CHAPTER 2 LITERATURE REVIEW

2.1 Municipal Solid Waste Generation in Malaysia

Global MSW was estimated to increase annually at 3.2%-4.5% and 2%-3% in developed countries and developing countries, respectively (Agamuthu, 2001; Suocheng et al., 2001). The increase is mainly due to rapid population and economic growth, change in consumption patterns and increase in living standard.

Statistics on demographics show that Malaysian population has increased 40.5% within 15 years, from 21 million people in 1997 to approximately 29.5 million people in 2012 (Department of Statistic, 2012). About 65% of the total population in urban areas where more organic waste is generated compared to rural areas (Jalil, 2010). In 2005, Malaysia generated approximately 7.34 million tonnes of solid wastes, an amount which is able to fill up 42 Petronas Twin Towers (Chandravathani, 2006) and 31,000 tonnes of MSW will be generated every day in 2020 (Latifah et al., 2009). According to Agamuthu et al. (2009), the daily generation of waste in Peninsular Malaysia has increased from 13,000 tonnes in 1996 to 19,100 tonnes in 2006. At present, the capital of Malaysia, Kuala Lumpur generates 3,500 tonnes of domestic and industrial waste daily with 50% being organic waste (Bavani, 2009; Jalil, 2010).

Table 2.1 shows the generation of MSW in major urban areas in Peninsular Malaysia. The MSW generation rate in all the major urban areas increased approximately 13% from 2002 to 2006. Among all major urban areas in Peninsular Malaysia, Kuala Lumpur recorded the highest MSW generation at 3100 tonnes/day, far leading other urban areas. Melaka ranked the second, only 632 tonnes/day followed by Klang, third, 538 tonnes/day (Agamuthu et al., 2009).

Table 2.1: Generation of MSW in major urban areas in Peninsular Malaysia (1970–2006)

Urban centre	Solid waste generated (mtric tonnes/day)				
	1970	1980	1990	2002	2006
Kuala Lumpur	98.9	310.5	586.8	2754.0	3100.0
Johor Bharu (Johor)	41.1	99.6	174.8	215.0	242.0
Ipoh (Perak)	22.5	82.7	162.2	208.0	234.0
Georgetown (Pulau Penang)	53.4	83.0	137.2	221.0	249.0
Klang (Selangor)	18.0	65.0	122.8	478.0	538.0
Kuala Terengganu (Terengganu)	8.7	61.8	121.0	137.0	154.0
Kota Bharu (Kelantan)	9.1	56.5	102.9	129.5	146.0
Kuantan (Pahang)	7.1	45.2	85.3	174.0	196.0
Seremban (Negeri Sembilan)	13.4	45.1	85.2	165.0	186.0
Melaka	14.4	29.1	46.8	562.0	632.0

Source: Agamuthu et al., 2009

Due to economic growth, rising of living standards and change of consumption pattern, the solid waste generation per capita has been increasing steadily, from 0.5kg/day in 1980s to about 1.5kg/day in 2007 (Figure 2.1) (Agamuthu et al., 2009). This increasing trend indicates that the 3R strategy (reduce, reuse and recycle) is unsuccessful. Recycling campaigns have been conducted for few years but end up with failure due to insufficient public response. However, public knowledge on related issues increased slightly (Agamuthu et al., 2009).

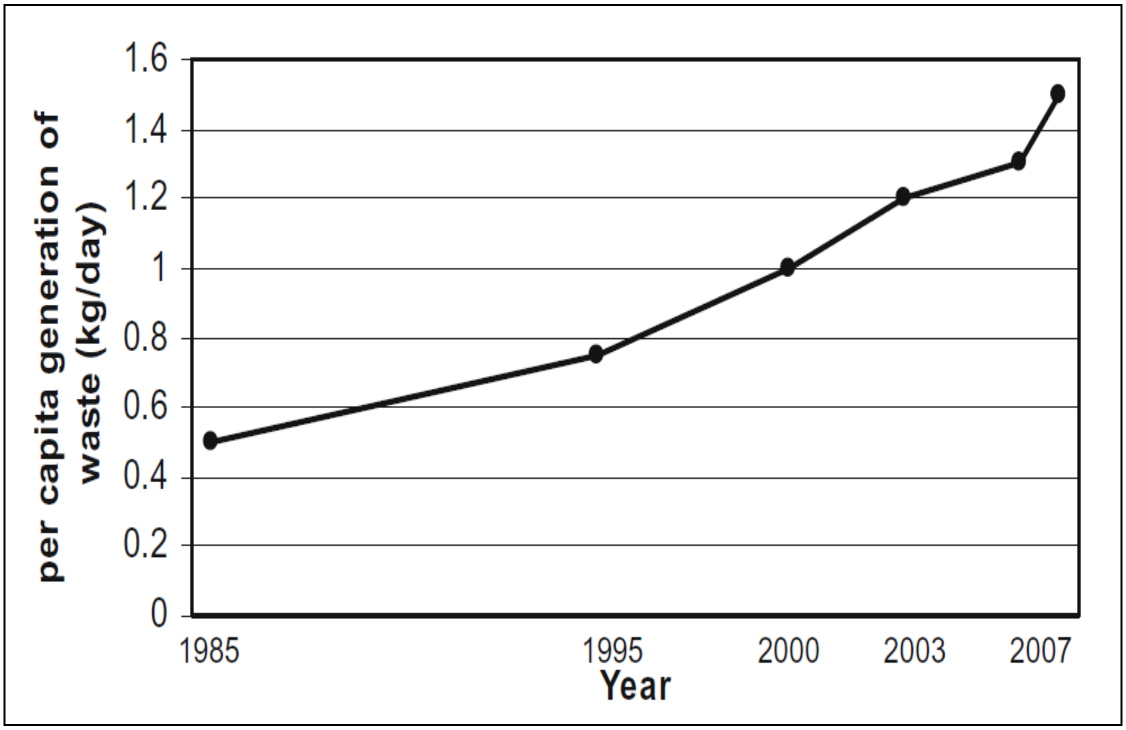


Figure 2.1: MSW generation per capita in Malaysia from 1985 to 2007

Source: Agamuthu et al., 2009

2.2 Municipal Solid Waste Composition in Malaysia

Waste composition directly influenced the density of the waste and the most efficient waste disposal methods to be applied, for instance, high recyclable and compostable content make waste recovery feasible (Al-Khatib et al., 2010). The common characteristics of solid waste in Asian countries is high organic and moisture content (Visvanathan et al., 2004). The common MSW compositions are food waste, plastic, paper, rubber/ leather, wood, metal, glass and textiles (Chiemchaisri et al., 2007).

MSW in Malaysia is highly heterogeneous and contain high fraction of organic matter (Agamuthu & Nasser, 2009). Statistics from 9th Malaysia Plan, prepared by the National Solid Waste Management Department (2005) is in parallel with this statement. Food waste took up almost half of the total waste amount generated in 2005 (45%) followed by plastic (24%) and paper (7%) (Figure 2.2). Organic content in MSW has a direct impact on the moisture content and bulk density.

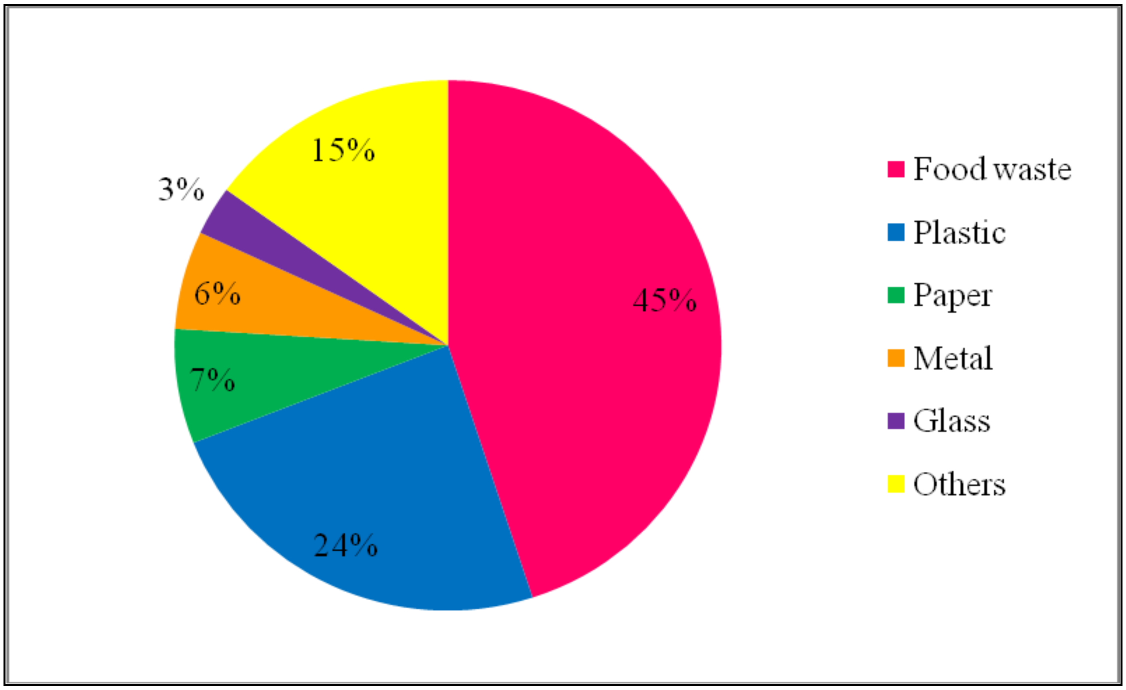


Figure 2.2: Solid waste composition in Malaysia, 2005

Source: National Solid Waste Management Department, 2005

Table 2.2 depicts the compositions of MSW from 1975 to 2005. Organic waste always is the main composition, followed by paper (Agamuthu et al., 2009). The paper and plastic composition recorded high in 1985 compared to other years resulted from the recognition of the materials as safe packaging materials in Malaysia Food Regulations (1985) (Neilsen & Ng, 2004). These compositions decreased due to economic turmoil from 1990 to 1999 but increased again in 2000 resulting from the materials been invented into more hygienic packaging materials (Agamuthu et al., 2009).

