020 is green growth which means reducing pollution and environmental impacts. This plan acts as a framework that will look to conserve existing natural resources to ensure they are not exploited by irresponsible parties. Besides, this plan will also develop strategies and implement new regulations to curb climate change. As a summary of the 11th Malaysia Plan, four key focus area has been identified.

Focus Area A: Strengthening the enabling environment for green growth

Green development requires principal changes and for this change to occur easily, the Government will give the significant arrangement and institutional structure for green development, for example, making long haul duty from all partners, organizations, common

society, and above all the general population. Three methodologies will be embraced to build up the empowering condition for green development:

1) Strategy A1: Strengthening governance to drive transformation

- Formulating and strengthening relevant policies and legislations
- Strengthening institutional framework
- Enhancing capacity and capability
- Improving checking and assessment instruments

2) Strategy A2: Enhancing awareness to create shared responsibility

- Well planned correspondence and mindfulness programs
- Platform for information exchanging and collaboration

3) Strategy A3: Establishing sustainable financing mechanisms

- Widening currents financial tools
- Funding green growth through new economic instruments

Focus Area B: Adopting the sustainable consumption and production concept

Sustainability is a term used to explain the manageability and use of resources such as water and energy in a way to ensure it can last for a long time. This also includes minimal waste emission. The following five strategies will be undertaken in this focus area:

1) Strategy B1: Creating green markets

- Implementing Government green obtainment
- Encouraging boundless appropriation of green structures criteria
- Strengthening green affirmation

2) Strategy B2: Increasing share of renewables in energy mix

- Exploring new renewable energy sources and enhancing capacity of renewable energy personnel
- Implementing net energy metering

3) Strategy B3: Enhancing demand side management

- Formulating a comprehensive demand side management master plan
- Expanding demand side management measures for buildings, industries and households

4) Strategy B4: Encouraging low carbon mobility

- Encouraging adoption of energy efficient vehicles
- Reducing environmental impact of transport sector

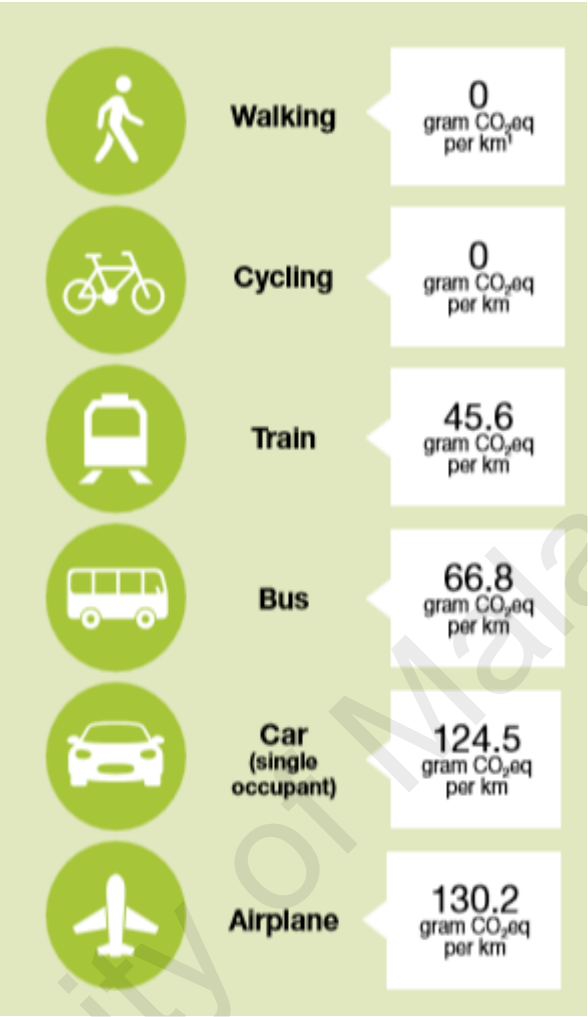

Figure 2.4: Comparison of Carbon Footprints by Different Transportation Modes

Source: 11th Malaysia Plan

5) Strategy B5: Managing waste holistically

- Increasing coordination on waste management
- Encouraging reduce, reuse and recycle (3R)
- Increasing investment in waste as a resource

Focus Area C: Conserving natural resources for present and future generations

Rationing Malaysia's biodiversity is a responsibility the Government will make to guarantee future ages have an indistinguishable access to these assets from the populace today. While Malaysia has vast forested zones, some have endured natural debasement in the ongoing past, featuring the need to additionally increase preservation endeavors. Expanding authorization against unlawful deforestation and poaching and undertaking reforestation in influenced zones will help towards this target. Two main strategies will be undertaken under this focus area.

1) Strategy C1: Ensuring natural resources security

- Conserving terrestrial and marine areas
- Conserving endangered plant and wildlife species
- Managing natural resources
- Strengthening biosafety

2) Strategy C2: Enhancing alternative livelihood for indigenous and local communities (ILC)

- Enhance ILCs involvement in biodiversity conservation
- Empowering ILCs for alternative economic opportunities

Focus Area D: Strengthening resilience against climate change and natural disasters

Expanded recurrence and power of cataclysmic events because of the antagonistic effect of environmental change has influenced the country. As Malaysia creates socio-economically, it is critical to guarantee its advancement picks up are not switched by catastrophic events. Strength of development is hence essential to guarantee the expansion

in ways of life appreciated by individuals today will keep on rising for who and what is to come. The accompanying systems will be embraced to achieve these goals:

1) Strategy D1: Strengthening disaster risk management

- Establishing a policy and institutional framework for disaster risk management
- Improving disaster detection and response capacity
- Incorporating DRM into development planning
- Improving communications and awareness

2) Strategy D2: Improving flood mitigation

- Generating investments from flood mitigation projects
- Long-term planning for flood mitigation
- Strengthening flood forecasting and warning system

3) Strategy D3: Enhancing climate change adaptation

- Developing a national climate change adaptation plan
- Building resilient infrastructure
- Strengthening natural buffers
- Increasing resilience of agriculture sector
- Creating public awareness on health impact of climate change

2.2.2 Malaysia's Green Technology Policy

Figure 2.5: Four Pillars of Green Technology Policy

Source: Malaysia Green Technology Corporation

Figure 2.5 shows the four pillars of the Green Technology policy. This policy is handled by The Ministry of Energy, Green Technology and Water Malaysia (KeTTHA). This ministry is responsible in coordinating and planning of strategies to ensure these pillars and goals are in line. The purpose of creating these pillars and goals is to ensure the betterment of nation lifestyle. **Figure 2.6** below shows the goals of the Green Technology policy.

Figure 2.6: Green Technology Policy Goals

Source: Malaysia Green Technology Corporation,2016

2.2.3 Challenges in Sustainable Development

Rising inequalities, the food, fuel and financial crises, and the breaching of planetary boundaries have made clear that a mere continuation of current strategies will not suffice to achieve sustainable development. The water, energy and food nexus shows the relationship and dependence between one sector and another and the importance to manage its resources. Global recession in 2009 due to financial crisis left a huge impact to many countries as the prices of food rose to new high level. The prices of food rose high because of the increase of fuel price (Gore, 2010).

As time passes with more rapid development, the rate of environmental degradation is increasing and this creates a challenge towards maintaining sustainability. Future predicts technologies will be available to overcome these challenges.

2.3 LOW CARBON CITY FRAMEWORK (LCCF)

It is well sure now that as a result of technology development, comes comfort such as urbanization which ease the community living and increase their standard of living.

However, together with comfort, come consequences such as global warming and climate change. This change has significantly increased the amount of CO_2 in the environment. Low carbon city is a framework to promote and encourage low carbon emission. Currently, there has not been a standard definition to define low carbon city. Low carbon city has quite similar characteristics to sustainable city. By controlling the emission of carbon designed with appropriate use of energy and resources consumption could create an ideal city that meets the specifications of a low carbon city. (Novotny, 2011).

Low Carbon City can be defined as a city that comprises of societies that consume sustainable green technology, green practices and emit relatively low carbon or GHG as compared with present day practice to avoid the adverse impacts on climate change. Two main criteria in Low Carbon City are:

- **Low carbon technology**

To promote the use of green technology as so to reduce carbon emission and at the same time increase energy consumption efficiency.

- **Low carbon usage**

In general, low carbon cities are incorporating some of the principles from sustainable development. In order to cause minimal effect to the environment, activities such as recycling and reusing are necessary. To ensure minimal carbon emission, cities are designed in such a way that it consumes less energy. Another advantage of low carbon city is it also uses renewable energy, recycling waste to convert into energy and composting to conserve the environment.(Premalatha, Tauseef, Abbasi, & Abbasi, 2013).

2.3.1 Needs of Low Carbon City Framework (LCCF)

The population in urban areas has been growing at a rate of 2.2% per annum versus the rural growth rate of 1.6%, over the period of 2000 to 2009 (Krausmann et al., 2009). Urban population has been rising from the year 2008. It is predicted that 75% of Malaysia's population will be urban population by the year 2020. (Ismail & Manaf, 2013).

Figure 2.7: Contributors to Greenhouse Gas Emission

Source: Cities and Climate Change-Global Report on Human Settlements 2011, UN-Habitat

The numbers in **Figure 2.7** above indicates that more and more people prefer to live in urban areas. Cities are normally the place where it consumes the most energy and temperature is normally the highest when compared to rural areas. Cities are also well known for its degradation towards the environment. Greenhouse gases gives the highest impact to global warming as these gases forms a layer in the atmosphere and traps heat in the environment by not allowing to escape the atmosphere. Malaysia has a carbon emission of 7.1 tonne per capita. This figure is definitely worrying as it is three times higher than the average emission in Asia Pacific based on the National Communications Report submitted

by each country to the United Nation Framework Convention on Climate Change (UNFCCC).

