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Economic and environmental benefits of landfill gas from municipal solid waste in Malaysia

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ABSTRACT

Discharge of Green House Gases (GHGs) and the management of municipal solid waste (MSW) continue to be a major challenge particularly in growing economies. However, these are resources which can be converted to green energy. Landfill gas which is essentially methane (50–55%) and carbon dioxide (40–45%) (both GHGs) is released from MSW by biodegradation processes. The estimation of this methane and its economic and environmental benefits for environmental sustainability are the objectives of this study. Methane emission from MSW disposed of in landfills was estimated using Intergovernmental Panel on Climate Change (IPCC) methodology. From the study, based on 8,196,000 tonnes MSW generated in Peninsular Malaysia in 2010, anthropogenic methane emission of about 310,220 tonnes per year was estimated. This was estimated to generate 1.9 billion kWh of electricity year^{-1} worth over RM 570 million (US$190 million). In addition, this leads to carbon dioxide reduction of 6,514,620 tonnes year^{-1} equivalent to carbon credit of over RM 257 million (US$85 million). These results were also projected for 2015 and 2020 and the outcomes are promising. Therefore, the exploration of this resource, besides the economic benefits helps in reducing the dependence on the depleting fossil fuel and hence broadening the fuel base of the country.

Contents

1. Introduction 2907
2. Municipal solid waste generation 2908
3. Characteristics of municipal solid waste 2908
4. Review of landfill management in Malaysia 2908
   4.1. Sanitary landfill facilities in Malaysia 2908
5. Anaerobic biodegradation of municipal solid waste in landfills 2909
6. Generation of methane from landfills 2910
   6.1. Estimation of methane emission from landfills by the IPCC method 2910
7. Estimation of methane emission from landfills in Peninsular Malaysia 2911
   7.1. Environmental and economic benefits of methane capture 2911
8. Conclusions 2912
   Acknowledgement 2912
   References 2912

1. Introduction

Human activities have led to the accumulation of Green House Gases (GHGs) in the environment which is responsible for environmental degradation faced today. This has triggered the concern for public and private bodies to engage in processes which have little or no negative impact on the environment. Methane is a GHG which constitutes 50–55% by volume of landfill gas (LFG) and has 21–23 times global warming potential than CO_2 [1]. However, it is a green fuel which can be used for electricity generation, a source of heat or a feedstock for fertilizer and methanol production. Methane is produced by anaerobic biodegradation of MSW in landfills and the amount of the gas produced can be estimated from a number of methods [2–4]. The conversion of LFG into resource depends on the management of MSW in landfills.

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Land filling is the main MSW disposal method in Malaysia. About 80–90% of the MSW in Malaysia is land-filled and mostly open dumping [5,6]. Less than 10% of these landfills are sanitary as such only a small portion of the LFG is utilized, the larger part escapes into the atmosphere and thus becoming a threat to the globe [6]. These landfills can be properly managed, by converting them to sanitary and capturing the methane for electricity generation onsite or channelled to industries for same or other purposes. In this way, revenue is generated and the threat to environment due to its emission is mitigated.

This study estimates the methane emission and revenue potentials from MSW disposed of in landfills in Peninsular Malaysia. In addition, reviews on the generation, characterization of MSW and landfill management and processes, which could provide basis for sustainable MSW management in Malaysia, is also presented.

2. Municipal solid waste generation

The management of solid waste continues to be a major challenge in urban areas throughout the world, particularly in the rapidly growing cities and towns of the developing countries. The increase in population causes increase in human activities and this in turn leads to increase in waste generation [7]. Statistics show that the world population is over six billion in 2001 with 46% of this population residing in urban areas. Global MSW generated in 1997 was about 0.49 billion tonnes with an estimated annual growth rate of 3.2–4.5% in developed nations and 2–3% in developing nations [8].

Malaysia like all developing countries is facing an increase in the generation of MSW and the problem of managing this waste is also on the increase. The Peninsular Malaysia generates about 17,000 tonnes of MSW per day (6.2 million tonnes/year) in 2002 and the per capita varies between 0.5 and 0.8 kg/day and has increased to 1.7 kg/day in big cities [9–11]. This rate can lead to MSW generation of 31,000 tonnes per day in 2020 [12,13]. Recent data on MSW generation in Malaysia is scarce and for this reason most researchers use projected or assumed values. Ref. [2] assumed a per capita MSW generation of 0.8–1 kg/day in 2009 for estimation of methane emission. Table 1 shows MSW generation projection until 2020. The projection was based on average generation rate of 2.14% from 1998 to 2000 [14].