Table 2.2: Waste composition (percentage of wet weight) in Malaysia from 1975 to 2005

Waste composition	1975	1980	1985	1990	1995	2000	2005
Organic	63.7	54.4	48.3	48.4	45.7	43.2	44.8
Paper	7.0	8.0	23.6	8.9	9.0	23.7	16.0
Plastic	2.5	0.4	9.4	3.0	3.9	11.2	15.0
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	3.3
Textiles	1.3	2.2	NA	NA	2.1	1.5	2.8
Wood	6.5	1.8	NA	NA	NA	0.7	6.7
Others	0.9	0.3	8.8	32.1	4.3	12.3	8.4

Source: Agamuthu et al., 2009

2.3 Municipal Solid Waste Management in Malaysia

Due to its heterogeneous characteristic, MSW should be managed using an integrated solid waste management as there is no single treatment that can handle all type of waste. In order to promote sustainable development, MSW management in many countries have moved from landfill-based to resource recovery-based solutions (Thanh et al., 2010). Consequently, various new technologies which are able to reduce GHG emissions from MSW are being focused as an important step against climate change. For example, incineration and landfill gas capture allows energy recovery to generate electricity (Chalita & Shabbir, 2008). Organic waste is converted into compost for soil application. These reduce the demand for fossil fuel, conserve natural resources and reduce GHG emissions (Chalita & Shabbir, 2008).

According to National Solid Waste Management Department, until September 2009, there were 176 landfills and disposal sites in Malaysia, while 114 landfills and disposal sites had been closed (National Solid Waste Management Department, 2009) (Table 2.3). Out of 176 landfills, only eight are sanitary landfills: Pahang (one), Selangor (three include Bukit Tagar Sanitary Landfill), Johor (one) and Sarawak (three) (The Star Online, 2010).

Table 2.3: Total landfills and disposal sites in Malaysia (September 2009)

State	Operating landfills and disposal sites	Closed landfills and disposal sites
Johor	13	21
Kedah	10	5
Kelantan	13	4
Melaka	2	5
Negeri Sembilan	8	10
Pahang	19	13
Perak	20	9
Perlis	1	1
Pulau Pinang	1	2
Sabah	21	1
Sarawak	51	12
Selangor	6	12
Terengganu	9	12
Wilayah Persekutuan KL	1	7
Wilayah Persekutuan Labuan	1	0
Total	176	114
Overall Total	290	

Source: National Solid Waste Management Department, 2009

Developed countries such as Japan and the United States are strongly promoting zero waste. The concept of zero waste gains more and more popularity to overcome problems of landfill scarcity, global climate change and resource depletion (ZWIA, 2009). Hence, this concept is being promoted as the next greatest innovation in waste management (Kozlowski Russell, 2009). Yet, Malaysia is still far behind as landfilling is the main waste disposal method. MSW disposed off at the landfills is 95% out of total MSW, generating approximately 3 million liters of leachate per day (Frank & Agamuthu, 2010; Fauziah & Agamuthu, 2009).

Table 2.4 depicts the methods of waste disposal since 2002 and proposed methods in 2020. National Recycling Program introduced in 2000 has failed as the recycling rate was 5.5% in 2006 compared to target 7% in 2005 (Agamuthu et al., 2010). The failure was due to lack of public participation as more than 90% of them are aware of recycling yet only 40% of them practice recycling (Fauziah et al., 2009). Ministry of Housing and Local Government has set a target to increase recycling from 5% to 22% by 2020 (Geetha, 2009). It clearly shows that Malaysia will move from open-disposal sites based to recovery and recycling as more MSW incinerators are proposed and 3Rs are emphasized (Agamuthu et al., 2009).

Table 2.4: Methods of waste disposal in Malaysia

Treatment	Percentage of waste disposed		
	2002	2006	Target 2020 (by Ministry of Housing and Local Government)
Recycling	5.0	5.5	22.0
Composting	0.0	1.0	8.0
Incineration	0.0	0.0	16.8
Inert landfill	0.0	3.2	9.1
Sanitary landfill	5.0	30.9	44.1
Other disposal sites	90.0	59.4	0.0
Total	100.0	100.0	100.0

Source: Agamuthu et al., 2006

Incineration plants are widely applied in developed countries like Japan, Singapore and European countries. However, currently, this technology is not widely implemented in Malaysia, it is only used to dispose hazardous waste (Latifah et al., 2009). There will be five mini incinerators and all of them are yet to commence, which are located at Pulau Pangkor, Labuan, Pulau Langkawi, Pulau Tioman and Cameron Highlands (The Star Online, 2010).

The first ever Act regarding solid waste management was gazetted in 2007, the Solid Waste and Public Cleansing Management Act 2007. The Act is aimed to improve current solid waste management by implementing hierarchy for integrated solid waste management: waste minimization, reuse, recycling, energy recovery and landfill. Waste minimization is emphasized through 3Rs, such as waste reduction at source; to use environmental friendly materials; to use certain amount of recycled materials for particular products; set limitation on the generation, import, use, discharge or disposal of particular products; promote recycling by doing coding and labeling on product; and reduce the negative environmental impacts imposed by MSW through reduce, reuse and recycling. Consequently, waste separation at source will become mandatory to waste generator. Waste generators are required to do waste separation at source. Take-back system and deposit-refund system also introduced under the Bill. The manufacturer, assembler, importer or dealer shall take back their products for recycling under the take-back system while its efficiency is ensured by the deposit-refund system.

2.4 Composting

2.4.1 Composting Process

Composting refers to a process which organic matter undergoes biological degradation by microbes under controlled aerobic conditions to produce compost (Farrell et al., 2009).

Generally composting process involves the following operational units (Agamuthu, 2000):

(a) Reception

Collected organic waste is weighed and unloaded on this temporary storage.

(b) Segregation

Organic waste is sometimes mixed up with plastic bags, paper and other forms of non compostable waste. Thus, they require separation of compostable and non compostable wastes which is done manually at the reception.

(c) Pre-composting

The compostable waste is sent for grinding to break down the larger components physical characters in order to reduce the volume.

(d) Composting

Organic waste is arranged according to desired shape. Bacteria present in the organic waste start biodegradation process through mesophilic and thermophilic stages. Additives such as worms, enzyme, bio-catalyst and sewage sludge are able to speed up the process. Aeration, moisture content, pH value and temperature are under closed monitoring until compost is matured.

(e) Marketing

At the final stage, the pulverized materials are sent to packaging area, stored temporarily before sales.

2.4.2 Types of Composting

There are few types of composting methods as below (US EPA, 2013):

(a) Aerated (turned) composting

Organic waste is formed into rows called windrows. Windrows are turned either manually or mechanically on certain period to provide an ideal condition (temperature, moisture content and oxygen amount) for composting.

(b) Vermicomposting

Organic waste is mixed with worms, being digested and become castings. Types of worms generally used in vermicomposting are red worm, branding worm and tiger worm (Agamuthu, 2000).

(c) Aerated static pile composting

Organic waste is formed into piles. Oxygen is blowed into the piles either through layers of loosely piled bulky agents such as wood chips and shredded newspaper or pipes which placed underneath the piles.

(d) In-vessel composting

Organic waste is placed in a container such as drum, silo concreted-lined trench or similiar condition. Unlike other composting methods mentioned above, all the factors which can affect the composting results are well-controlled.

2.4.3 Benefits of Composting

Benefits of composting include reduce volume of biodegradable fraction in waste (Bogner et al., 2008), a low cost alternative to landfill and incineration (Bruun et al., 2006) and compost is useful for soil remediation (Agamuthu et al., 2005). Factors that affect the composting rate include C/N ratio, surface area, oxygen supply, moisture content and temperature (Agamuthu & Khan, 1997; Jakobsen, 1995; Schenkel, 1996; Tchobanoglous et al., 1993). This waste recycling option contributes mass reduction, vary depending on authors. Omran et al. (2007) reported mass reduction of 20%-40%, Somjai & Nakorn (2011) reported mass reduction 40%-62% in dry waste (dw), Andersen et al. (2010) reported mass reduction 55%-73% in wet waste (ww), Agamuthu et al. (2005) reported mass reduction 60%, Luz et al. (2009) reported mass reduction 66.6%.

Due to the increase in environmental awareness, composting is gaining more popularity as an alternative MSW disposal (Agamuthu et al., 2005; Gabrielle et al., 2005). This is because less GHG emissions generated from composting process compared to landfilling as the biodegradation process is aerobic. Composting is successful in Europe as it has proper policy as guidelines. There are approximately 2000 composting facilities in that region (Boldrin et al., 2009). Composting is more feasible in developing countries as they have higher organic fraction in waste. However, small-scale and decentralised operations are more successful in developing countries compared to large-scale (Cofie et al., 2009).

2.4.4 Clean Development Mechanism (CDM) Composting Project in Malaysia

United Nation Framework Convention on Climate Change (UNFCCC) methodology used for Clean Development Mechanism (CDM) composting projects is AM0025 (large-scale projects) and AMSIII.F (small-scale projects). Currently, there is only one CDM MSW composting project in Malaysia, which is the Kota Kinabalu Composting Plant, located in Kayu Madang Sanitary Landfill in Telipok, Sabah (UNFCCC, 2008b).

Kota Kinabalu City Hall has provided 18 acres of land within the Landfill to MS Smart Recycling Sdn Bhd to operate a 500 tonnes/day capacity sorting plant and composting plant. GHG emissions will be avoided by diverting MSW from landfill to sorting and composting plant. Recyclable will be recovered while organic matter will be converted into compost. Anaerobic decomposition is replaced by aerobic process. As a result, CO_2 will be released into the atmosphere instead of CH_4. This move has initiated Kota Kinabalu Composting Plant becomes the first commercial-scale MSW composting in Malaysia. It demonstrates a new waste management approach through waste minimization, serving as an exemplary project to other city councils in mitigating environmental issues especially GHG emissions resulted from solid waste management (NL EVD Internationaal, 2010).

Out of the 18 acres of land, approximately 3.2 acres were designated for sorting plant and administrative building while the remaining 15 acres for composting plant. The sorting plant has started operation in April 2006 while the composting plant is yet to start. The composting plant is designed with ten years of operational lifespan under an operation schedule of six days a week and shut down on every Sunday for maintenance work (The World Bank, 2008; UNFCCC, 2008b).

Equipments such as MSW reception area, storage area and a sorting area with three parallel process lines which include conveyors, screens and magnetic separators are installed at the sorting plant. The garbage trucks are weighed before unloading MSW on the tipping floor of the reception area. Large items such as tires, batteries, tree logs and big cardboards are removed manually. Recyclables such as plastic, paper, textile, glass and metal are collected, baled and stored before sold to respective recyclers. The waste that remains on the sorting conveyor is screened at 10cm by a trammel screen to separate the organic materials which are then sent to the composting plant by using truck (The World Bank, 2008).