2.3.2 Benefits of Low Carbon City Framework (LCCF)

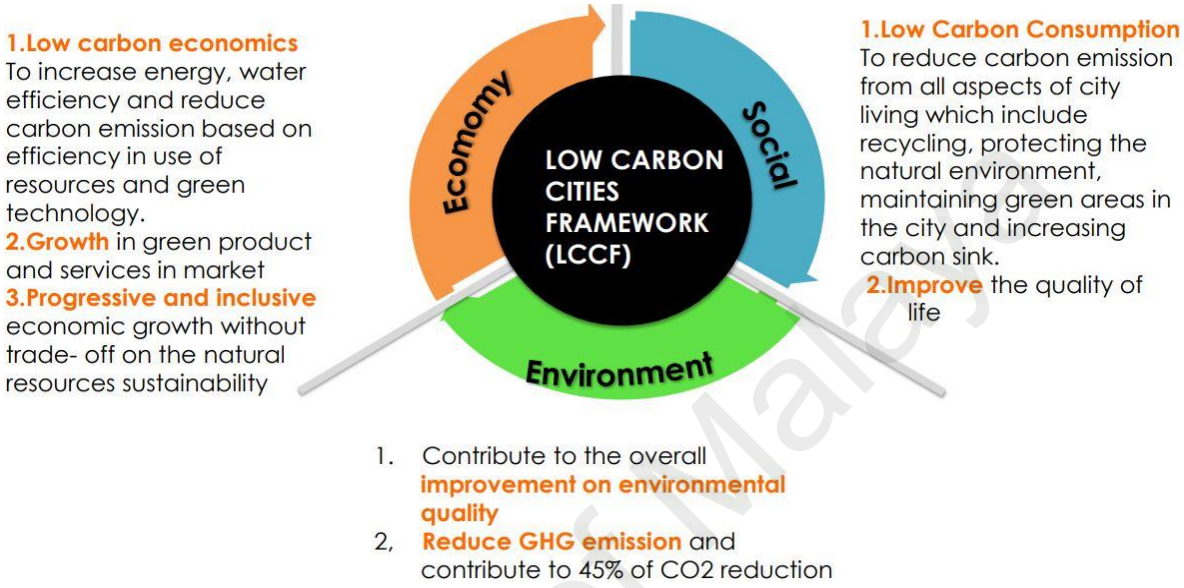

Figure 2.8: Benefits of LCCF

Sources: Malaysia Green Technology Corporation,2016

2.3.3 Majlis Bandaraya Petaling Jaya (MBPJ) Carbon Management Plan

Cutting carbon emissions as part of the fight against climate change should be a key priority for local and city governments around the world. The need to bring down carbon emissions to prevent global temperature increasing by more than two degrees over preindustrial averages is now urgent (Rogelj et al., 2016), and local government action is a key enabler of this as municipalities hold many planning, housing, community engagement, taxation and transport powers necessary to bring about a successful and prosperous low carbon transition. A clear mitigation strategy is vital. It will not only save money whilst it will also reduce the risk of dangerous climate change. MBPJ has developed a city carbon

action plan through to year 2030 that commits the city to a target of reducing CO_2 by 30% against business as usual.

On June 2016, Petaling Jaya Municipal Council was upgraded to a City Council (MBPJ) that has an estimated population of 620,000 people. The city comprises of an area of 97.2 square kilometers. Petaling Jaya is known as the leading growth centre in Selangor and estimates an increase in population rate by 2.7 % per year (Yaakob, 2006). This poses a significant threat in attempting to reduce carbon. In order to achieve the goal of 30% reduction, people in the city must reduce pollution, cut waste and avoid inefficient use of natural resources. A low carbon city will enhance the quality of life of the residents in the city towards a greener growth.

Aims of MBPJ Carbon Management Plan include:

- Reduce carbon emission up to 30% based on 2014 emission baseline
- Embrace in becoming a low carbon operated city
- Develop a systematic carbon management plan that acts as a guideline in carbon management
- Become a role model to other City Council to reduce carbon emission
- To promote positive economic impact

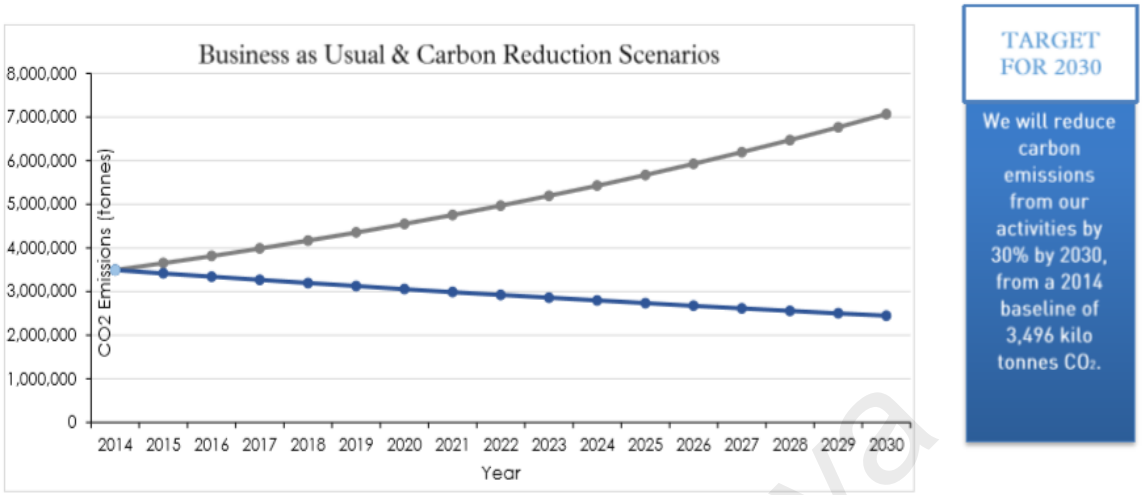

Figure 2.9: Carbon Reduction Target For Year 2030

Source: MBPJ Low Carbon City Action Plan,2015

Figure 2.9 above shows the carbon reduction target by the year 2030. Achieving a 30% reduction of carbon emission from baseline over this period will result in final year emission savings of 4,600 kilo tCO_2 by 2030.

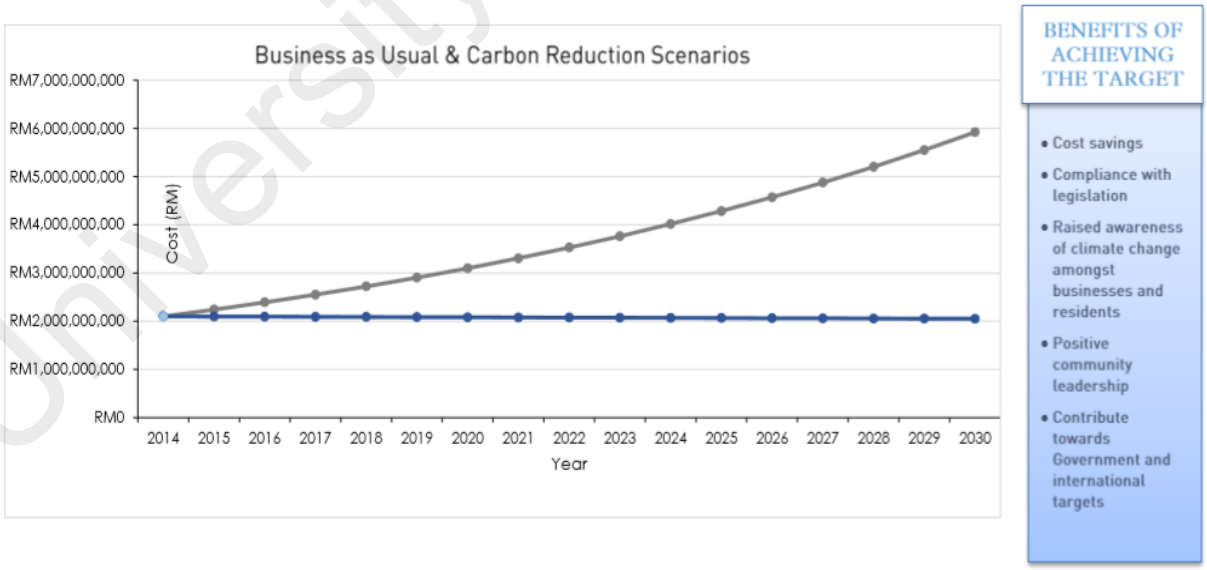

Figure 2.10: Savings Based on Carbon Reduction by Year 2030

Source: MBPJ Low Carbon City Action Plan,2015

Figure 2.10 above shows the savings that can be achieved based on carbon reduction by year 2030. With no action on carbon, annual energy costs could increase from RM 2.1 billion to almost RM 6 billion by 2030. Achieving a 30% of carbon reduction emission could result in gross cumulative savings to businesses, communities and people of Petaling Jaya.

There are basically six main goals listed in order to achieve a 30% reduction of carbon emission. These goals act as a guideline in various sectors such as energy, transportation, waste management, urban forestry and climate change adaptation. More focus will be given on waste management such as types of wastes being produced and how this waste is being managed in order to reduce carbon emission. Below are the lists of goals initiated.

GOAL 1: Buildings and Energy

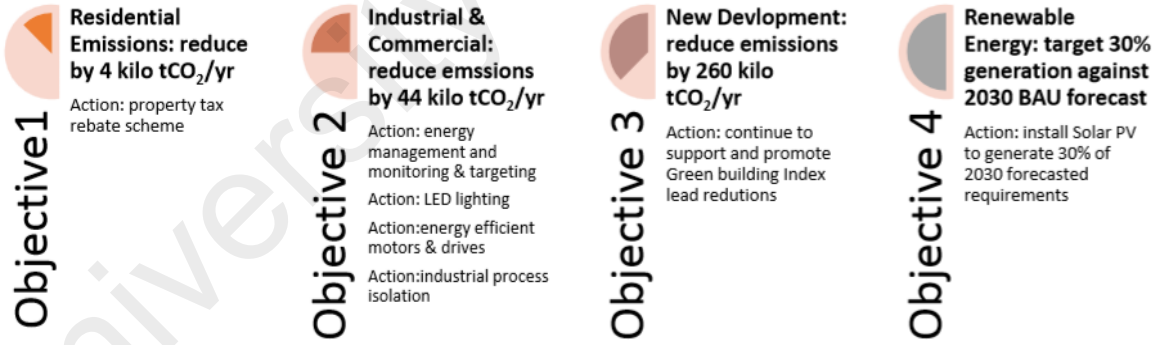

Figure 2.11: Objectives of Carbon Reduction for Buildings and Energy

Source: MBPJ Low Carbon City Action Plan,2015

Figure 2.11 shows the objectives of carbon reduction for buildings and energy. Building energy use is the largest contributor to carbon emissions in Petaling Jaya. This accounts for 63% of the measured footprint. Improving the energy efficiency of buildings

will not only reduce carbon but at the same time improve savings. All of these can be achieved by installing LED lights, using solar energy and 5 star rating electrical appliances.

GOAL 2: Transportation

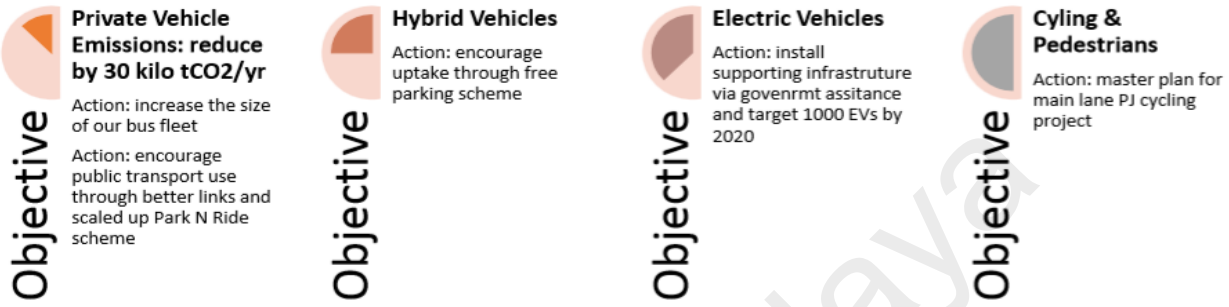

Figure 2.12: Objectives of Carbon Reduction for Transportation

Source: MBPJ Low Carbon City Action Plan,2015

Figure 2.12 shows the objectives of carbon reduction for transportation. Approximately, 17% of the land is dedicated for transportation. This percentage does not include LRT and KTM lines. Petaling Jaya experience's a high amount of road traffic congestion.. Level of service (LOS) is defined as the saturation level of the road. This is the ratio between volume of vehicles and road capacity. Roads are considered in bad congestion when LOS is more than one (de Palma & Lindsey, 2011). Part of this goal is to cope with traffic congestion by increasing accessibility of public transportation, PH City Free Bus and creating a city Cycleway Network.