From Table 1, the MSW generation in 2010, 2015 and 2020 were estimated to be 8,196,000 tonnes, 9,111,000 tonnes and 9,820,000, respectively, in Peninsular Malaysia. The total average increase rate is 2.14%. Based on the states, in 2010 the estimation showed that Selangor was the top MSW generator with estimate at 1,595,000 tonnes/year followed by Johor with 1,395,000 tonnes/year and thirdly Kuala Lumpur with an estimate of 1,202,000 tonnes/year.

The MSW generation is increasing and this is expected because population and economy of Malaysia which are highly related to waste generation are also increasing [7]. This increase in human elements (i.e. population and economy) should be positively converted as they are two of the four drivers of sustainable waste management in Asia [7].

3. Characteristics of municipal solid waste

The characterization of waste is crucial in deciding which management option/options to adopt in managing that particular waste. A waste characterization study on a typical Malaysian MSW is shown in Table 2.

Table 2 indicates that at least 61.17% of Malaysian MSW is made up of biomass materials – food, paper and wood. Due to its high moisture content of 55.01% [10] the MSW is favourable for LFG generation or composting. Food/organic is made up of 37.43% while paper (mix paper, news print, high grade paper and corrugated paper) is 16.78% and wood and yard is 6.96%. The largest single constituent of the waste is food/organic, making up 37.43% and occurring mostly in residential low income waste (54.04%).

4. Review of landfill management in Malaysia

In Malaysia, MSW management is a responsibility under the Ministry of Housing and Local Government. Initially it was the responsibility of the Local Authorities, as stipulated in Section 72 of the Local Government Act 1976. The government has tried to improve the management of MSW in landfills especially, but has faced a lot of challenges mainly due to lack of expertise and fund.

In 2001 for instance, there were 155 disposal sites under the responsibility of local authorities in Malaysia which differ in sizes from 8 to 60 ha, depending on the location and amount of waste disposed [6]. Most of these sites are open dumpsites, and the capacity has been overloaded. The operation of these sites has been extended due to the absence of appropriate and cost-effective alternatives to treat the waste. The types and number of landfill sites are shown in Table 3.

4.1. Sanitary landfill facilities in Malaysia

Most of the landfill facilities in Malaysia are not sanitary and because of this there are lots of problems including fire incidents due to LFG emission and pollution due to leachate discharge. Solving these problems by converting the landfill sites to sanitary status will also help in capturing the bio-gas as a source of renewable energy. Furthermore, the government in its effort to

Table 1
MSW generation by states in Peninsular Malaysia in thousand tonnes [14].

State	1998	1999	2000	2010[a]	2015[a]	2020[a]
Kuala Lumpur	1058	1070	1082	1202	1262	1322
Selangor	1169	1204	1240	1595	1772.5	1950
Pahang	202	206	210	250	270	290
Kelantan	123	126	120	87	72	42
Terengganu	119	122	125	155	170	185
N. Sembilan	267	278	291	411	471	531
Melaka	208	216	225	310	352.5	395
Johor	927	956	1005	1395	1590	1785
Perlis	28	28	29	34	36.5	39
Kedah	569	569	631	941	1096	1251
Penang	611	611	648	833	925.5	1018
Perak	719	719	763	983	1093	1012
Total	6000	6105	6369	8196	9111	9820

[a] Projection based on (1998–2000) average increase rate of 2.14%.

Table 2
Typical Malaysia MSW characterization [10].