The composting plant adopts windrows technology which receives approximately 300 tonnes/day of feedstock (60% from total MSW received) include food waste, yard waste and highly biodegradable organic materials from the sorting plant. Impermeable surface at the composting plant prevent contamination groundwater by wastewater or leachate. Perimeter drains and rainfall pretention pond are constructed to prevent contamination of surface water by the leachate. A minimum 60 windrows are required to process 300 tonnes organic material. The feedstock is piled into long windrows of 1.5 meters (height) x 3.6 meters (width) x 100 meters (length) each. Windrow turner will pass through the passage between each adjacent windrow, approximately 2-meter width. Windrows go through 30 days of fermentation followed by another 30 days of maturation before packing as compost for retail sale. Feedstock will be reduced 50% after composting. By producing approximately 150 tonnes/day (45,000 tonnes/year) of compost, GHG emissions are estimated to reduce at 73,738 tCO_2e (The World Bank, 2008).

2.4.5 GHG Emission from Composting

GHG emission from composting depends on the feedstock. Higher degradable organic carbon (DOC) content contributes higher GHG emission during aerobic decomposition while lower DOC content requires longer composting period due to lower decay rate. CO_2

and water vapor (H_2O) are released from aerobic decomposition while CH_4 is released from anaerobic decomposition due to heterogeneous characteristic of compost pile. Very few studies were done on N_2O emission from composting. The emission is due to incomplete ammonium oxidation or denitrification (Lou & Nair, 2009). According to IPCC Guidelines for National Greenhouse Gas Inventories, only CO_2 is emitted from composting. However CO_2 emission from composting is biogenic origin and excluded for GHG emissions (IPCC, 2006). Hence, the main source of emission during composting process comes from operational such as composting technologies. However, there is some suggestion for the need to include all GHG emissions from non-fossil carbon as climate does not differentiate emission from fossil or non-fossil carbon (Hogg et al., 2008).

Elena & Cristina (2011) have summarised the theoretical estimates and practical GHG measurements from composting, which was 0.284–0.323 tCO_2e per tonne of mixed waste and 0.183–0.932 tCO_2e per tonne of mixed waste, respectively. This indicates that theoretical calculations tend to overestimate real emission. On the other hand, Andersen et al., (2010) concluded that emissions from composting were 177-252 $kgCO_2\ Mg^{-1}$ wet waste, 0.4-4.2 $kgCH_4\ Mg^{-1}$ wet waste, 0.30-0.55 $kgN_2O\ Mg^{-1}$ wet waste and 0.07-0.13 $kgCO\ Mg^{-1}$ wet waste.

Boldrin et al., (2009) studied GHG emissions from composting by using upstream-downstream approach. They included CH_4 and N_2O covered several composting technologies, which are reactor composting (tunnel reactor, box and container and rotating drum), enclosed composting (channel and cell and aerated pile) and open composting (windrows, static pile and mat). The emissions range is -9.000 (net savings) to 0.3000 (net load) tCO_2e per tonne of wet waste. Results of other studies fall into this range, -183 kg

CO_2e per tonne of waste for the USA (US EPA, 2006b) and between -32 to -58 kg CO_2e per tonne of waste for Europe (Smith et al., 2001). Emission from upstream is little and it increased to operation. Compost application and compost substitutes determine the savings or burden of GHG emissions. Substitution of fertilizer with compost application to land brings saving approximately 8 kgCO_2e per tonne of wet waste composted, compost application to soil approximately -4 kgCO_2e per tonne of wet waste composted and substitution of peat -81 kg of CO_2e per tonne of wet waste composted (UNEP, 2010).

2.5 Landfilling

2.5.1. Landfill Gas Generation

Landfill gas (LFG) is generated through three processes: waste degradation, volatilization and chemical reactions (ATSDR, 2001):

(a) Waste degradation

When organic materials in waste such as food waste, garden waste and paper are broken down by bacterias through biological degradation process, LFG is generated.

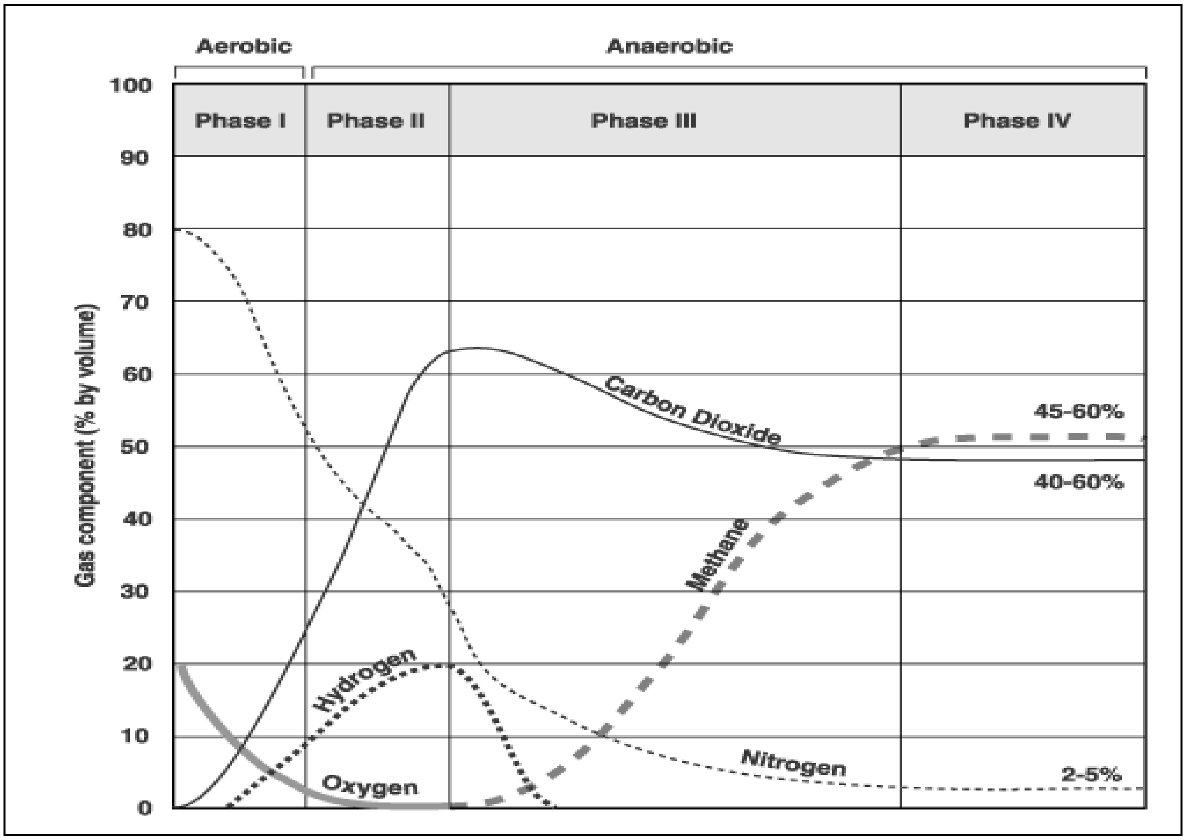
(b) Volatilisation

Volatilisation refers to the process where waste especially organic materials change from solid or liquid into vapor.

(c) Chemical reactions

Some trace gas components are created by chemical reactions within the waste especially industrial waste.

According to Nickolas & Priscilla (2007), after MSW is deposited at landfill, the organic components of waste near to the surface which is exposed to oxygen will be degraded aerobically. After the aerobic first phase, anaerobic degradation will take place. Methane will increase continuously until 45%-60% in phase IV. While other gases decrease, for example carbon dioxide drops to 40%-60% in phase IV (Figure 2.3).



Note: Phase duration time varies with landfill conditions

Figure 2.3: Production phases of landfill gas

Source: US EPA, 1997

Basically, anaerobic degradation consists of three phases. During the first phase, complex dissolved organic matter is hydrolised into dissolved organic matter by fermentative bacteria. It is then converted by acid forming bacteria into organic acids such as acetic acid, propionic acid, butyric acid and ethanol, CO_2 and hydrogen. In the final phase, methanogenic bacterias take place and generate CH_4, either by breaking down the acids to CH_4 and CO_2 or by reducing CO_2 with hydrogen (Nickolas & Priscilla, 2007).

The reactions involved are as below:

Acetogenesis

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

Methanogenesis

$CH_3COOH \rightarrow CH_4 + CO_2$

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

The above formulas can be simplified to represent the possible generation of maximum amount of natural gas during anaerobic decomposition as below (Nickolas & Priscilla, 2007):

$C_6H_{10}O_4 + 1.5H_2O = 3.25CH_4 + 2.75CO_2$

The production rate of LFG is dependent on size and composition of solid waste, age of landfill and solid waste, moisture content, temperature at landfill, quantity and quality of nutrients, organic content of solid waste, pH of liquids at landfill and presence of hazardous materials (Agamuthu, 2001).

2.5.2. Landfill Gas Composition

Landfill gas mainly consists of CH_4 (50%-60%) and CO_2 (40%-50%) (Hamid & Debra, 2011) and traces gases such as nitrogen, hydrogen sulfide and non-methane organic compounds (NMOCs) such as trichloroethylene, benzene, and vinyl chloride (Nickolas & Priscilla, 2007; ATSDR, 2001) (Table 2.5).

Table 2.5: Composition of landfill gas

Composition	Volume (%)
Methane	45-50
Carbon dioxide	40-60
Nitrogen	2-5
Oxygen	0.1-1
Ammonia	0.1-1
NMOCs (Non-methane organic compounds)	0.01-0.6
Sulfides	0-1
Hydrogen	0-0.2
Carbon monoxide	0-0.2

Source: Tchobanoglous et al. (1993); EPA (1995)

Composition of LFG generated varying through phases of waste decomposition activities which are basically divided into four phases (MassDep, 2011). In phase I, aerobic bacterias decompose long molecular organic materials such as carbohydrates, proteins and lipids into mainly CO_2. Nitrogen content is high at this phase and declines throughout the phases. This phase ends when the oxygen content in the waste being fully used up. Materials produced in Phase I is then converted into acetic, lactic and formic acids and alcohols such as methanol and ethanol by anaerobic bacterias. Hence, acidic condition is formed at the landfill. The byproducts of this phase are CO_2 and hydrogen. In phase III, anaerobic bacterias convert organic acids produced in phase II into acetate. At this phase, methanogenic bacterias begin to react by consuming the CO_2 and acetate. Hence, CH_4 content is high at this phase. In last phase, LFG production rate is consistent at this phase.