GOAL 3: Waste Management

Amount of waste being generated in Malaysia has been on the rise. It is estimated that over 20,000 tonnes of waste are being generated daily from various fields. Similarly, with increase of urbanization, this number could rise up to 30,000 daily. (Aja & Al-Kayiem, 2014). From the amount of waste produced, only less than 5% are being recycled. More landfill means more carbon emission. **Figure 2.13** below shows the waste hierarchy.

As can be seen, prevention is at the top of the hierarchy and is at the core of many other countries waste management strategy.

Figure 2.13: Waste Management Hierarchy

Source: Environmental Protection Agency

GOAL 4: Urban Forestry

Urban forestry is defined as having a forest in the middle of the city. This can be achieved by planting large amounts of trees around the city. A city abundant with trees offers a wide range of benefits which includes improved air quality, more recreational areas and aesthetics neighborhoods. Trees act as an important role in addressing climate change as it absorbs CO_2 and releases O_2 (Barrett, 2009). The main objective of MBPJ is expanding the number of trees by planting 100,000 large coverage trees by 2030. In order to encourage the expansion of tree planting, several steps such as private programs to public to encourage planting, encourage the restoration of natural resources and creation of nature landscape around the city.

GOAL 5: Climate Change Adaptation

Rapid urbanization and population growth in Petaling Jaya is leading to increased vulnerability. This creates additional pressures on ability to respond to extreme weather events such as flooding, heat stress and droughts. This eventually has a negative impact on

the economy and also infrastructure of the city. Adapting to climate change will encourage socio economic development and reduce vulnerabilities of people and the city infrastructure. The main objective is to conduct a climate change risk assessment

GOAL 6: Local Government Operations

The main objective by local government such as MBPJ is to reduce carbon emission by 30% by year 2030 based on 2014 baseline. MBPJ identifies tangible and intangible benefits of Carbon Management and describe the governance arrangements to keep the programme on track. Reducing the energy consumption and carbon under out control not only reduces harmful greenhouse gas emissions but also delivers tangible cost savings. Some of the carbon reduction projects identified are good housekeeping, invest to save projects and investing in Solar Photovoltaic projects. One of the other projects to be focus on is to convert waste into liquid compost which can reduce waste being transferred to landfills. Furthermore, this converted waste can be used as compost for plantation or be sold to the public creating resources.

2.4 WASTE MANAGEMENT SYSTEM

Solid waste management is an organized management system that is responsible in collecting and treating waste either from household or industries. A part of this management system also includes separating recyclable items to ensure it is not sent to landfill. Solid waste management has been an issue for a long time. The best method is to reuse these items into something more valuable. (Hoornweg & Bhada-Tata, 2012). Awareness on solid waste management should be incorporated within all households.

Solid waste is one of the three major environmental problems in Malaysia. It plays a significant role in the ability of nature to sustain life within its capacity. Currently, over 33,000

tonnes of waste is produced each day in Malaysia (Agamuthu & Fauziah, 2011). Despite huge amount of waste being generated, only less than 5% are being recycled and another 95% are being sent directly to landfill. It is such a waste as there is still some values contain in the waste. Waste management standards in Malaysia are still not up to date compared with other advance countries as there are no proper guidelines or laws to be imposed to the relevant parties if they do not recycle their waste. As a result, most of it are just dumped in the landfill.

Solid waste management is done to ensure they do not cause any harm to the environment and also to human. The purpose is to ensure clean environment to improve quality of life and increase the standard of living. Some of the important parameter to be considered when involving solid waste management are:

- Proper handling of waste generation
- Systematic waste collection timetable
- Efficient transportation of waste to landfill site
- Separation of waste and treatment process
- Disposal or burying of waste

2.4.1 Sources and Types of Waste in Malaysia

There are many types of waste being generated in Malaysia. Unknowingly, most of the waste are mixed up and sent to the landfill. Improper waste handling and management can create negative impacts such as bad smell, existence of rodents and pests which can eventually cause harm to the health and safety of humans in the nearby locations (Khan & Ghouri, 2011). These wastes comprise of household, industrial, agricultural and other

various activities. **Table 2.1** below shows the sources of major waste generation in Malaysia.

Table 2.1: Types of Waste in Malaysia

Source	Typical Waste Generators	Types of solid wastes
Residential	Single and multifamily dwellings	Food waste, paper, cardboards, plastics, textiles, leathers, electronic goods, batteries
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants	Housekeeping waste, packaging, food waste, construction waste, hazardous waste
Commercial	Stores, hotels, restaurants, markets, office buildings	Plastic, wood, food waste, metals, hazardous waste
Institutional	Schools, hospitals, prisons, government centres	Paper, cardboard, plastic, wood, food waste, metals, hazardous waste
Construction and demolition	New construction sites, road repairs, renovation sites, demolition of buildings	Wood, steel concrete, dirt
Municipal Services	Street cleaning, landscaping, parks, beaches, recreational areas, water and wastewater treatment plant	Street sweepings, tree trimming, general waste from parks and beaches, sludge
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process waste, scrap materials, slag
Agriculture	Crops, orchards, vineyards, dairies, farms	Spoil food wastes, agriculture waste, hazardous

		waste (pesticide)

2.4.2 Effects of Ineffective Waste Management System

Improper waste management system such as delay in collection of waste causes waste to pile up which eventually creates problems. These problems are piling up and causing harm in many ways. First, it causes **pollution**. Since these wastes piles up and left under open environment of rain and sun, these wastes will start to decompose causing it to be absorbed under the soil. During rainy days, leachate produced will move around resulting in bad smell causing odour pollution to the surrounding. Besides, with the rapid growth of population, more waste is being produced. Sad to say the mentality of Malaysian towards waste management is still very low. Some may just throw rubbish out of a moving car or train. This waste end up in the nearby drain causing it to be clogged. This will result in great amount of waste including biodegradable waste (Desa, Kadir, & Yusooff, 2011).

Next, ineffective waste management system also creates a possible platform for the **spread of diseases**. Unhygienic condition becomes a breeding ground for rodents such as rats and becomes a potential spread of diseases such as cholera and leptospirosis. Moreover, it may also ruin the beauty of the particular area. Wates just being left by the roadside crates a negative impression from the visiting tourists. Industrial waste and effluents may require more proper handling as this waste may contain hazardous items that can cause **environmental pollution** (Förstner & Wittmann, 2012). The hazardous substance in the industrial waste can affect the fertility of soil causing the soil to be unfertile.

The most worrying effect of improper waste management system is it ccontributes to **climate change**. When waste is just left, it decomposes and produces methane gas as a bi product (Chandra, Takeuchi, & Hasegawa, 2012). Methane is considered as greenhouse gas.

Greenhouse gases absorb and retain heat from the Sun. They regulate the Earth's climate by holding warmth in an atmospheric blanket around the planet's surface. Scientists call this phenomenon as the Greenhouse Effect. Solid waste affects climate change through landfill methane emission. The source of manmade methane gas is from the landfills themselves, which happens when organic waste is left to decay anaerobically.

2.4.3 Air and Water Pollution

Wastes such as plastic, glass and paper must be ended up at a recycling facility. If it is incorrectly sent to landfills site or just be left at any other place, it has the possibilities of being absorbed into the soil.

- Plastic water bottles in the end breakdown to discharge DEHA, Diethyl hydroxylamine, a cancer-causing agent which harms our conceptive capacities, causes liver problems and weight reduction issues.
- DEHA saturates into soils and water bodies and damages the creature and vegetation subject to it.
- The ink from the paper isn't naturally reused by the earth. Rather, it pollutes this effectively declined soil, facilitating putting living creatures at grave hazard.

When, wastes are just left abandoned, it disintegrates and releases liquid called leachate. Liquid that forms as water trickles through contaminated areas is called leachate. It forms very harmful mixture of chemicals that may result in hazardous substances entering surface water, groundwater or soil. Leachate that flows into rivers cause potential threat towards animal and marine life. This can affect the properties of the marine ecology causing the fishes to die. The remaining of fish then floats on the surface of water resulting to water bound diseases.

2.5 IMPACT OF GREENHOUSE GASES

As the global population has increased over the years, more waste is being produced. Unnoticing, landfills areas are becoming limited and existing ones are becoming more compact. Wastes exposed at landfill area exposed to sunlight decompose with time and releases Greenhouse gases such as methane and CO_2. Gases such as carbon dioxide are already naturally occurring gas in the atmosphere and through our interference with the carbon cycle through burning forest lands, or mining and burning of coal, we artificially move carbon from solid storage to its gaseous state, thereby increasing atmospheric concentrations. All these activities have brought major impacts to the humans and more importantly to the environment.

2.5.1 Global Warming

Global warming is the momentum increment in temperature of the Earth's surface for both land and water and it's climate. Normal temperatures around the globe have ascended by 0.75°C in the course of the most recent 100 years. But something more to be worried is about two thirds of this increase has occurred since 1975 (Hansen, Ruedy, Sato, & Lo, 2010). Previously, when the Earth experienced increments in temperature it was the aftereffect of naturally occurring events but yet today it is being caused by the amassing of ozone harming substances in the environment created by anthropogenic activities. The greenhouse impact keeps up the Earth's temperature at a sheltered level making it workable for people and numerous other living things to exist. Be that as it may, since the Industrial Revolution anthropogenic activities have essentially improved the greenhouse impact making the Earth's normal temperature ascend by right around 1°C. This is making the worldwide temperature alteration we see today. Some may say how 1 ^{o}C can affect human life. But this rise of temperature is all related to the phenomenon of desertification,

increased in melting of snow and ice, rising of sea levels and natural disasters such as stronger hurricanes and cyclones.

Water issues such as water shortage is also becoming more adverse in countries where there are severe droughts. Season of rain can no longer be predicted as the season cycle change is no longer consistent. Shortage of water can result in severe droughts to the people in dry regions which are slowly being converted into a desert. This process is called **desertification.** Desertification also cause problems like infertile soil where the soil becomes not usable. The soil can be blown away by wind or washed away by rain. Nutrients in the soil can be removed by wind or water. Salt can build up in the soil which makes it harder for plant growth. Besides, the soil is not suitable for growing food. Therefore, the amount of food being produced will decline drastically. If the population is growing, this will cause economic problems and starvation. Moreover, desertification can cause flooding, poor water quality, dust storms, and pollution. These effects can hurt people living within the radius of affected region. **Figure 2.14** below shows the illustration of desertification.