Source	Residential high income (%)	Residential medium income (%)	Residential low income (%)	Commercial (%)	Institutional (%)	Average (%)
Food/organic	30.84	38.42	54.04	41.48	22.36	37.43
Mix paper	9.75	7.22	6.37	8.92	11.27	8.71
News print	6.05	7.76	3.72	7.13	4.31	5.79
High grade paper	–	1.02	–	0.35	–	0.69
Corrugated paper	1.37	1.75	1.53	2.19	1.12	1.59
Plastic (rigid)	3.85	3.57	1.90	3.56	3.56	3.29
Plastic (film)	21.62	14.75	8.91	12.79	11.82	13.98
Plastic (foam)	0.74	1.72	0.85	0.83	4.12	1.65
Pampers	6.49	7.58	5.83	3.80	1.69	5.08
Textile	1.43	3.55	5.47	1.91	4.65	3.40
Rubber/leather	0.48	1.78	1.46	0.80	2.07	1.32
Wood	5.83	1.39	0.86	0.96	9.84	3.78
Yard	6.12	1.12	2.03	5.75	0.87	3.18
Glass (clear)	1.58	2.07	1.21	2.90	0.28	1.61
Glass (coloured)	1.17	2.02	0.09	1.82	0.24	1.07
Ferrous	1.93	3.05	2.25	2.47	3.75	2.69
Non-ferrous	0.17	0.00	0.18	0.55	1.55	0.49
Aluminium	0.34	0.08	0.39	0.25	0.04	0.22
Batteries/hazards	0.22	0.18	–	0.29	0.06	0.19
Fine	–	0.71	2.66	0.00	0.39	0.94
Other organic	0.02	0.00	–	1.26	1.00	0.57
Other inorganic	–	0.27	0.25	–	8.05	2.86
Others	–	–	–	–	6.97	6.97

Table 3
Types and number of landfill sites in Peninsular Malaysia [6].

State	Open dump	Control. dump	Sanit. landfill	Total
Johor	12	14	1	27
Kedah	9	5	1	15
Kelantanan	12	2	0	14
Melaka	2	3	0	5
Negeri Sembilan	8	6	0	14
Pahang	7	5	3	15
Perak	15	11	4	30
Perlis	0	1	0	1
Pulau Pinang	1	1	1	3
Selangor	5	15	0	20
Terengganu	2	8	1	11
Total	73	71	11	155

promote renewable energy and energy efficiency in the country approved the proposal of some Small Renewable Energy Project (SREP) of LFG types in 2004. The proposals were submitted to the United Nations Framework Convention on Climatic Change as Clean Development Mechanism (CDM) projects. Table 4 shows the proposed LFG plants and the utilization system proposed.

These proposed CDM projects involve the installation of equipment for LFG capture and combustion as well as the treatment of leachate from the landfills. In Taman Beringin and Kampung Kelichap Landfills, the combustion heat recovered from LFG will be used to evaporate the leachate collected from the landfill. Excess LFG will be flared. The equipment to be installed consists of piping that connects existing LFG wells to a condensing unit and combustion system.

Table 4
LFG plant and gas utilization system [11].

Location	State	Utilization
Bukit Tagar	K. Lumpur	Electricity generation for own consumption and sale
Seelong	Johor	Electricity generation for own consumption and sale
Terman Beringin	K. Lumpur	Combustion with generation of heat to evaporate leachate
Kampung Kelichap	Johor	Combustion with generation of heat to evaporate leachate

Table 5 shows some existing sanitary landfills and their status in Peninsular Malaysia.

Table 5 shows that out of the ten sanitary landfills six are in operation. The Pulau Burung sanitary landfill has the highest MSW disposed of in it (19 million tonnes) and a methane reduction of 45,538 tonnes CO_2 equivalent. On the other hand, Bukit Tangar landfill is the highest methane reducing facility of 219,625 tonnes CO_2 equivalent, though containing a lower amount of MSW (2.8 million tonnes).

The first grid connected renewable energy facility is the Air Hitam Sanitary Landfill (AHSL). It is owned by Jana Landfill Sdn. Bhd. (JLSB) which was constructed in 2003 to produce and utilize LFG for electricity generation for 20 years. It generates about 2 MW of electricity using 2 Austrian made internal combustion engines. The landfill has a capacity of 7 million tonnes of MSW but with only 1.61 million tonnes MSW in place or 23% of the total capacity. The LFG is made up of over 55% methane, up to 80% moisture content and a calorific value of 5.32 kWh/m^3 [11]. Unfortunately, this facility was out of operation since 2007 due to some technical problems.

5. Anaerobic biodegradation of municipal solid waste in landfills

The essential reaction in a landfill is anaerobic biodegradation of the organic component of MSW. The reaction is in three stages. Firstly, the complex molecules are hydrolyzed by bacteria into soluble products (like glucose). Secondly, these soluble products are converted by acid forming bacteria to simple organic acids, carbon dioxide and hydrogen; the principal acids produced are acetic acid (ethanoic acid), propanoic acid, butanoic acid and ethanol. And finally, methane is formed by bacteria either by breaking down the acids or by reducing CO_2 with H_2. The second and third reactions can be represented as follows [4]:

Acetogenesis

$$\underset{\text{glucose}}{C_6H_{12}O_6} \rightarrow 2C_2H_5OH + 2CO_2 \quad (1)$$

Table 5
Existing sanitary landfill facilities in Peninsular Malaysia [2].