2.5.3. Landfill CH_4 Emission

Life stages of a landfill are divided into operating stage and closed stage (Lou & Nair, 2009). Figure 2.4 describes the general trend of landfill CH_4 emission during their operating post closure years. Operating landfill emits more CH_4 compared to closed landfill due to its active decomposition activities (Fourie & Morris, 2004). After landfill closure, CH_4 emission from landfill is still observed for hundreds of years (Lou & Nair., 2009). Hence, it requires proper management until negative impacts to human and environment diminish (David et al., 2011).

Variation in LFG generation rates mainly depend on the waste composition (Lou & Nair, 2009; Anders et al., 2011). There are three key factors determining CH_4 at landfills: waste volume disposed off at landfills, degradable organic carbon (DOC) and decay rate (Thompson et al., 2009). Thus, it is important to understand the waste composition disposed off at landfills.

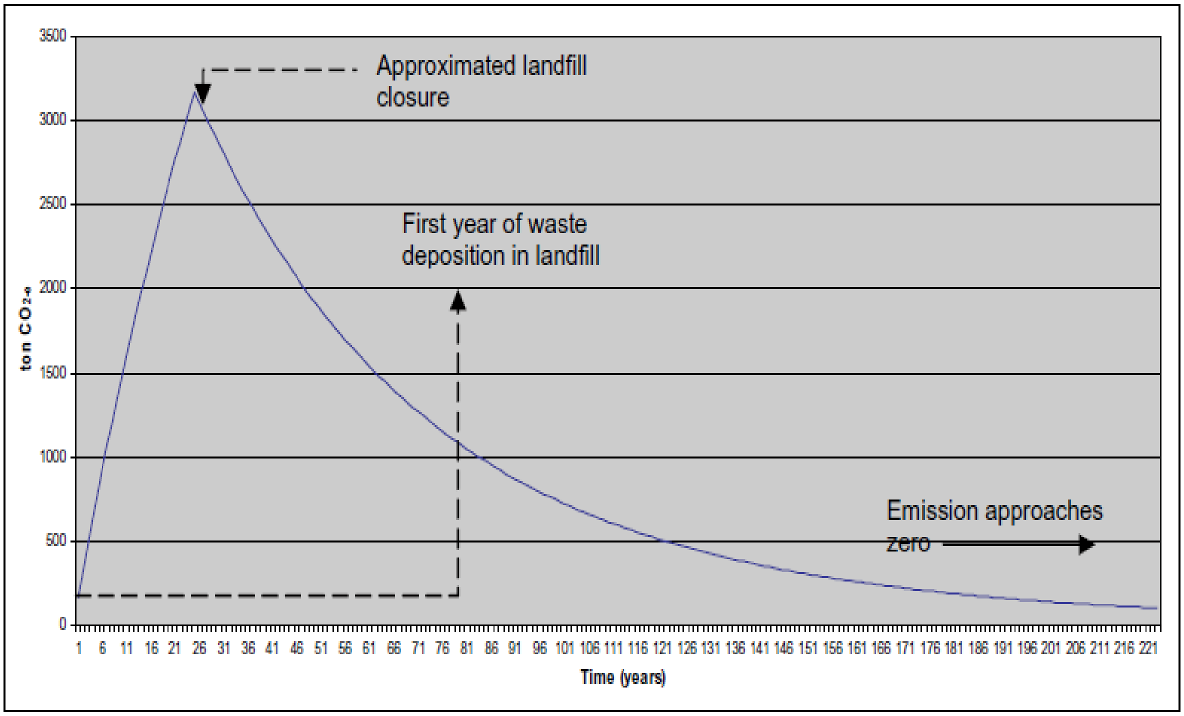


Figure 2.4: General trend of CH_4 emission from landfills in their operating post closure years (calculated using the IPCC 1st order decay model)

Source: Lou & Nair, 2009

2.5.4. Calculation of GHG Emission from Landfills

Industralisation process has increased global CH_4 concentration from 715 ppb (parts per billion) during pre-industrial to 1732 ppb in early 1990s and to 1774 ppb in 2005 (IPCC 2007d). More than 60% of global CH_4 budget is contributed by anthropogenic activities (Denman et al., 2007). 18% of anthropogenic CH_4 is from waste sector, with landfills identified as main source, releasing 35-69 Tg CH_4 per year (Bogner et al., 2007). 29% of CH_4 emissions from waste sector is contributed by developing countries and it is expected to increase tremendously to 64% by 2030 (Monni et al., 2006). The increase might caused by population growth and changes in waste collection services and landfill technology such as move from aerobic open dumping to sanitary and anaerobic bioreactors landfills (Elena & Cristina, 2011).

The global warming potential is a ratio of the amount of heat that would be trapped by one kilogram of a GHG compare to one kilogram of CO_2 (US EIA, 2011a). It is calculated over a specific time interval, such as 100 years. Values are shown in CO_2 equivalent (CO_2e). GWP of CH_4 is 25 due to its stronger molar absorption coefficient and longer atmospheric residence time (Marion et al., 2011). This means CH_4 will trap 25 times more heat than CO_2 in 100 years. Carbon dioxide is biogenic origin, thus it is not accounted for estimation of GHG emission from landfills (Lou & Nair, 2009).

Methane emission from landfills is calculated with several models with different orders of kinetics, such as zero-order, first-order and second orders (Kamalan et al., 2011). The most popular model is the first order models such as GasSim, LandGEM, TNO, Belgium, Afvalzorg, EPER and Scholl Canyon (Kamalan et al., 2011). A variation of the Scholl Canyon model is used in the IPCC 1996 and 2006 guidelines, particularly on calculation of CH_4 emission from landfills (IPCC, 1996b; IPCC, 2006). These guidelines cover CH_4 emissions from different types of solid waste disposal sites and waste categories (food waste, paper, garden waste, wood and inerts). Thus, these guidelines are globally used to estimate GHG inventories from waste in all countries with provided default values by feeding them into globally recognized methodologies under UNFCCC (Elena & Cristina, 2011). The UNFCCC methodological tool incorporates with the IPCC first order decay model (IPCC, 2006) to determine CH_4 emissions from disposal of waste at a solid waste disposal site (UNFCCC, 2008a).

Studies had been focused on landfill CH_4. Table 2.6 indicates that global landfill CH_4 have historically increased since 1990 and it is believed that this increase trend will continue. Study of US EPA (2006b) was based on 1996 IPCC Tier 1 methodology for landfill CH_4 while Monni et al., (2006) used FOD methodology in 2006 IPCC Guidelines. Lower estimates by Monni et al., (2006) from 1995-2010 is due to its lower emission growth rate relative to the waste growth rate. Since then, higher estimates is due to slower decrease in landfilling in Europe. In developed countries, policies which focusing in landfill CH_4 recovery, reduce landfilling and waste generation have been stabilised CH_4 emissions. While in developing countries, landfill CH_4 continues to increase due to increase in population and urbanization, it may increase from 520-750 Mt CO_2eq to 820-1000 Mt CO_2eq in 2020 (Bogner et al., 2007). Future emission reduction would highly dependent the post-Kyoto mechanisms (IPCC, 2007b).

Table 2.6: Trends for landfill CH_4 using (a) 1996 and (b) 2006 IPCC inventory guidelines, extrapolations, and projections (MtCO_2e, rounded)

Source	1990	1995	2000	2005	2010	2015	2020	2030	2050
Landfill CH_4[a]	760	770	730	750	760	790	820		
Landfill CH_4[b]	340	400	450	520	640	800	1000	1500	2900
Average	550	585	590	635	700	795	910		

Notes: Emission estimates and projections as follows:

[a] Based on reported emissions from national inventories and national communications, and (for non-reporting countries) on 1996 inventory guidelines and extrapolations (US EPA, 2006a).

[b] Based on 2006 inventory guidelines and BAU projection (Monni et al., 2006).

On the other hand, few studies had been done to estimate GHG emissions from different types of solid waste disposal sites. Study of Barton et al. (2008) focused in developed countries. They have concluded that GHG emission from sanitary landfills without LFG capture is the highest (1.20 tCO$_2$e/tonne wet waste) followed by open dumpsites (0.74 tCO$_2$e/tonne wet waste), sanitary landfills with gas collection and flaring (0.19 tCO$_2$e/tonne wet waste) and sanitary landfills with gas collection and electricity recovery (0.09 tCO$_2$e/tonne wet waste) (Table 2.6). Study of Manfredi et al. (2009) focused in developed countries (Europe) based on lower biogenic carbon content of the waste. GHG emissions from open dumpsites are similar to developing countries, accounted for 1.00 tCO$_2$e/tonne wet waste while sanitary landfills with gas collection and energy recovery accounted for 0.30 tCO$_2$e/tonne wet waste (Table 2.7). Results of both studies indicate that LFG controls such as flaring and energy recovery system are useful in reducing the amount of GHG released into the atmosphere.

Table 2.7: GHG emissions at different types of solid waste disposal sites

Authors	Sanitary landfills with no LFG capture (per tonne of ww)	Open dumpsites (per tonne of ww)	Sanitary landfills with gas collection and flaring (per tonne of ww)	Sanitary landfills with gas collection and electricity recovery (per tonne of ww)
Barton et al., 2008 (developing countries)	1.2 0 tCO$_2$e	0.74 tCO$_2$e	0.19 tCO$_2$e	0.09 tCO$_2$e
Manfredi et al., 2009 (developed countries-Europe)	0.30 tCO$_2$e (conventional mixed waste) 0.07 tCO$_2$e (low-organic-carbon waste)	1.00 tCO$_2$e	N/A	-0.70 to 0.30 tCO$_2$e

There are various mitigation strategies to reduce LFG such as oxidizing top covers, gas collection systems with flares or gas recovery to energy (electricity and heat) (Anders et al., 2011). In many developed countries, it is mandatory to control the release of LFG into the atmosphere, either through capturing and combusting or other methods followed by monitoring to minimize the risk of fire (Seema & Anju, 2010). Yet, these technologies require huge implementation capital which is not affordable to many developing countries. Kyoto mechanism – Clean Development Mechanism (CDM) would accelerate landfill CH_4 recovery. Estimation of GHG by using methodologies under UNFCCC is pre-requisite to evaluate the potential of each CDM projects technically and financially. The calculation of GHG from landfills involve a life cycle assessment as it includes emissions from transport and energy used in the site operation and so on (Elena & Cristina, 2011).

2.6 Intergovernmental Panel on Climate Change (IPCC), United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol

Climate change is the severest threat to humanity in 20th century and is highly discussed worldwide. Excessive anthropogenic GHG emission such as CO_2 and CH_4 is identified as one of the major causes to global warming and associated changes in climate pattern. Figure 2.5 depicts the increase of global CO_2 emission from below 20,000 metric tonnes in 1980 to approaching 30,000 metric tonnes in 2005 and to date the emission still showing a growing trend (US EIA, 2006). As a result, global average temperature has been increased and consequently extreme climate occurs frequently, such as tropical storms, heat waves, flood and drought.