Figure 2.14: Desertification

Sources: Editorial, G. (2015). Causes and effects of desertification.

Next impact is the melting of glaciers due to extreme temperatures. The north and south poles have been experiencing a much higher rate of melting of snow and ice. Based on research done by (Comiso & Hall, 2014) , the Artic has been experiencing the melting of snow at a rate of 11.5% per decade. This is very worrying as the ecosystem ahs been affected. Another research done by (McMillan et al., 2014) shows that the melt rate at Antartic has doubled. Melting of glaciers effect both humans and animals. Villagers who live near the Himalayas rely on fresh water supply from the melting of this glaciers. If this glaciers melt in a higher rate, it will interrupt the water supply in the future. In the case of animals, the Himalayan is home to some of the world's rarest animals, such as the Marco Polo sheep, the Himalayan brown bear and the Siberian ibex whose habitat is closely linked to the glaciers. **Figure 2.15** below shows the illustration of melting of snow and ice.

Figure 2.15: Melting of Snow and Ice

Sources: Melting glaciers, ice caps and sea-level rise (2013).

Besides, global warming also causes sea level to rise. The Earth's sea level has risen by 21 cm since 1880 (Church et al., 2011). The water level is rising at a great pace and it has shocked many researches. (Hunter, 2010). This increase in water levels is due to warmer temperatures cause the melting of ice and glaciers. Besides, the ocean may also expand due to warmer temperatures. When the ocean expands, there will be excess water. This will eventually affect low lying areas in the world where they may be at risk of being affected by flood. Not only human beings but also crops and animals are also at risk to be washed out by the ocean. Countries such as Bangladesh and India are more prone towards this risk. **Figure 2.16** below shows the illustration of rising of sea levels.

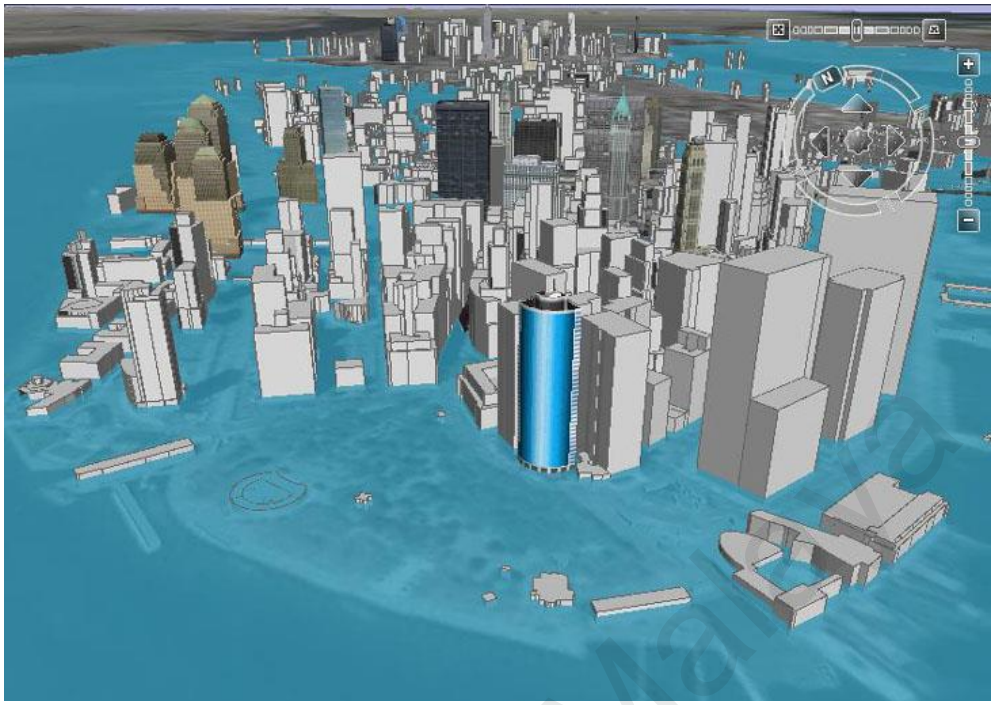

Figure 2.16: Rising of Sea Level

Sources: High resolution sea level rise Retrieved October 24, 2016, from the geography tools

Last but not the least, global warming create stronger hurricane and cyclones. Cyclones has becoming more common since the 19th century (Yu & Chiu, 2012). Cyclones are able to cause massive destruction depending on the intensity of it. Cyclones often come with strong winds accompanied by heavy rain. Sometimes, floods may also occur damaging houses and private properties. Due to stagnant water after the disaster, spread of disease is also quite common. **Figure 2.17** below shows the illustration of cyclones and hurricanes.

Figure 2.17: Hurricanes and Cyclones

Sources: Rice, D. (2014, June 2). Ladykillers: Hurricanes with female names deadlier

2.5.2 Climate Change

Climate change are undesirable changes in the environment that may cause disaster and harm the people and environment. Most of the impacts are already threatening the world. Such impacts are flooding, longer droughts and longer cold and heat waves. Flooding has affected low land areas. Longer droughts caused be to die and starve to death. Due to infertility of soil, crops are not able to grow. Cold and hot waves caused the ecosystem to be changed that not only affect humans but also plants and animals. **Figure 2.18** until **Figure 2.20** shows some of the effects of climate change.

Figure 2.18: Increased Flooding

Figure 2.19: Longer Droughts

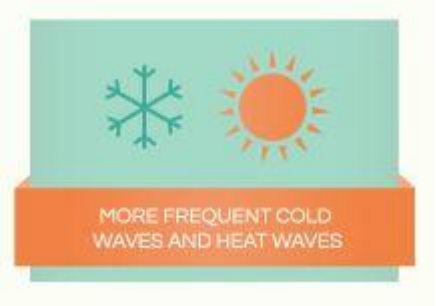

Figure 2.20: Cold and Hot Waves

2.5.3 Greenhouse Effect

When the level of carbon dioxide increases in the atmosphere, it rises to the ozone layer. As sunlight rays enter in the atmosphere, it cannot be reflected to the outer space because a layer of carbon dioxide is blocking the atmosphere. This cause the earth's surface to be hotter which lead to an increase of temperature. Another phenomenon is incomplete combustion. When there is incomplete combustion of fuel in the automotive and power plant industry, carbon monoxide, CO is being released to the atmosphere. This carbon monoxide then reacts with ozone, O_3 to form more carbon dioxide. Even more devastating, the ozone layer becomes thinner which causes sun rays to enter more easily. **Figure 2.21** below shows the structure of the ozone layer.

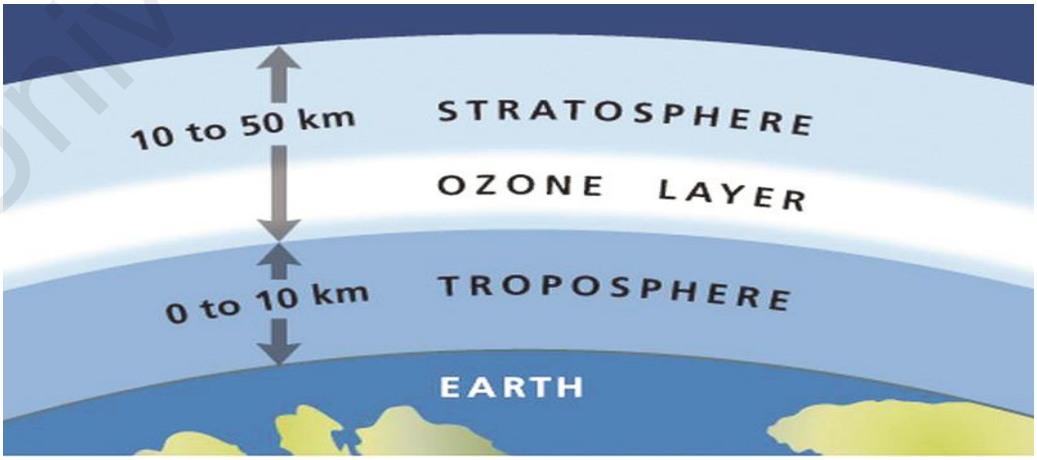

Figure 2.21: Ozone Layer

Sources: Observer, O. (2014, September 16). Oman observer.

2.6 WAYS TO REDUCE GREENHOUSE GAS EMISSION

Solving greenhouse gas emission is not an easy task. Greenhouse gas is a global issue. Only a few countries trying to reduce emission will only result in a minimal positive impact. All leading countries need to cooperate and committed in reducing greenhouse gas emission. Besides, not only industries are responsible. The community also plays as important role as their daily habits also contributes to the emission. There are a few ways where nations and people can take to reduce greenhouse gas emission and most importantly CO_2 emission.

The use of renewable energy is still lacking throughout the world. Resources such as solar and wind if harvested properly could result in plenty of savings. Renewable energy is delivered in the same way from fossil-fuel burning. These entire renewable energy source emit very less carbon dioxide and is clean to the environment. Alternative to this, humans can also consume less electricity. This can be done by installing programmable lights that switch on and off automatically with the presence of light. When changing any electrical appliances, look for appliances with energy star ratings. By changing human habits it can eventually fight global warming.

Figure 2.22: Green Technology

Sources: CactusThemes. (2016, September 1). CONTACT.

We throw too much away and still recycle too little of what must be discarded. Many of us are not used to recycling habit. By recycling, amount of waste being sent to landfill can be reduced. For an example, when purchasing electronic equipment, the item is heavily wrapped with plastics bubbles to protect it if it is accidently dropped. Most of us just throw in the dustbin. However, the plastic wrappers could actually be recycled by returning it back to the shop owner. Besides, old clothing could be repurpose to be used for cleaning or donated to charity. All these recycling activities reduces the power of purchasing which indirectly reduces energy consumption.

Figure 2.23: Reduce, Reuse, Recycle

Sources: Ind, E. N. (2016). 3R.

In addition, local products must be supported rather than imported products. Imported products travel thousands of mile by plane to arrive. All this travelling emits tremendous carbon dioxide. Food miles are now firmly part of the new carbon lingo. This is a way of expressing how far an item of food has travelled before it reaches your dinner table, and therefore how much CO_2 has been emitted during travelling. Therefore, buying local products avoid the travelling. When buying local food or products that were manufactured in your country or even more locally, nation's economy is being boosted. Most importantly, pollution is being reduced that are caused indirectly through consumption. Local consumption can really help reduce greenhouse gas emissions and impact.

Figure 2.24: Buying Local Products

Sources: Green, R. Buy local - rebel green: Eco-Friendly products responsibly made in the U.S.A.

Finally, some emissions are unavoidable. But, by proper offsetting programs, we can make up the amount of carbon dioxide that had been released to the atmosphere. One of the examples is planting trees. When gardening, select plants that are well suited to your climate and require minimal watering and attention. Better yet, plant a tree, and it will provide shade and soak up carbon from the atmosphere. Besides, encourage tree planting programs in school so the younger are well educated on the importance of carbon footprinting from the young.