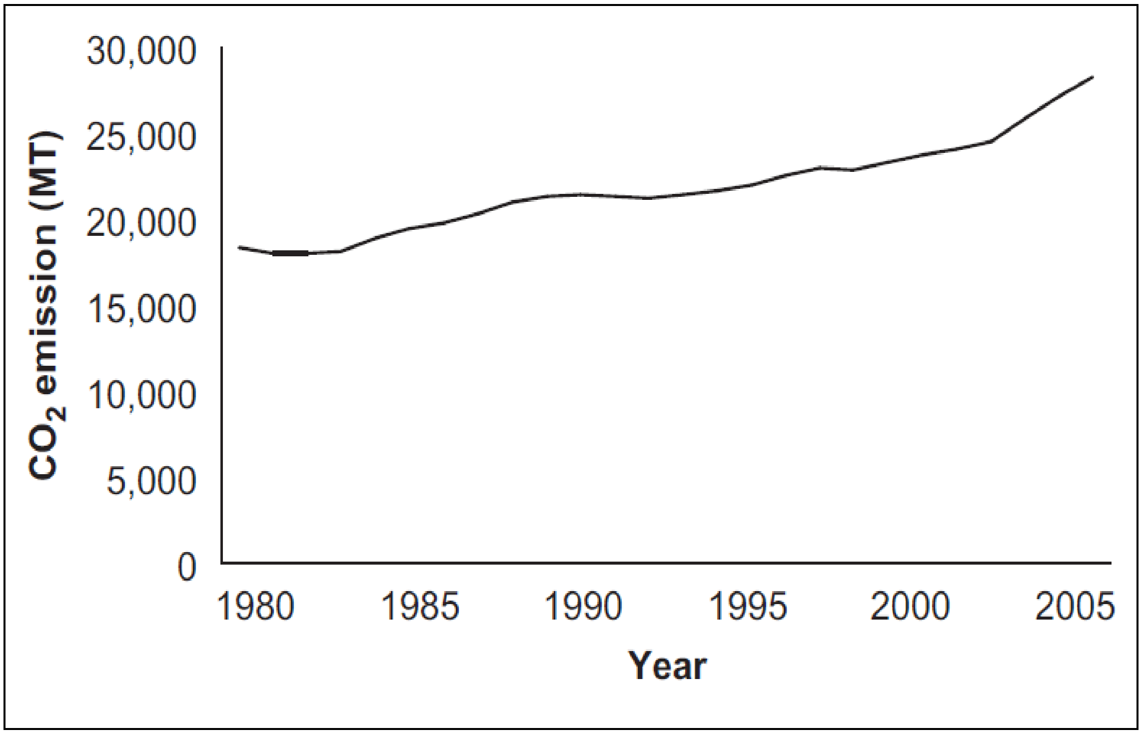


Figure 2.5: Global CO_2 emissions from 1980–2005

Source: US EIA, 2006

The average global temperature was estimated to increase between 1.1 ℃ and 6.4 ℃ in next century (IPCC, 2007d). In fact, an increase of merely 2 ℃ is more than enough to cause devastation. Higher temperature expands ocean water, melting mountain glaciers and ice caps, contributing to sea level rise (Climate Institute, 2011). The sea level rise was estimated between 0.6 and 2 feet (0.18 to 0.59 meters) in the next century (IPCC, 2007a). This is going to give many coastal environments a disastrous impact as those areas are densely populated. For instance, coastal areas less than 10 meters above sea level are populated with more than 600 million people and two-thirds of the world's cities with population over five million are located at these areas (NPR, 2007).

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 to act as an independent body to understand the risk of human-included climate change (European Commission, 2010). IPCC produces assessment report at regular five-year intervals. The first assessment report helped to establish United Nations Framework Convention on Climate Change (UNFCCC) while the second assessment report assisted to set up Kyoto Protocol (European Commission, 2010).

The United Nations Conference on Environment and Development (UNCED), informally known as the Earth Summit, held in Rio de Janeiro from June 3 to 14, 1992 had produced an international environmental treaty, called UNFCCC to abate global climate change by controlling GHG concentration in the atmosphere (Wikipedia, 2011). Parties of UNFCCC are:

- Annex I countries – developed countries with emission reduction target to achieve under the Protocol.
- Annex II countries – developing countries and do not have any emission reduction obligation.

The convention serves non-mandatory effect. Hence, the Kyoto Protocol was adopted on 11 December 1997 in Kyoto, Japan. This international treaty started to enforce on 16 February 2005 (UNFCCC, 2011b). Under this treaty, Annex I countries which have ratified the Protocol must collectively reduce GHG emissions by 5.2% against 1990 levels in the first crediting period 2008-2012. Six major GHGs were identified as the main cause of global warming or greenhouse effect. They are CO_2, CH_4, nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)

(UNFCCC, 2011c). Although GWP other GHG is higher than CO_2 such as CH_4 and NO_2, however tropospheric concentration of CO_2 is the largest compared to other GHG (Table 2.8). Hence, the Protocol has set CO_2e as the value of emission reduction for Annex I countries which have ratified the Protocol and invest in GHG emission abatement projects in non-Annex I countries (Lau et al., 2009).

Table 2.8: Tropospheric concentration and GWP of GHGs

GHGs	**Tropospheric concentration**[1]	**GWP (100-year time horizon)**[2]
Concentration in part per million (ppm)		
Carbon dioxide	388.5	1
Concentration in part per billion (ppb)		
Methane	1870[3] / 1748[3]	25
Nitrous oxide	323[3] / 322[3]	298
Concentration in part per trillion (ppt)		
CFC-11	241[3] / 239[3]	4750
CFC-12	534[3] / 532[3]	10900
CF-113	75[3] / 75[3]	6130
HCFC-22	218[3] / 194[3]	1810
HCFC-141b	22[3] / 19[3]	725
HCFC-142b	22[3] / 19[3]	2310
Halon 1211	4.3[3] / 4.1[3]	1890
Halon 1303	3.3[3] / 3.2[3]	7140
HFC-134a	62[3] / 52[3]	1430
Carbon tetrachloride	87[3] / 86[3]	1400
Sulfur hexafluoride	7.12[3] / 6.73[3]	22800

[1] Besed on CDIAC, 2011

[2] Based on IPCC, 2007e

[3] The first value in a cell represents Mace Head, Ireland, a mid-latitude Northern-Hemisphere site, and the second value represents Cape Grim, Tasmania, a mid-latitude Southern-Hemisphere site. "Current" values given for these gases are annual arithmetic averages based on monthly background concentrations for year 2010. The SF_6 values are from the AGAGE gas chromatography - mass spectrometer (gc-ms) Medusa measuring system.

Carbon emissions of each country varied (Figure 2.6). Hence, every participating country is assigned with different individual emission quotas, either higher or lower than collective target 5.2% or even increase (Michael, 2011). For example, 8% reduction for the European

Union, 7% for the U.S., 6% for Japan, 0% for Russia and permitted increase of 8% for Australia and 1% for Iceland (UNFCCC, 1998). Annex I countries meet their obligations by year 2012 (first committing period 2008-2012) met either at the country itself, through investing in CDM projects, buying carbon credits, generally from developing countries with lower carbon footprint or buying carbon credits from developed countries with excessive carbon allowance from recognized exchanges (Danny, 2009). Several mechanisms created under the Protocol for this purpose, such as International Emissions Trading (IET), Clean Development Mechanism (CDM) and Joint Implementation (JI) (IPCC, 2007c).

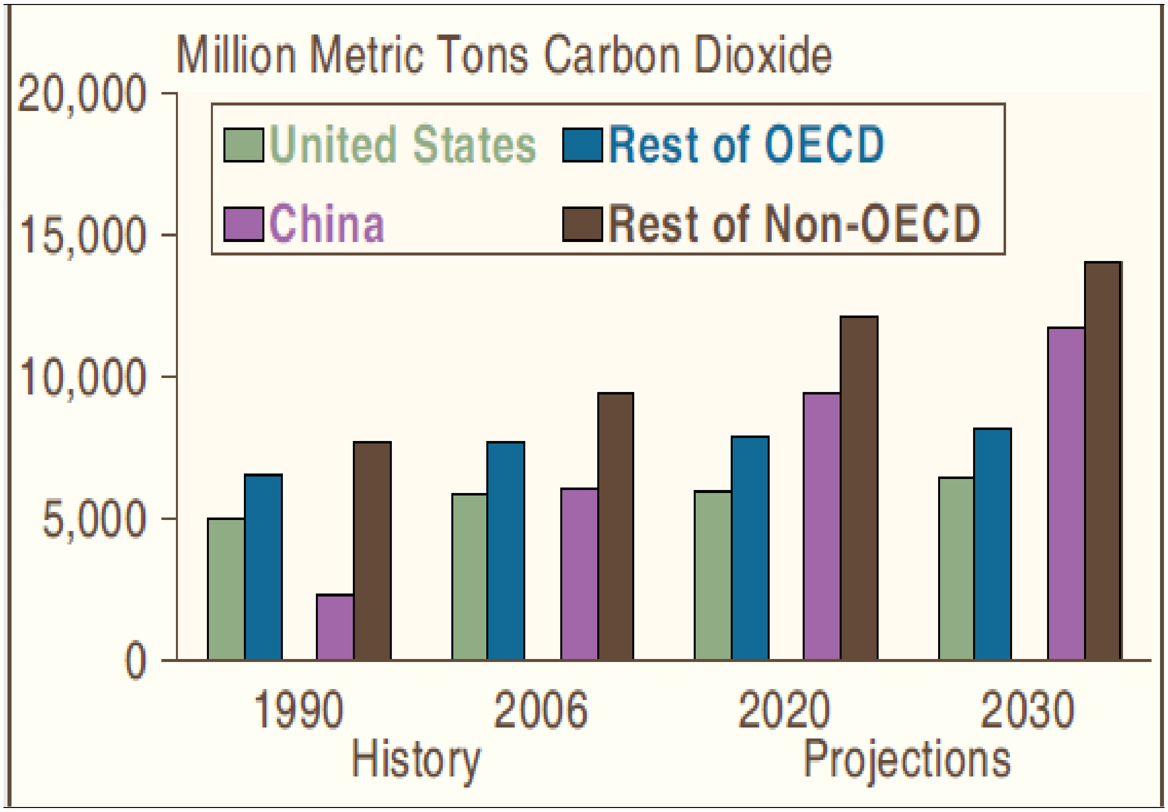


Figure 2.6: World carbon emissions by region, 1990, 2006, 2020 and 2030

Source: US EIA, 2009

Almost every country has signed the Protocol. Signature represents support to the Protocol while ratification carries legal obligation (Michael, 2011). Currently, 192 countries have ratified the Protocol as their commitment against global warming. Of the signatories, only the U.S. refuses to ratify the Protocol. The excuse given is that the emission cut will bring negative effect to their economy. The U.S. emitted approximately 6.6 billion metric tonnes CO_2e of GHG in 2009. Other significant sources were contributed by China, Europe, Russia and Japan (US EIA, 2011a).

2.6.1. Loophole of Kyoto Protocol

Global emission reduction targets will only be achieved with the participation of the world's largest emitting nations, together with the most rapidly industrialising developing countries and large transition economy countries such as China and India (Jane et al., 2007). In 2007, world's total energy-related CO_2 emissions accounted for 29,728 MMT. 20% (6,022 MMT) contributed by the U.S., 46% (13,711 MMT) from Organization for Economic Coorperation and Development (OECD) - including OECD North America, OECD Europe, Japan, South Korea, Australia and New Zealand the remaining 54% (16,017 MMT) from non-OECD countries (Figure 2.7). Annual Energy Outlook 2011 (AEO2011) Reference Case pointed out that energy-related CO_2 emissions from the U.S. were estimated to rise 0.2% annually from 2007 to 2035, non-OECD countries 1.7%, China 10% and India 7% (US EIA, 2011c). From this increase projection, China contributes 56% of the total (US EIA, 2011b).

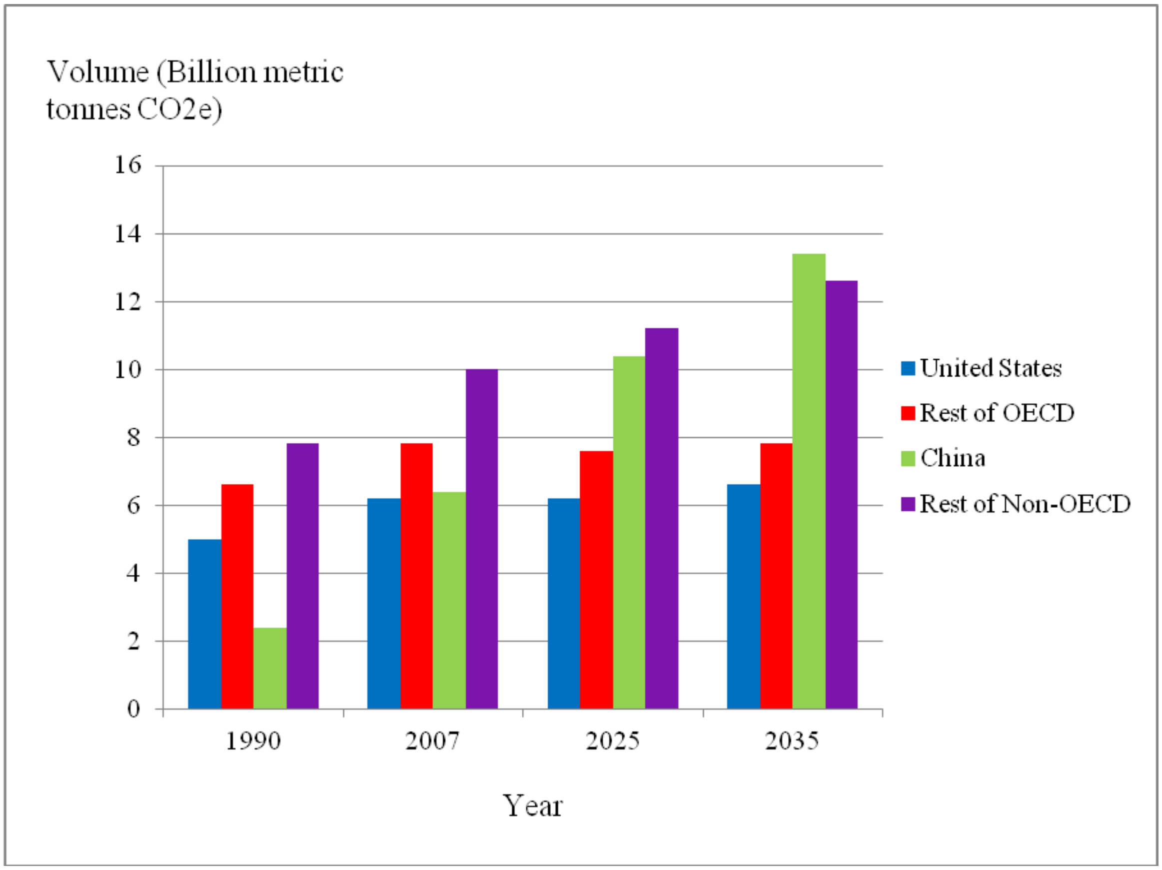


Figure 2.7: World carbon dioxide emissions by region, 1990, 2007, 2025 and 2035

Source: US EIA, 2011b

This statistic indicated that China soon or later will overtake the U.S. as the world's largest emitter. However, China is free from any emission reduction obligation as it falls under non-Annex I countries in the Protocol. Probably, the developing countries will be required to have a emission reduction target. Without ratification from the U.S and China, the estimated residual (net) demand for Kyoto assets is 230 MtCO2e will be hard to meet (Carbon Finance Unit of the World Bank, 2010). Another loophole is under the Protocol, the West 'mis-use' CDM projects to outsourced most of its emission to China and India due to their relative low labour cost (Michael, 2011).

2.6.2. Post-Kyoto Era

In 2009, the first phase of the Protocol expired. Thus, the 15th Meeting of the Patties of UNFCCC which held in Copenhagen Denmark in December 2009 got most global attention. Representatives from 192 countries failed to reach global emission reduction agreement from 2012-2020 (Zhang & Niu, 2011). The failure was caused by various attitudes of individual countries. Main focus was not merely to combat climate change, but also included political and economic considerations. The U.S. being the world power status rejected to commit 4% reduction. However, positive commitments were given by other power countries: EU promised to reduce 30% by 2020 and 95% by 2050; the president of Russia promised a GHG emission reduction of 25% by 2010; by 2020, India will reduce CO_2 emission emissions of per GDP of 20%-25% based on that of 2005, Japan will reduce 80% by 2050 under the Climate Warming Countermeasures Basic Act. Those positive emission reductions targets definitely will put pressure on the U.S. to promise some reduction targets. Otherwise, its status and prestige will be affected in the following international summit (Zhang & Niu, 2011).

There is yet any post-2012 climate treaty to restrict global GHG emissions. The future of CDM projects and global carbon market remain uncertain. However, Zhang & Niu (2011) showed a positive support as abundant of resources have been provided to the basic conditions of project implementation, such as research methodology.

2.6.3. Clean Development Mechanism (CDM)

Currently, the CDM, is the only market-based mechanism to trigger changes in emission-intensive activities in emerging economies (Malte et al., 2010). Under the CDM, certified emission reduction (CER) credits will be generated by emission reduction projects which normally take place in developing countries where cost of emission reduction is lower. CERs are awarded by Designated Operational Entity (DOE) after going through strict procedures under the UNFCCC (Climate Avenue, 2010). Each CER is equivalent to one tCO_2 mitigated. These CERs can be used by the Annex I countries who pay for the projects to fulfill their emission reduction obligations under the Protocol (UNFCCC, 2011c). Besides that, the CERs are tradable and saleable to other Annex I countries, a tradable equities in global climate exchange just like securities and commodities in the stock markets (Climate Avenue, 2010).

The mechanism which was created by Article of the Protocol in 1997 boosts a win-win situation. It brings more emission reduction projects which help developed countries to fulfill their emission reduction obligations under the Protocol. On the other hand, developing countries benefit from financial and technology transfer towards sustainable development. Besides that, the CDM projects also provide employment opportunity to local community of host countries. Thus, it plays a role in poverty alleviation (Srikanth & Bob, 2011).

Over 2000 projects have been registered under the CDM until mid-March 2010, China and India being the biggest and second users of CDM projects (Ian & Shama, 2010). Over 385 million CERs have been issued (Ian & Shama, 2010). However, some of the CERs are not real. This is because developed countries are not eventually making reduction in developing countries (Schneider, 2007; Wara and Victor, 2008). The CDM increases global emission instead. In other study, Sathaye and Phadke (2006) showed that transfer of emission-reduction technology to developing countries is more costly than doing in developing countries. This does not help in cost saving but brings profit to technology providers.

Approximately 90% of registered small-scale CDM projects are related to renewable energy and energy efficiency projects (UNFCCC, 2006a). Developing countries put high expectations on the benefits resulted from the CDM projects. However, Srikanth & Bob (2011) found that developing countries predominantly did not benefit from the CDM projects. This is because the host countries failed in establishing, applying and monitoring the sustainable development criteria for small-scale CDM projects might cause the failure. Another problem with the CDM is the lengthy procedures and regulatory obstacles (Capoor & Ambrosi, 2008). As a result of the inefficiency, CDM projects are stuck in pipeline, waiting for their CERs to be issued.

2.7 Global Carbon Market

2.7.1. Carbon Offset Standards and Carbon Credits

Different standards have emerged to cater different types of projects (Carbonfund.org, 2011). However, full-fledged carbon offset standards generally cover three main components: accounting standards, monitoring, verification and certification standards and registration and enforcement systems (Anja et al., 2008). There are two types of carbon credits based on market type. Carbon credits in regulatory markets are called certified carbon credits while voluntary carbon credits are in voluntary carbon markets. Carbon credits are certified according to relevant standards and verified by an independent auditor to ensure its high quality (ClearSky Climate Solutions, 2011).

Carbon offset standards in regulatory markets include CDM which issues Certified Emission Reduction (CER) credits, JI issues Emissions Reduction Units (ERUs) and EU ETS issues European Union Allowances (EUAs). While carbon offset standards in voluntary markets include: the Voluntary Carbon Standard (VCS) issues Voluntary Carbon Units (VCUs), the Gold Standard issues Voluntary Emissions Reductions (VERs) and the Climate, Community and Biodiversity Standard (CCB) (Carbon Footprint, 2011).

2.7.2. Types of Global Carbon Market

There are two types of carbon markets: the regulatory (compliance) markets and voluntary markets (Markit Environmental Registry, 2010). Prices of carbon credits vary among markets. For instance, US$6-16/$tCO_2$ in CDM, US$18-23/$tCO_2$ in EU ETS (for 2008 allowances) and US$5-20/$tCO_2$ in voluntary carbon markets (Green Markets International, 2007). Transaction volume of both markets made up the total volume of global carbon market.