Figure 2.25: Planting a Tree

2.7 LIFE CYCLE ASSESSMENT OF WASTE

Life Cycle Assessment (LCA) and Waste Management are intimately connected to one another, although they operate on two different levels. LCA, which regards the entire

life cycle of a product, also considers its end-of-life, and so Waste Management, in the defining and revisiting of its procedures and methodologies, makes use of LCA in order to carry out an in-depth evaluation of the environmental impact of specific choices and procedures.

As stated in the Malaysia Solid Waste and Public Cleansing Management Act 2007 (ACT 672), there are a few methods on food waste disposal. Some of the methods are either by composting, burying or incinerating (Lim, Chin, Yusof, Yahya, & Tee, 2016). Most of the waste operators prefer to use landfilling method. However, this is becoming more difficult as the number of empty lands are decreasing and there few space left to carry out landfilling process (Moh & Manaf, 2014). Besides that, incineration is also a preferred choice. However, the cost to operate is high and there is also a concern for air pollution (Zhang, Su, Baeyens, & Tan, 2014). As noticed, both landfilling and incineration causes environmental impacts. Hence, a proper disposal and waste management system is required.. **Figure 2.26** below shows the application of LCA to waste management.

Figure 2.26: Application of Life Cycle Analysis to Waste Management

Source: North Carolina State University,2015

2.7.1 Countries with Good Waste Management System

In **Japan**, there are two main generation of waste commonly known as industrial and non-industrial waste. Non industrial waste normally includes household waste. Industrial waste are normally managed by waste generators or are managed by private contractors (Matsuda, Yano, Hirai, & Sakai, 2012). Non industrial waste for food mostly comes from restaurant outlets which includes rice, vegetables meat and fruits.

Japan disposes huge amount of waste each year. Approximately, more than 5 times the amount of food given as charity are waste by local restaurant operators. However, despite producing huge amount of food waste, nearly 70% are recycled forming into useful substance. For instance, the leftover food waste are processed and converted into feed, methane gas extraction and fertilizers.

Another country with excellent waste management system is **Belgium**. Belgium is able to divert nearly three quarter of their waste into recycling, reusing or composting. One of the method developed by Belgium to divert their waste away from landfill is introducing the Ecolizer. Ecolizer functions as a calculator that is used to assess environmental impacts. Certain parameters such as energy used during processing and transportation required are investigated to measure its footprint.

Another initiative developed by Belgium is the green event and assessment guide. This is a tool that is sued to prevent waste generation by calculating the impact they can cause to the environment. Moreover, this tool has also location that provide free usable cutlery to avoid wastage of disposable plastic items

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter explains in details the methodology for Quantifying Carbon Footprint Reduction by converting Food Waste to Liquid Compost. The methodology is best expressed as the procedure on how research or data collection will be conducted. The summary of methodology for this study is shown in Figure 3.1. The flow chart shows the way from the beginning until the project is completed. Furthermore, tools such as Microsoft excel will be used to compute carbon footprint reduction. Target area for sampling and questionnaires designed will also be briefly explained.

3.2 FLOW CHART

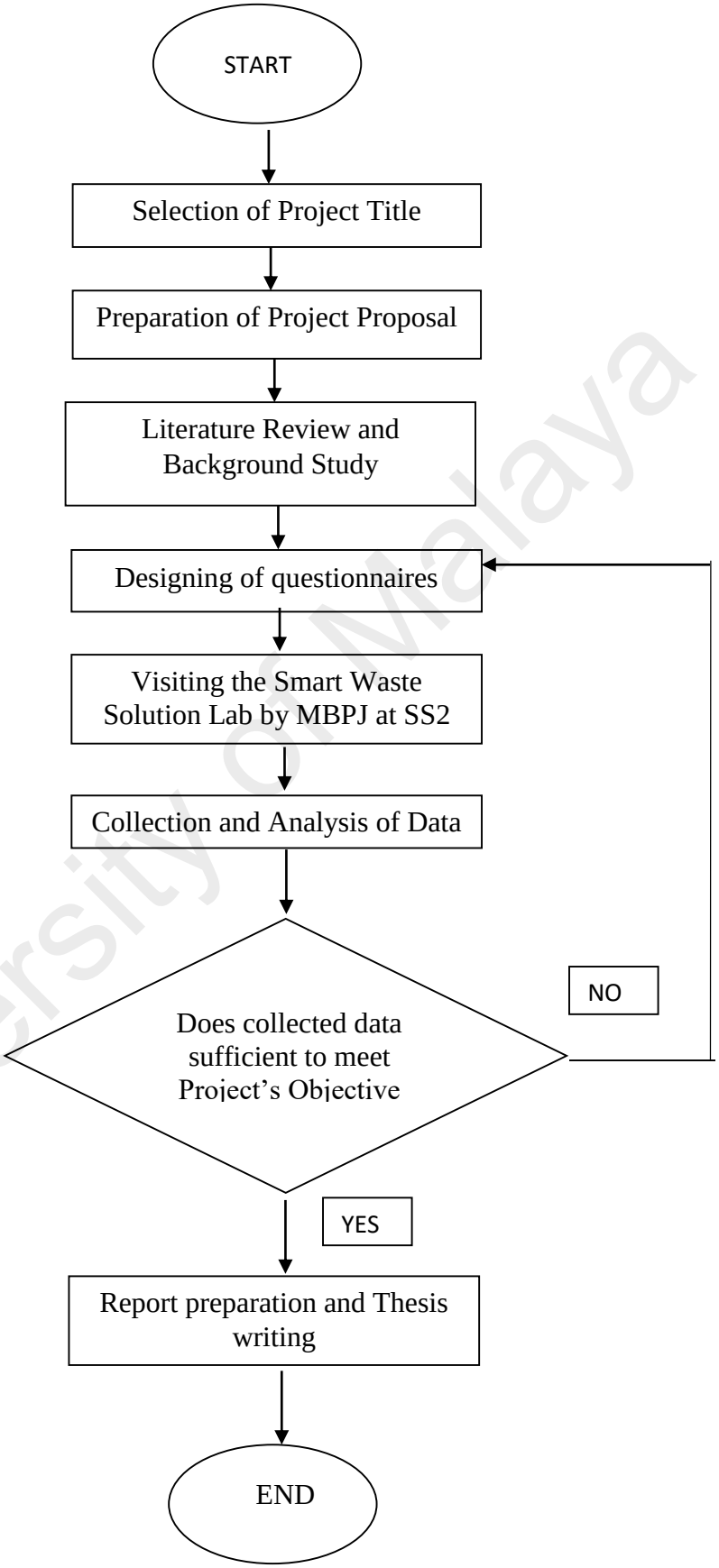

Figure 3.1: Project Flow Chart

3.3 SUMMARY ON ACHIEVING OBJECTIVES

In this subtopic, methods to achieve the objectives of this research will be explained in brief. In this research, there are three objectives. Hence, summary to achieve the objectives are shown in **Table 3.1** below.

Table 3.1: Methodology Summary

No	Objectives	Method Involved
1	To identify the sources and effects of ineffective waste management in Malaysia	Literature Review and secondary data assessment and evaluation
2	To quantify the reduction of carbon footprint by converting food waste to liquid compost	a) Literature review b) Questionnaires - to estimate carbon emission from food waste, transportation and operating emission such as electricity. c) Interview - to understand composting process and parameters that affect carbon emission d) Microsoft Excel - to quantify carbon emission

3.3.1 Target Sampling Area and Methodology Scope

Sampling area will be based at Majlis Bandaraya Petaling Jaya located at SS2 Petaling Jaya. Food waste will be collected from the nearby hawker stalls. Data will be collected based on total amount of food waste collected daily. SS2 hawker food stalls are chosen as sampling area because of its dense population and it is also near to Universiti

Malaya. The scope of the methodology will include timeframe, materials, boundaries and any related issues. Scope of methodology is shown in **Table 3.2** below.

Table 3.2: Scope of Methodology

Scope	Explanation
Timeframe	Data will be collected for a period of 6 months from January until June
Material Type	Material will be focused on food waste and organic waste from SS2 hawker stalls that can be composed
Boundaries	Geography: Petaling Jaya Organization: MBPJ
Other issues	Carbon emission before and after composting process

3.4 STEPS INVOLVED IN METHODOLOGY

In this section, detailing steps beginning from defining scope, designing of questionnaires until data analyzing will be discussed.

3.4.1 Scope Defining

While defining the scope to be taken into consideration for a carbon footprint calculation, the literature can consider two different approach of emissions.

Scope 1: direct emissions

Scope 2 indirect emissions that can be controlled by the project operator's action, typically electricity consumption.

Scope 3: Emissions that can be avoided

The following **Table 3.3** provides an overview of the scope of GHG emissions produced by a typical landfilling process compared to Anaerobic Digestion (AD) process being carried at Smart Waste Solution Lab.

Table 3.3: Scope of Greenhouse Gas Emission

Activity	**Scope 1: Direct Emissions**	**Scope 2: Indirect Emissions**	**Scope 3: Avoided Emissions**
Anaerobic Digestion	i. CO_2 released from fuels consumed in waste collection and transportation to and from the facility. ii. CH_4 and N_2O released in anaerobic processes during waste treatment	CO_2 from grid electricity consumption	CO_2 avoided through energy recovery from combustion of biogas produced in anaerobic digestion
Landfilling	i. CO_2 released from fuels consumption in waste collection and transportation to and from the facility. ii. CH_4 released from landfill	N/A	CO_2 avoided through energy recovery from landfill gas

3.4.2 Designing of Questionnaires and Interview

Questionnaires and interview questions were designed to meet the primary objectives of the research. These were done by giving out questionnaires to the waste

operators and also conducting interview sessions with the waste operators. This is to ensure the waste operators fully understand the topic and the objectives of the research. Some of the areas covered in the questionnaires and interview session are:

i. Estimation on daily amount of waste generated
ii. Waste composition produced by restaurant owners
iii. Waste collection, storage and handling
iv. Anaerobically Digestion (AD) process
v. Factors that affect the AD process
vi. Carbon emission from the AD process
vii. Transportation process to collect the waste

3.5 DEVELOPMENT OF CARBON FOOTPRINT CALCULATOR

The quantification of GHG emissions typically includes the following Kyoto gases that are considered most relevant for the waste management sector.

i. Carbon dioxide (CO_2)
ii. Methane (CH_4)
iii. Nitrous dioxide (N_2O)

Total emissions of these gases are counted in units of CO_2 equivalents (CO_2 eq), which are calculated based on their different global warming (GHG) potential:

i. GHG factor applied for CO2 emissions: 1
ii. GHG factor applied for CH4 emissions: 28
iii. GHG factor applied for N2O emissions: 265

3.5.1 Electricity

Based on Malaysia Energy Statistic Handbook 2017 printed by Suruhanjaya Tenaga Malaysia, its electricity generation mix are natural gas (43.5 %), coal (42.5%), hydro (13.0%), diesel (0.4%), fuel oil (0.3%) and others (0.35). The intensity of carbon emission is different based on the type of fuel used. The distribution of intensity of carbon emission is shown in **Table 3.4** below.

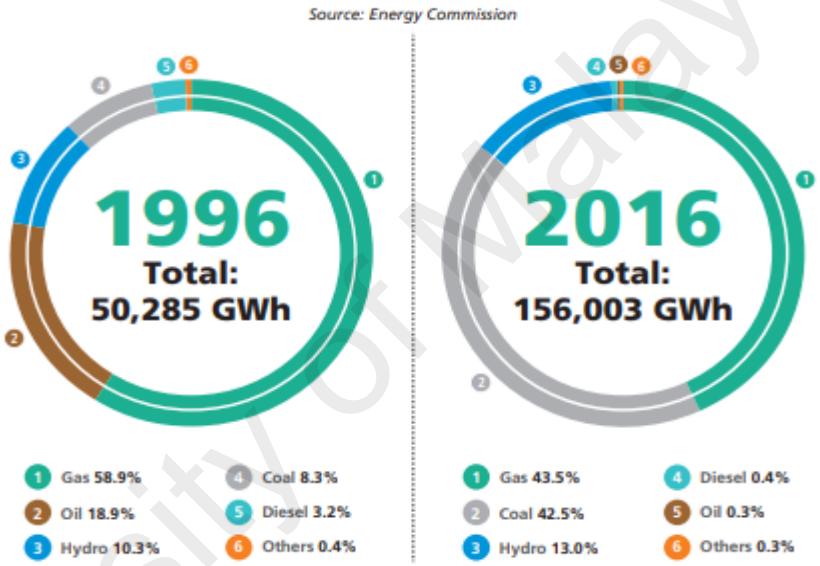

Figure 3.2: Malaysia's Electricity Generation Mix

Sources: Suruhanjaya Tenaga Malaysia 2017

Table 3.4: Intensity of CO_2 per KWh

Fuel Type	CO_2 Released per KWh (Kg)
Natural gas	0.37
Coal	0.76
Hydro	0
Diesel	0.27

Fuel oil	0.28

Sources: Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories

Based on electricity consumption in kilowatt hour (KWh), the amount of of CO_2 being released to the atmosphere can be calculated. This can be done by using the equation below:

Electricity Consumption (kWh) x CO_2 intensity (kg) x Electricity generation mix *(1)*

3.5.2 Transportation

For transportation, the amount of CO_2 being released to the atmosphere is calculated based on the amount of fuel (petrol or diesel) is used (litres). Unlike normal vehicle, dump truck to transport waste consumes more fuel. **Table 3.7** below shows the average emission of CO_2 per km tavelled

Table 3.5: Intensity of CO_2 per km

Fuel Type	Kg CO_2 Released per km
Diesel	10.03

Sources: Carbon Trust & MBPJ

Carbon emission from transportations can be calculated using the equation below:

Distance travelled (km) x CO_2 intensity (kg) *(2)*

3.5.3 Waste

Wastes are normally categorized as food wastes and organic wastes. These wastes release CO_2 and methane gas. One kg of waste releases approximately 1.04 kg of CO_2 and

0.075 kg of methane respectively. *(Sources: IPCC,Fifth Assessment Report)* Therefore, for calculation purpose:

Amount of waste (kg) x 1.04 kg CO_2 *(3)*

Amount of waste (kg) x 0.075 kg CH_4 *x 28 (4)*

The equation is multiplied with 28 in order to find equivalent CO_2 released from methane.

CHAPTER 4

RESULTS & DISCUSSION

4.1 INTRODUCTION

This chapter will analyze and discuss the results obtained from the questionnaire and interview session conducted. The first objective is to identify the sources and effects of ineffective waste management to the nation was achieved by conducting literature review respectively. For the second objective to quantify reduction of carbon footprint by implementing a close loop cycle at Smart Waste Solution Lab was achieved by conducting questionnaires and interview session with the waste operators and MBPJ staff at the site near SS2 Petaling Jaya. The carbon emission from initial process and improvised current process will be shown to quantify the reduction of carbon emission.

4.2 CARBON EMISSION FROM INITIAL PROCESS

Data was collected for a period of six months beginning from January to June 2018. Generally, carbon emission was focused on three different sectors mainly emission from the food waste, transportation and electricity consumption. For the initial process, all the food waste is dumped directly to the landfill collection area situated at SS2. This activity of open dumping will release Carbon Dioxide (CO_2) and Methane (CH_4) to the atmosphere. For transportation, the dump trucks will then transport all the waste to the landfill site which is known as Jeram Landfill. Only one dump truck operates and it will make three

trips daily from Monday to Sunday. For electricity, there is no electricity consumption as there are no any activities being conducted at the site. **Table 4.1** below shows a brief summary for the initial process. Based on the initial process, the carbon emission can be calculated

Table 4.1: Initial Process at SS2

Process	Activity
Food Waste	All food waste are directly disposed at landfill collection site
Transportation	One dump truck to transport waste from SS2 to Jeram Landfill three times daily everyday
Electricity Consumption	None

4.2.1 Carbon Emission from Food Waste

For food waste, there are three locations where operators send their food waste namely, Medan Selera Ibumie SS2, Selera Malam and morning market at SS2. **Table 4.2** below shows the breakdown of food waste can be collected from January until June 2018.

Table 4.2: Collection of Food Waste

Month	Food waste (Kg)			Total (Kg)
	Selera Malam	Morning Market	Ibumie	
January	2,979.97	8,732.36	1,149.75	12,862.08
February	1,432.05	6,507.86	661.90	8,601.81
March	2,033.55	10,778.73	1,242.08	14,054.36
April	5,919.57	26,018.95	526.00	32,464.52

May	1,205.26	8,812.89	1,090.70	11,108.85
June	809.67	8,387.50	1,026.05	10,223.22
Total	**14,380.07**	**69,238.29**	**5,696.48**	**89,314.84**

Hence, carbon emission from food waste can be calculated using equation 3 and 4.

From Equation 3,

Amount of waste (kg) x 1.04 kg CO_2 *(3)*

89314.84 kg x 1.04 kg CO_2

= 92887 kg CO_2e

From Equation 4,

Amount of waste (kg) x 0.075 kg CH_4 x 28 *(4)*

89314.84 kg x 0.075 kg CH_4 x 28

= 187561 kg CO_2e

*The equation is multiplied with 21 in order to find equivalent CO_2 released from methane.

Hence, total CO_2 emission from food waste is

= 92887 kg CO_2 + 187561 kg CO_2

= 280448 Kg CO_2e

Figure 4.1 below shows the screenshot of the Carbon Calculator developed to compute the emission of carbon from food waste by just inserting the amount of food waste collected.

Waste	Landfills (CO2)	89314.84	kg	92887.4336	
	Landfills (Methane)	89314.84	kg	187561.164	
	TOTAL				280448.5976

Figure 4.1: Carbon Emission from Food Waste

4.2.2 Carbon Emission from Transportation

For transportation, the dump truck transport the waste collected from SS2 to Jeram landfill which is located approximately at a distance of 42 km one way. Initially, the dump truck makes three trips daily everyday. Based on sources from Carbon Trust, for each km travelled, the dump truck releases 10.03 kg of CO_2 approximately. There is no emission for collection of food waste to collection site as all waste and transported by foot as it is walking distance. **Figure 4.2** below shows a sketch of the location of the Smart Waste Solution Lab, Ibumie Selera Makan, Selera Malam, Morning Market and Jeram Landfill. Carbon emission from the dump trucks can be measured using equation 2.

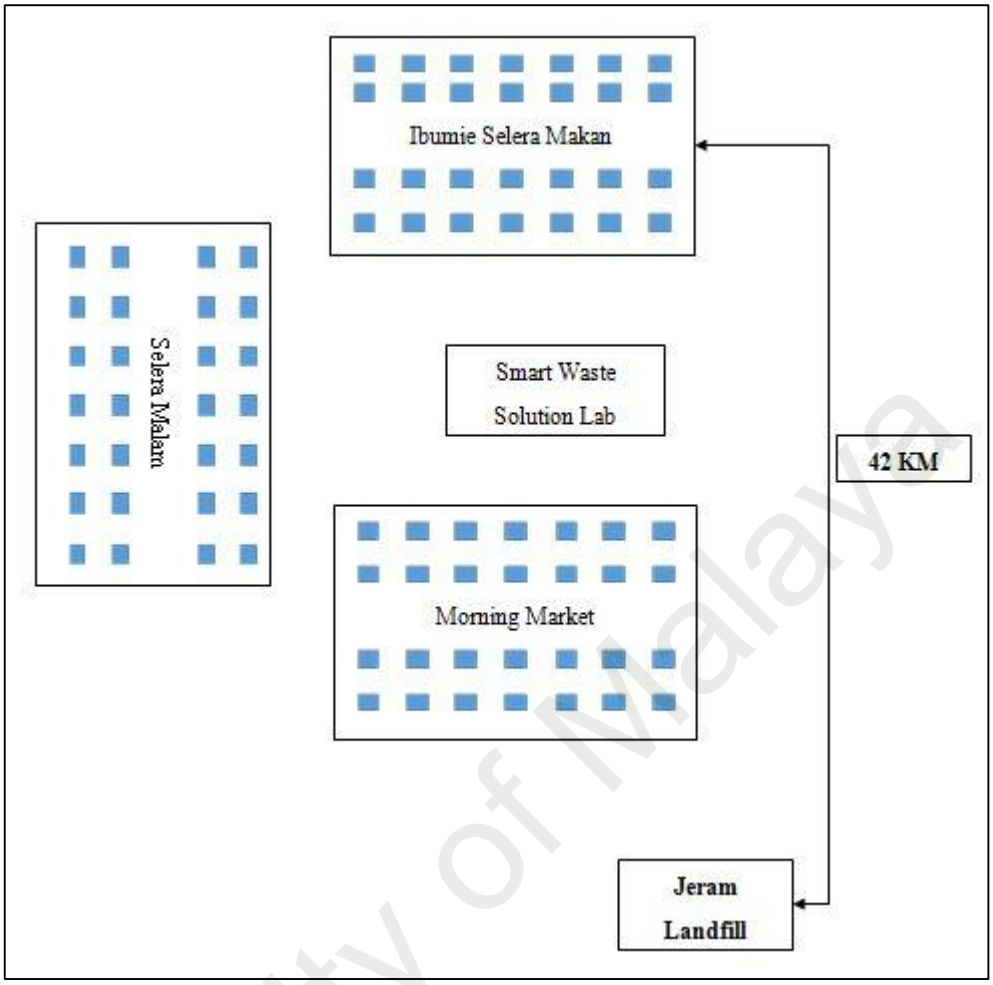

Figure 4.2: Map Sketch of Smart Waste Solution Lab

From Equation 2

Distance travelled in one day (km) x CO_2 intensity (kg) *(2)*

= 42 km x 2 way x 3 trips daily x 10.03 kg CO_2

= 2527.56 kg CO_2e / day

For a period from January until June, there is a total of 181 days

Hence, total CO_2 emission from transportation is:

= 181 days x 2527.56 kg CO_2 / day

= 457488 Kg CO_2e

Figure 4.3 below shows the screenshot of the Carbon Calculator developed to compute the emission of carbon from transportation by just inserting the total distance travelled by the dump trucks. Since the dump truck travel a distance of 252 km/day, hence the total distance travelled for a period of 181 days is 45612 km.