Trading of pollution-emission credits is booming due to global warming and increasing environmental consciousness. Consequently, carbon trading is growing steadily and is becoming one of the fastest growing industries. According to the latest annual report from the World Bank, global carbon market grew 6% from US$135 billion in 2008 to US$144 billion with 8.7 billion tCO_2e traded in 2009 (Carbon Finance Unit of the World Bank, 2010) (Figure 2.8).

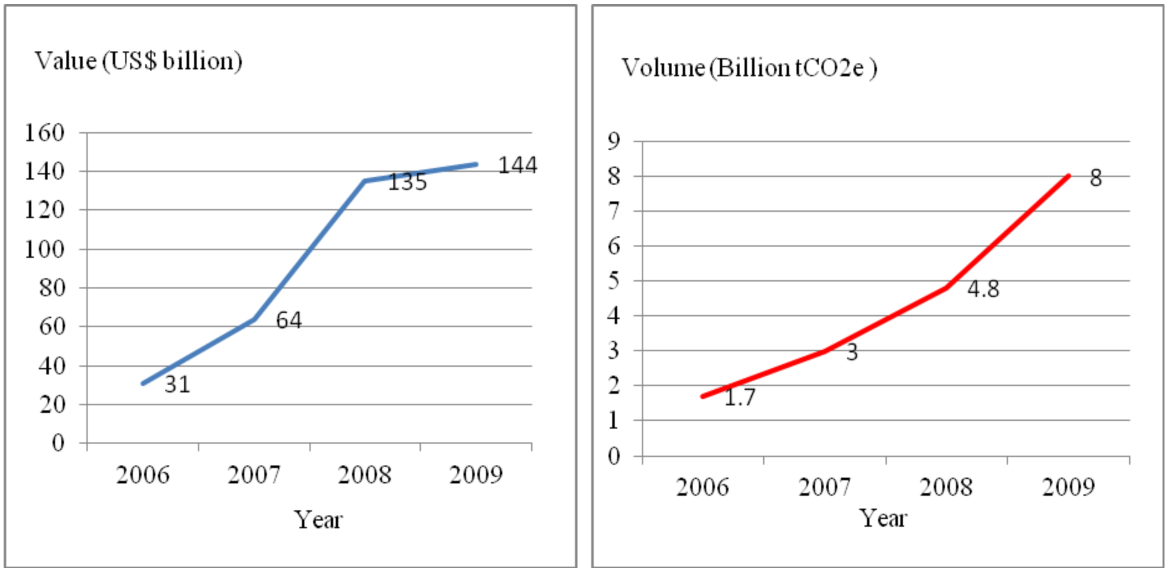


Figure 2.8a: Value of global carbon market Figure 2.8b: Volume of global carbon market

Figure 2.8: Trend of global carbon market

Source: Carbon Finance Unit of the World Bank, 2010

(a) Regulatory Carbon Market

The regulatory markets exist due to the reduction obligation under the Kyoto Protocol. Some of the participating countries have established their own trading schemes such as the Europen Union’s Emissions Trading Scheme (EU ETS) and the impending schemes in Australia, the United States and New Zealand (Ecosystem Marketplace, 2011a).

Though prices declined, value of global carbon market increased 11% to US$ 176 billion in 2011, recorded a new high transaction volume of 10.3 billion tCO$_2$e (Table 2.9). The EU ETS which started in the EU in 2005 is the largest market in operation, accounts for 84% of global carbon trading market. EU Allowance (EUA) trading volume increased to 7.9 billion tCO$_2$e, valued at US$ 148 billion. The market value of pre-2013 primary CER market declined 32% to US$ 1 billion in 2011 due to uncertainty after first commitment period ends in 2012. However, market value of post-2012 primary CER market increased 6% to US$ 2 billion despite depressed prices. Primary CERs are generated from primary CDM projects (new projects) in Asia, Africa and Latin America (non Annex 1 countries) (CDM Update, 2011). The primary CERs which are then sold to third party is called secondary CERs (CDM Update, 2011).

Table 2.9: Transaction volumes and values for global carbon market, 2010 and 2011

	2010		2011	
	Volume ($MtCO_2e$)	Value (US$ million)	Volume ($MtCO_2e$)	Value (US$ million)
Allowance market				
EUA	6,789	133,598	7,853	147,848
AAU	62	626	47	318
RMU	N/A	N/A	4	12
NZU	7	101	27	351
RGGI	210	458	120	249
CCA	N/A	N/A	4	63
Others	94	151	26	40
Subtotal	**7,162**	**134,935**	**8,081**	**148,881**
Spot & Secondary offset market				
sCER	1,260	20,453	1,734	22,333
sERU	6	94	76	780
Others	10	90	12	137
Subtotal	**1,275**	**20,637**	**1,822**	**22,350**
Forward (primary) project-based transactions				
pCER pre-2013	124	1,458	91	990
pCER post-2012	100	1,217	173	1,990
pERU	41	530	28	339
Voluntary market	69	414	87	569
Subtotal	**334**	**3,620**	**378**	**3,889**
TOTAL	**8,772**	**159,191**	**10,281**	**176,020**

Source: Carbon Finance Unit of the World Bank, 2012

(b) Voluntary Carbon Market

Voluntary carbon market is unregulated and operates outside regulated market (Reuters, 2010). Businesses, governments, NGOs and individuals voluntarily offset their carbon footprint by purchasing carbon credits though they do not have carbon emissions reduction obligation (Global Greenhouse Warming.com, 2011). Its transaction volume is relatively small but is apparently growing significantly (Green Markets International, 2007). It consists of three main trading platforms: Chicago Climate Exchange (CCX), the voluntary over-the-counter (OTC) and other exchanges. OTC market refers all voluntary carbon credits transactions (mostly project-based emissions reductions credits) outside of the CCX. It also includes CCX bilateral trades (Ecosystem Marketplace, 2011b). Global voluntary carbon market worth US$ 569 million in 2011, increased 37% from 2010, with 87 $MtCO_2e$ was transacted (Table 2.9).

2.7.3. Current Global Carbon Market Trend and Post 2012 Global Carbon Market

Lengthy time required in the registration of CDM projects and validation of CERs had prohibited emission-reduction project developers to invest (Carbon Finance Unit of the World Bank, 2010). However, the waiting time has been shorten significantly from months to weeks (Carbon Positive, 2011).

The issuance rate of CERs has gradually increased annually. 132 million CERs were issued in 2010 compared to only 500 million CERs issued since 2006 (Carbon Positive, 2011). Over the past five years, the global carbon market achieved a 256% compound annual growth rate (CAGR) (SBI Energy, 2009). Though worldwide economic turmoil caused significant negative impact to carbon markets in term of transaction values and prices, a growth rate of 15% was predicted in 2011, increase from US$128 billion in 2010 to US$148 billion in 2011 (Bloomberg, 2011). The pick-up is due to higher prices and increased demand from energy companies for new reductions under EU ETS start in 2013 (Ben, 2010). Thus, carbon markets are predicted to reach US$669 billion in 2013 (SBI Energy, 2009). Barclays Capital forecasts CER prices holding within US$ 15 to US$17 per tonne despite increased supply. According to the IDEAcarbon pCER Index, prices in the primary market range from US$10 to US$14 per tonne across 2009-2012 (Carbon Positive, 2009).

The first commitment period of the Kyoto Protocol will expire in 2012. Yet to date, there is no post-2012 climate treaty. Thus, the long term outlook beyond 2012 holds further uncertainty (Carbon Positive, 2009). However, experts have assured demand will remain and a strong market will stay prevalent due to certain factors. For instance, the world's second largest carbon market will exist in the United States by 2012 through its own cap-and-trade system, creating a value close to US$117 billion by 2013. This has given a positive outlook on global carbon markets (SBI Energy, 2009). Besides that, anticipation from Australia is expected too since last turndown by Senate. With the anticipation from the United States, Australia and Japan by implementing their own trading schemes, global carbon market could reach US$1.4 trillion in 2020 (Bloomberg, 2011).

2.8 Potential of Carbon Trading and CDM in Malaysia

According to UNFCCC officials, global carbon trading market worth US$60 billion and this amount has a growth potential of reaching US$1 trillion in a decade (Danny, 2009).

Most of the developing countries do not have any carbon emission reduction target. Nevertheless this global rapidly growing industry can beneficial those countries (Palm Oil HQ, 2008). Currently, the largest carbon market exists in Asia with China (64.97%) and India (10.60%) lead the pack, followed by Brazil (3.73%) and Republic of Korea (2.94%), from total 674,327,561 CERs. In Southeast Asia countries, Indonesia and Vietnam are actively involved in CDM projects, with 1.54% and 1.45% respectively (Figure 2.9). To date, Southeast Asia accounts for only 1% of EU ETS. Apparently, carbon trading market in this region has a great potential to grow in next few years as European Unions need to meet their reduction targets by 2012 (Climate Avenue, 2010; Palm Oil HQ, 2008).

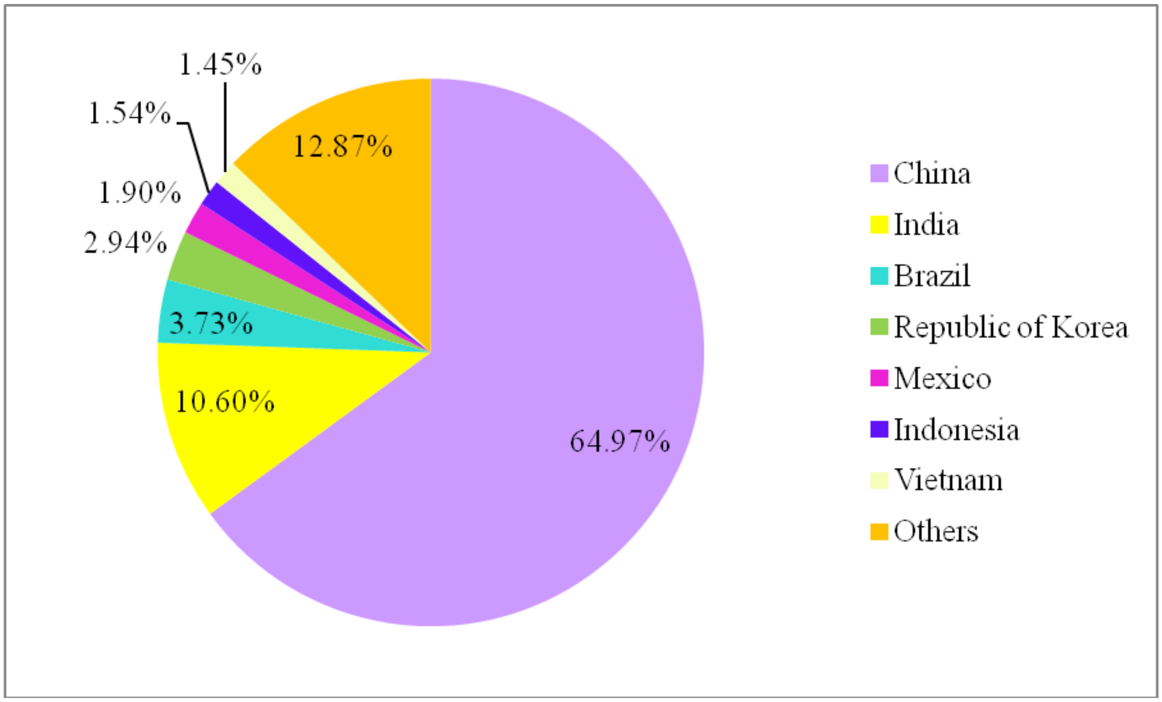


Figure 2.9: Expected average annual CERs from registered projects by country

Source: UNFCCC, 2012

Carbon market is a relatively new business in Malaysia. However, there is something special to take note. The first project in the world to be awarded with CERs by the United

Nation Executive Board (EB) is a biomass project in Sabah (Climate Avenue, 2010). As of October 2012, Malaysia ranked the sixth in number of CDM projects in Asia, after China, India, Vietnam, Thailand and Indonesia (Figure 2.10) while ranked the fifth in volume of CERs (Figure 2.11). Malaysia had 100 million tonnes of potentially traded carbon credits emitted between 2006 and 2010, which is equivalent to RM4.8 billion, showed in a research done by the Malaysia Energy Centre (Danny, 2009; Palm Oil HQ, 2008).

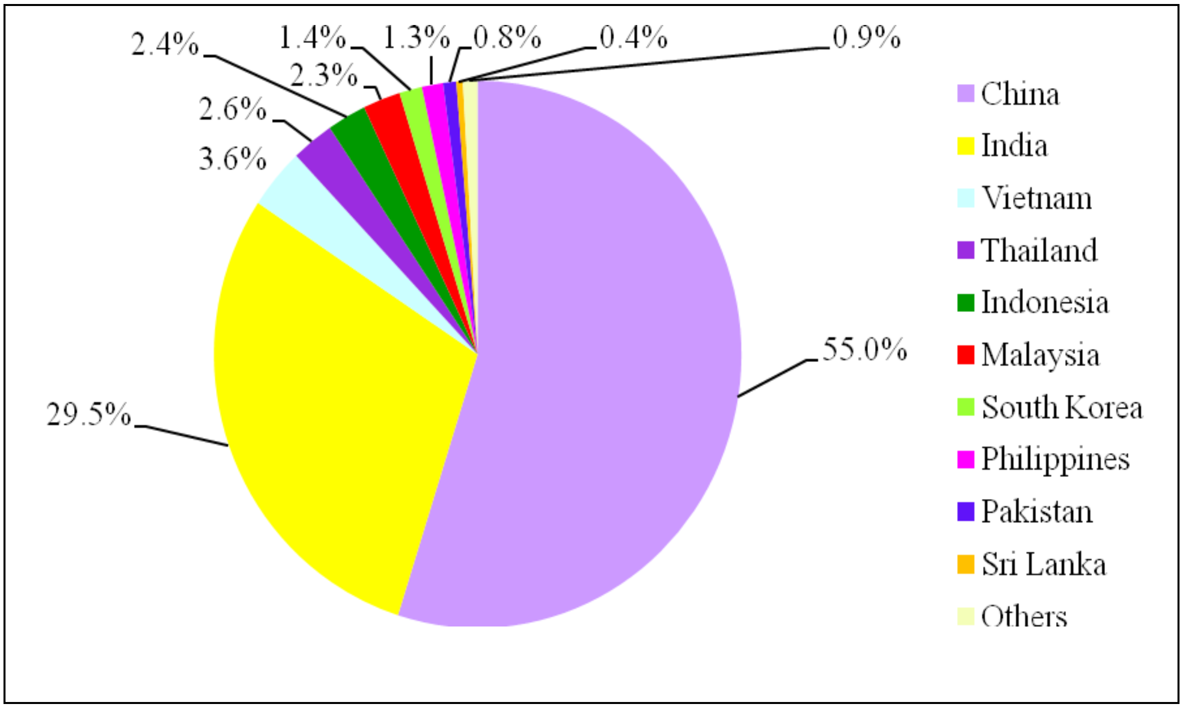


Figure 2.10: Number of CDM projects in Asia by country

Source: UNEP, 2012

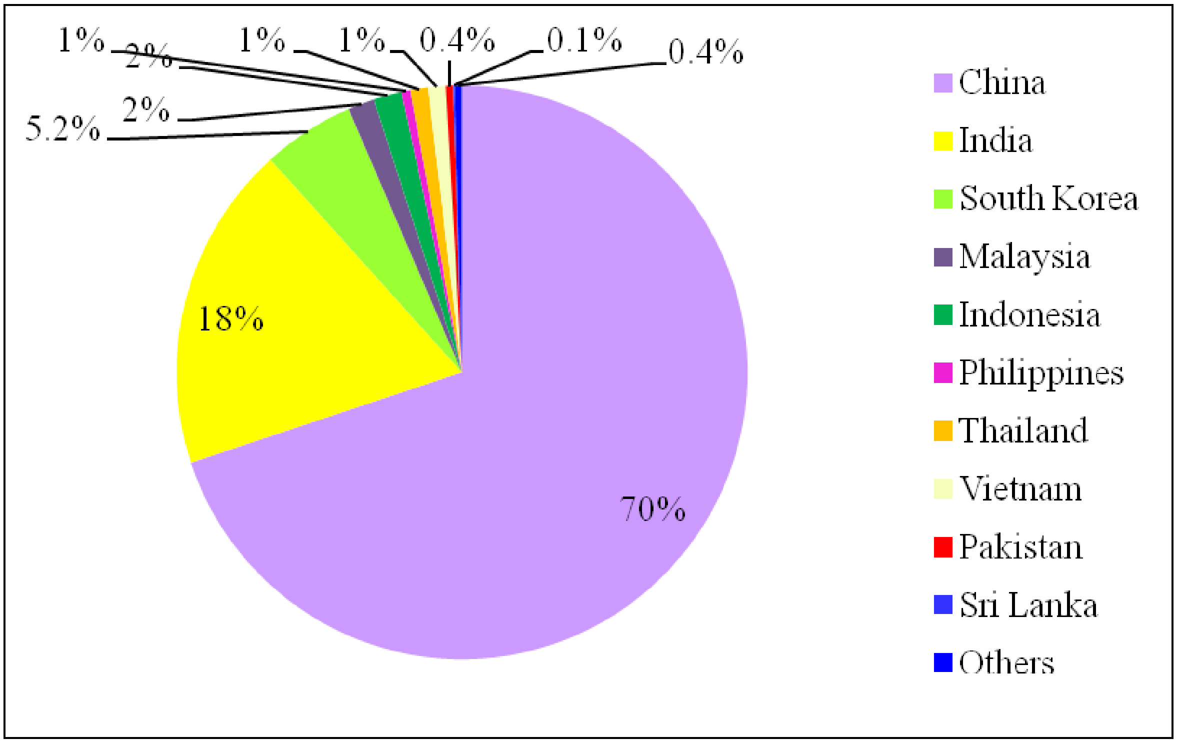


Figure 2.11: Volume of CERs in Asia by country

Source: UNEP, 2012

Being a developing country with plenty of agricultural resources, plantation sector is identified as the most beneficiary sector in Malaysia (Oh & Chua, 2010). Other potential beneficiaries are the power, manufacturing, waste management, forestry, oil and gas, and transportation sectors (Palm Oil HQ, 2008). In 2010, there were 709 registered CDM projects. Out of this, Malaysia had only 1% of the list. Followed by the expected growing demand from EU, the Government is promoting this green business via various incentives, for instance, income generated from carbon credits is exempted from income tax between 2008 to 2010 (The Star Online, 2008). Until May 2010, 81 CDM projects took place in the country, the highest number of CDM projects in South East Asia (Bernama, 2010a). In order to show its effort in climate change combat, the Prime Minister Datuk Seri Najib Tun Razak promised a voluntary reduction of up to 40% from 2005 levels at the Climate

Change Conference in Copenhagen in 2010, if there is assistance from developed countries (Bernama, 2010a).

Ministry of Natural Resources and Environment is the national authority for CDM in Malaysia, helps the country to keep updated with latest technologies and achieve sustainable development cost effectively (Bernama, 2010a). The ministry had established Malaysian Green Technology Corporation, which is in charge of Malaysia Energy Centre (PTM) to stimulate the development and use of renewable energy and energy-efficient activities and technologies in sectors such as transportation, industrial processes, agriculture and forestry (Bernama, 2010b). Renewable energy is expected to reduce eleven million tCO_2e, energy efficiency will contribute nine million tCO_2e and waste management sector 10 million tCO_2e (Bernama, 2010a). Consequently, various incentives had been introduced by the Government, such as pioneer status for corporations, investment tax allowance and import duty and sales tax exemption for equipment used in energy conservation (Bernama, 2010b).

Table 2.10 describes briefly the expected potential of CERs revenues from different types of CMD projects in Malaysia and corresponding amount of megawatt (MW) of renewable energy. The figures are preliminary results and based on an assessment of the potential in energy sector (Green Tech Malaysia, 2011). Biogas from palm oil mill effluent (POME) and animal manure generates the highest amount of CERs, followed by flaring from oil production and landfill gas. This shows that agricultural and waste sector have a great potential in CDM as Malaysia is rich with oil palm plantation and landfilling is the most common waste disposal method to date.

Table 2.10: Expected potential of CERs revenues from different types of CMD projects in Malaysia and corresponding amount of megawatt (MW) of renewable energy

Project Type	CERs per year in 2010	MW electricity
Biogas POME + animal manure	5,900,000	190 MW
Landfill gas	3,700,000	45 MW
Reduction of gas flaring from oil production	4,600,000	N/A
Mini hydro	70,000	25 MW
Biomass CHP	380,000	90 MW
Other projects	3,150,000	N/A
Total	**17,800,000**	**350 MW**

Source: Green Tech Malaysia, 2011