Transportation	Dump Truck (Diesel)	45612	km	457488.36	
	TOTAL				457488.36

Figure 4.3: Initial Carbon Emission from Transportation

Therefore, total carbon emission from the initial process is:

= carbon emission from food waste + carbon emission from transportation

= 280448 Kg CO_2 + 457488 Kg CO_2

= 737936 Kg CO_2e

4.3 CARBON EMISSION FROM CURRENT IMPROVISED PROCESS

Similar to the initial process, data was collected for a period of six months beginning from January until June 2018. In this case, carbon emission from food waste can be avoided as the food waste undergoes anaerobic digestion (AD) instead of being sent to landfill. Biogas produced from AD process is burnt instantaneously to avoid any

greenhouse gas emission to the atmosphere. Hence, it can be considered there is zero emission from food waste with this process. For transportation, the number of trips reduced from three trips to two trips daily due to lesser waste being sent to landfills. However, there is some minor emission due to electricity consumption. **Table 4.3** below shows a brief summary for the current process. Based on the current process, the reduction carbon emission can be calculated by comparing to the initial emission

Table 4.3: Current Process at SS2

Process	Activity
Food Waste	Food waste are collected and undergoes AD process to convert into liquid compost instead of sending directly to landfill
Transportation	One dump truck to transport waste from SS2 to Jeram Landfill two times daily everyday
Electricity Consumption	Minor electricity consumption from the use of machineries

4.3.1 Carbon Emission from Food Waste

Since all of the food waste are being treated using AD process, there will be no emission of carbon and methane to the atmosphere. Hence, it can be concluded that the all of the carbon emission from the initial process has been reduced.

4.3.2 Carbon Emission from Transportation

By converting the food waste to liquid compost, there are lesser waste needed to be transported to landfill site. Hence, the number of trips by dump trucks reduced from three

trips to two trips daily. Carbon emission from the dump trucks can be measured using equation 2.

From Equation 2

Distance travelled in one day (km) x CO_2 intensity (kg) *(2)*

= 42 km x 2 way x 2 trips daily x 10.03 kg CO_2

= 1685.04 kg CO_2e / day

For a period from January until June, there is a total of 181 days

Hence, total CO_2 emission from transportation is:

= 181 days x 1685.04 kg CO_2 / day

= 304992 Kg CO_2e

Figure 4.4 below shows the screenshot of the Carbon Calculator developed to compute the emission of carbon from transportation by just inserting the total distance travelled by the dump trucks. Since the dump truck travel a distance of 168 km/day, hence the total distance travelled for a period of 181 days is 30408 km.

Transportation	Dump Truck (Diesel)	30408	km	304992.24	
	TOTAL				304992.24

Figure 4.4: Current Carbon Emission from Transportation

4.3.3 Carbon Emission from Electricity

Mainly, electricity consumption is quite minor and it is used to operate the machines to convert food waste to liquid compost. **Table 4.4** below shows the electricity consumption from January until June 2018. The facility at SS2 is currently using Tariff B – Low Voltage Commercial Tariff as shown in **Figure 4.5** below.

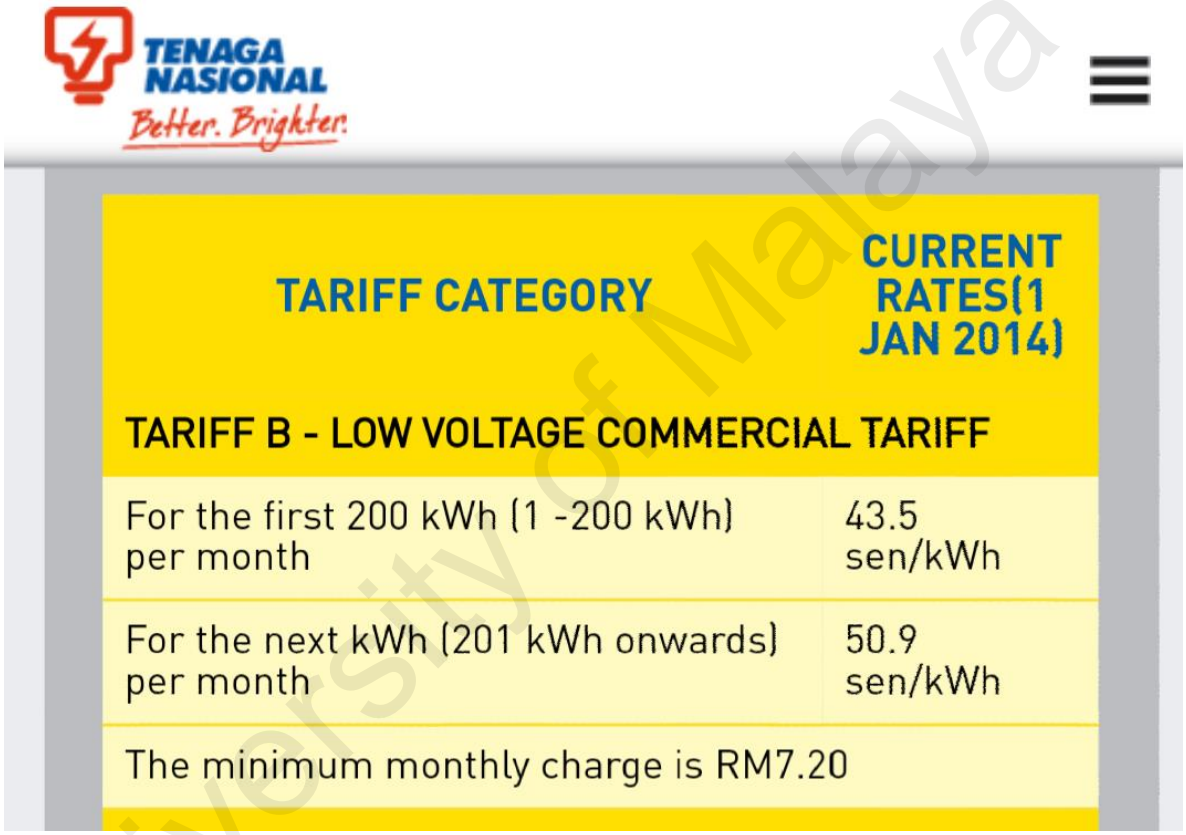

Figure 4.5: Tariff Category at Smart Waste Solution Lab SS2

Sources: Tenaga Nasional Berhad

Table 4.4: Electricity Consumption from January until June 2018

Month	Electricity Bill (RM)	kWh
January	52.00	119.54
February	33.90	77.93
March	28.00	64.37
April	45.64	104.92

May	47.45	109
June	50.55	116.21
Total	**257.54**	**591.97**

Using the tariff rate given by Tenaga Nasional Berhad, electricity consumption in kWh can be calculated by dividing the monthly bill with the rate for one kWh. Carbon emission as a result of this electricity consumption can be calculated using equation 1.

From Equation1:

Electricity Consumption (kWh) x CO_2 intensity (kg) x Electricity generation mix *(1)*

i) 591.97 kWh x 0.76 (coal) x 0.425 (coal) = 191 kg CO_2e

ii) 591.97 kWh x 0.37 (natural gas) x 0.435 (natural gas) = 95.3 kg CO_2e

iii) 591.97 kWh x 0.28 (fuel oil) x 0.003 (fuel oil) = 0.5 kg CO_2e

iv) 591.97 kWh x 0 (hydro) x 0.13 (hydro) = 0 kg CO_2e

v) 591.97 kWh x 0.27 (diesel) x 0.004 (diesel) = 0.64 kg CO_2e

Hence, total carbon emission is:

= 191 + 95.3 + 0.5 + 0.64

= 287.62 kg CO_2e

Figure 4.6 below shows the screenshot of the Carbon Calculator developed to compute the emission of carbon from electricity consumption by just inserting the total kWh consumed.

	1	2		3	4
	Energy Source	Annual Total		Kg of CO2 released	Total CO2 emissions (Kg)
Electricity Consumption	Electricity (Coal) : 42.5%	591.97	kWhr	191.21	
	Electricity (Natural Gas) : 43.5%	591.97	kWhr	95.28	
	Electricity (Fuel Oil) : 0.3%	591.97	kWhr	0.50	
	Electricity (Hydro) : 13%	591.97	kWhr	0.00	
	Electricity (Diesel) :0.4 %	591.97	kWhr	0.64	
	TOTAL				287.62

Figure 4.6: Current Carbon Emission from Electricity Consumption

Therefore, total carbon emission from the CURRENT process is:

= carbon emission from food waste + carbon emission from transportation + carbon emission from electricity consumption

= N/A Kg CO_2e + 304992 Kg CO_2e + 287.62 Kg CO_2e

= 305279 Kg CO_2e

4.4 REDUCTION OF CARBON EMISSION

Reduction of carbon emission can be measured by taking the initial carbon emission and subtracting the current carbon emission.

Reduction of carbon emission = initial emission – current emission

= 737936 Kg CO_2e – 305279 Kg CO_2e

= 432657 Kg CO_2e

Hence, it can be concluded that carbon emission can be reduced by over 432 tonnes Kg CO_2e by converting food waste to liquid compost for a period of six months.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

As conclusion, it can be seen that nearly half of the carbon emission can be reduced by the implementation of converting food waste to liquid compost. Initial carbon emission was around 737 tonnes Kg CO_2e while the current emission is now around 305 tonnes Kg CO_2e. Most of the carbon reduction is from diverting the food waste to landfill and instead undergoes anaerobic digestion (AD) to convert into liquid compost. Hence, the objective to quantify reduction of carbon footprint by converting food waste to liquid compost was clearly achieved. Sub objective to identify sources of ineffective waste management was also achieved as it was discussed in detail in Chapter 2.

5.2 RECOMMENDATIONS

As can be seen, with the implementation of one facility, nearly 432 tonnes Kg CO_2e can be reduced. Imagine, the amount of reduction of CO_2 can be achieved if this initiative is implemented throughout the nation. Based on statistics as at 31 December 2017, Malaysia's carbon emission is at 255.78 million tones Kg CO_2. One of the goals in the Sustainable Development Goals (SDG) is Climate Action. The aim of this goal is to take urgent actions to combat climate change and its impact by regulating carbon emissions. Even before the

implementation of these goals, Prime Minister of Malaysia have already pledge to the leaders of the world to reduce carbon emission of Malaysia by 40% based on year 2005 during the Conference of Parties (COP 21). Since the SDG is a long term plan until the year 2030, the reduction of carbon emission from this initiative will be projected to give a better visual on the importance of this project.

5.2.1 Yearly Carbon Reduction Projection

For a period of six months, a total of 432 tonnes of carbon reduction was recorded with the initiative to convert food waste to liquid compost. Assuming the amount of food waste collected to remain constant, total carbon reduction for one year will be approximately 864 tonnes Kg CO_2e. **Table 5.1** below shows the projection estimation cumulative carbon reduction until year 2030.

Table 5.1: Estimation Cumulative Carbon Reduction

Year	Cumulative Carbon Reduction (tonnes CO_2)
2018	864
2019	1728
2020	2592
2021	3456
2022	4320
2023	5184
2024	6048
2025	6912
2026	7776

2027	8640
2028	9504
2029	10368
2030	11232

With just one initiative, a huge amount of carbon reduction can be achieved. Initiative done by Majlis Bandaraya Petaling Jaya (MBPJ) can be taken as a role model for other city council to duplicate this initiative and contribute towards carbon reduction.

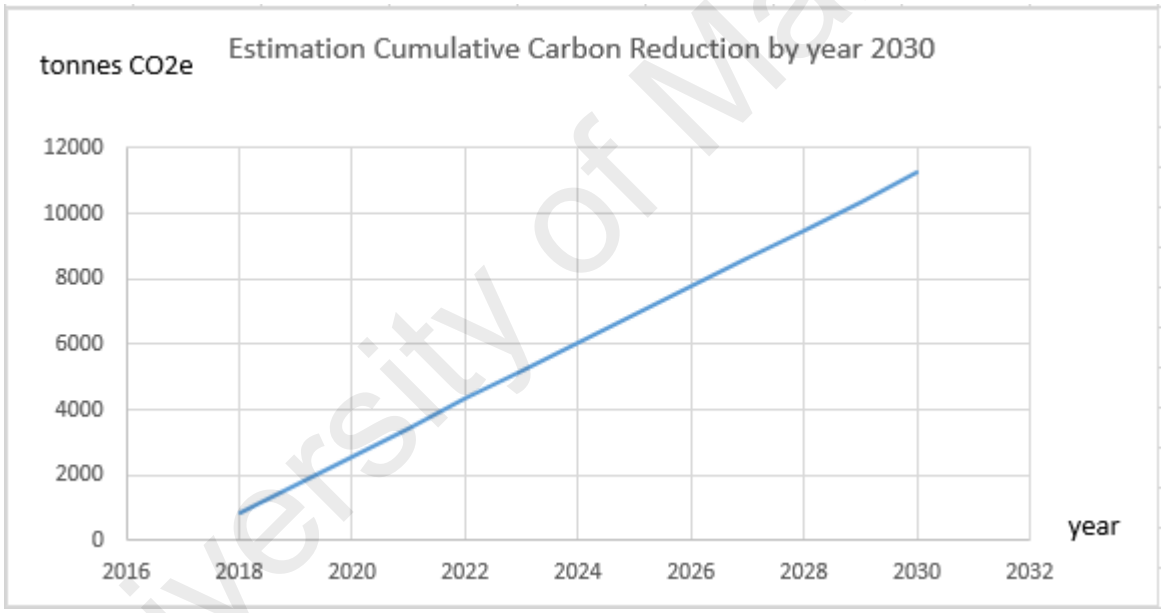

Figure 5.1: Estimation of Carbon Reduction by Year 2030

5.2.2 Future Recommendations

Future recommendations include micro and macro recommendation. In micro scale, there are few improvements can be done to increase the accuracy of results obtained. Firstly, the duration of data collection can be increased from six months to one year.

Currently, data is only collected for six months and assuming constant data, hence results for one year can be predicted. Next, comparison study can also be done with other well established composting facility to compare results obtained.

In terms of recommendation as an overall, government should play an important role in encouraging small entities such as household to large entities such as industries in reducing carbon emission. Furthermore, reducing carbon emission is a conservative effort instead of an individual effort. It requires the commitment of many parties to make it a success. This is where Government should work hand in hand with private and local companies to coordinate on the importance of reducing carbon emission.

With just one initiative, a huge amount of carbon reduction can be achieved. Initiative done by Majlis Bandaraya Petaling Jaya (MBPJ) can be taken as a role model for other city council to duplicate this initiative and contribute towards carbon reduction.

Current Local Authorities in Malaysia = 149

Approximate yearly carbon reduction = 864 Tonnes Kg CO_2e

Hence, if all local authorities duplicate this initiative, huge amount carbon reduction can be achieved.

= 149 x 864 tonnes

= 128,736 tonnes CO_2e

REFERENCE

Agamuthu, P., & Fauziah, S. (2011). Challenges and issues in moving towards sustainable landfilling in a transitory country-Malaysia. *Waste Management & Research, 29*(1), 13-19.

Aja, O. C., & Al-Kayiem, H. H. (2014). Review of municipal solid waste management options in Malaysia, with an emphasis on sustainable waste-to-energy options. *Journal of material cycles and waste management, 16*(4), 693-710.

Barrett, S. (2009). The coming global climate-technology revolution. *Journal of Economic Perspectives, 23*(2), 53-75.

Chandra, R., Takeuchi, H., & Hasegawa, T. (2012). Methane production from lignocellulosic agricultural crop wastes: A review in context to second generation of biofuel production. *Renewable and Sustainable Energy Reviews, 16*(3), 1462-1476.

Cheng, H., & Hu, Y. (2010). Municipal solid waste (MSW) as a renewable source of energy: Current and future practices in China. *Bioresource technology, 101*(11), 3816-3824.

Church, J. A., White, N. J., Konikow, L. F., Domingues, C. M., Cogley, J. G., Rignot, E., . . . Velicogna, I. (2011). Revisiting the Earth's sea-level and energy budgets from 1961 to 2008. *Geophysical Research Letters, 38*(18).

Comiso, J. C., & Hall, D. K. (2014). Climate trends in the Arctic as observed from space. *Wiley Interdisciplinary Reviews: Climate Change, 5*(3), 389-409.

de Palma, A., & Lindsey, R. (2011). Traffic congestion pricing methodologies and technologies. *Transportation Research Part C: Emerging Technologies, 19*(6), 1377-1399.

Desa, A., Kadir, N. B. y. A., & Yusooff, F. (2011). A study on the knowledge, attitudes, awareness status and behaviour concerning solid waste management. *Procedia-Social and Behavioral Sciences, 18*, 643-648.

Förstner, U., & Wittmann, G. T. (2012). *Metal pollution in the aquatic environment*: Springer Science & Business Media.

Gore, C. (2010). The global recession of 2009 in a long-term development perspective. *Journal of International Development, 22*(6), 714-738.

Grubb, M., Vrolijk, C., & Brack, D. (1997). *The Kyoto Protocol: a guide and assessment*: Royal Institute of International Affairs Energy and Environmental Programme.

Hansen, J., Ruedy, R., Sato, M., & Lo, K. (2010). Global surface temperature change. *Reviews of Geophysics, 48*(4).

Hoornweg, D., & Bhada-Tata, P. (2012). What a waste: a global review of solid waste management.

Hunter, J. (2010). Estimating sea-level extremes under conditions of uncertain sea-level rise. *Climatic Change, 99*(3-4), 331-350.

Ismail, S. N. S., & Manaf, L. A. (2013). The challenge of future landfill: A case study of Malaysia. *Journal of Toxicology and Environmental Health Sciences, 5*(6), 86-96.

Keeble, B. R. (1988). The Brundtland report:'Our common future'. *Medicine and War, 4*(1), 17-25.

Khan, M., & Ghouri, A. M. (2011). Environmental pollution: its effects on life and its remedies.

Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.-H., Haberl, H., & Fischer-Kowalski, M. (2009). Growth in global materials use, GDP and population during the 20th century. *Ecological Economics, 68*(10), 2696-2705.

Lim, W., Chin, N., Yusof, A., Yahya, A., & Tee, T. (2016). Food waste handling in Malaysia and comparison with other Asian countries. *International Food Research Journal, 23*.

Matsuda, T., Yano, J., Hirai, Y., & Sakai, S.-i. (2012). Life-cycle greenhouse gas inventory analysis of household waste management and food waste reduction activities in Kyoto, Japan. *The International Journal of Life Cycle Assessment, 17*(6), 743-752.

McMillan, M., Shepherd, A., Sundal, A., Briggs, K., Muir, A., Ridout, A., . . . Wingham, D. (2014). Increased ice losses from Antarctica detected by CryoSat-2. *Geophysical Research Letters, 41*(11), 3899-3905.

Moh, Y. C., & Manaf, L. A. (2014). Overview of household solid waste recycling policy status and challenges in Malaysia. *Resources, Conservation and Recycling, 82*, 50-61.

Novotny, V. (2011). Water and energy link in the cities of the future–achieving net zero carbon and pollution emissions footprint. *Water Science and Technology, 63*(1), 184-190.

Pearce, D., Barbier, E., & Markandya, A. (2013). *Sustainable development: economics and environment in the Third World*: Routledge.

Peters, G. P., Andrew, R. M., Boden, T., Canadell, J. G., Ciais, P., Le Quéré, C., . . . Wilson, C. (2013). The challenge to keep global warming below 2 C. *Nature climate change, 3*(1), 4-6.

Premalatha, M., Tauseef, S., Abbasi, T., & Abbasi, S. (2013). The promise and the performance of the world's first two zero carbon eco-cities. *Renewable and Sustainable Energy Reviews, 25*, 660-669.

Rogelj, J., Den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., . . . Meinshausen, M. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2 C. *Nature, 534*(7609), 631.

Rostami, R., Khoshnava, S., & Lamit, H. (2014). *Heritage contribution in sustainable city.* Paper presented at the IOP Conference Series: Earth and Environmental Science.

Unit, E. P. (2015). 11th Malaysia Plan 2016-2020. *Prime Minister's Department, Malaysia*.

Velders, G. J., Andersen, S. O., Daniel, J. S., Fahey, D. W., & McFarland, M. (2007). The importance of the Montreal Protocol in protecting climate. *Proceedings of the National Academy of Sciences, 104*(12), 4814-4819.

Weidema, B. P., Thrane, M., Christensen, P., Schmidt, J., & Løkke, S. (2008). Carbon footprint. *Journal of industrial Ecology, 12*(1), 3-6.

Wright, L. A., Kemp, S., & Williams, I. (2011). 'Carbon footprinting': towards a universally accepted definition. *Carbon management, 2*(1), 61-72.

Yaakob, U. H. (2006). The Malaysian census 2000: Characteristics and critical issues. *Journal of the Malaysian Branch of the Royal Asiatic Society*, 27-42.

Yu, J.-Y., & Chiu, P.-G. (2012). Contrasting Various Metrics for Measuring Tropical Cyclone Activity. *Terrestrial, Atmospheric & Oceanic Sciences*, *23*(3).

Zhang, C., Su, H., Baeyens, J., & Tan, T. (2014). Reviewing the anaerobic digestion of food waste for biogas production. *Renewable and Sustainable Energy Reviews, 38*, 383-392.