Location	State	Status	MSW (in 2009), tonnes	Methane recovery	Starting year of methane reduction	Av. methane red., tonnes CO_2.eq
Pulai	Kedah	In operation	440,000	No recovery	–	–
Ampang Jajar	Pinang	Closed	3,360,000	No recovery	–	–
Pulau Burung	Pinang	In operation	19,050,000	Passive aeration	2010	45,538
Jobor Jerangau	Pinang	In operation	2,920,000	Recovering	2008	15,418
Air Hitam	Selangor	Closed	1,610,000	No recovery	–	–
Kg. Hang Tuah	Selangor	Closed	530,000	No recovery	–	–
Jeram	Selangor	In operation	1,500,000	No recovery	–	–
Bukit Tagar	K. Lumpur	In operation	2,850,000	Recovering	2009	219,625
Krubong	Melaka	Closed	4,100,000	Recovering	2007	57,830
Seelong	Johor	In operation	2,500,000	Recovering	2007	108,335

Methanogenesis

$$\underset{\text{acetic or ethanoic acid}}{CH_3COOH} \rightarrow CH_4 + CO_2 \quad (2)$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O \quad (3)$$

The maximum amount of LFG generated in the anaerobic decomposition can be estimated by the following simplified reaction:

$$\underset{\text{adipic acid (waste)}}{C_6H_{10}O_4} + 1.5H_2O \rightarrow 3.25CH_4 + 2.75CO_2 \quad (4)$$

The LFG produced here contains about 50–54% CH_4 and 40–46% CO_2 and other minor products such as ammonia and hydrogen sulphide. The reaction progresses better in the presence of water, which is the principal reagent [4].

Eq. (4) shows that 5.4 kg of the waste can react with 1 kg of water (since MW of the waste is 146 and water 18). In addition, since MSW contains about 20% moisture in US, there is enough moisture to react with the waste. However, the bacteria responsible for the biodegradation thrive well at water concentrations of above 40%, so continuous addition of water is required [4].

6. Generation of methane from landfills

The methane emission from MSW in developed countries is expected to be decreasing due to improved recycling-reuse program, increased LFG regulation and improved recovery technologies. On the other hand in developing countries, the emission will be increasing because of population increase and poor recycling program. The global methane emission from MSW was estimated to be 760.6 million tonnes $CO_{2\,eq}$ in 2010 [15]. Fig. 1 shows the top 7 countries in terms of methane emission from MSW landfills.

Fig. 1 indicates that in 2010, United States (US) was the highest emitter of methane in the world with an estimated emission of 125.4 million tonnes $CO_{2\,eq}$, it was followed by China with 47.5 million tonnes of $CO_{2\,eq}$.

A typical MSW in US contains 69.5% biomass or 60% dry biomass excluding contained moisture and inorganic dirt. This corresponds to 417 kg (2.86 kmol) of $C_6H_{10}O_4$/tonnes of total MSW. Material balance based on Eq. (4) will give 208 Nm^3 methane or 0.149 tonnes of methane (1 kmol of CH_4 is equal to 22.4 Nm^3) [4].

Comparing the above theoretical values with experimental from the literature, Ref. [16] estimated 213 Nm^3 or 0.153 methane/tonnes of dry biomass reacted. Ref. [17] also estimated 100–200 Nm^3 of LFG (54–108 Nm^3 methane) per tonnes MSW (assuming 60% biomass). This is equivalent to 73–135 Nm^3 methane/tonnes dry biomass corresponding to 35–65% of that estimated from Eq. (4). Furthermore, Refs. [18,19] estimated 83 Nm^3 (0.12 tonnes) and 62 Nm^3 methane/tonnes MSW, respectively.

In addition, Ref. [2] estimated methane emission from MSW in Malaysia (i.e. Peninsular Malaysia including Sabah and Sarawak) in 2009 to be 318.8 Gg (318,800 tonnes) and 201 Gg (201,000 tonnes) using IPCC 1996 and IPCC 2006 FOD models, respectively. In the same vein, Ref. [20] estimated 2 million tonnes of methane emission from MSW in United Kingdom (UK) in 1990. In the UK in 1990, 70% of the MSW was disposed of in landfills and 120 million tonnes of MSW was disposed of in 3500 landfills; there were other 20,000 landfills that were either closed or receiving MSW.

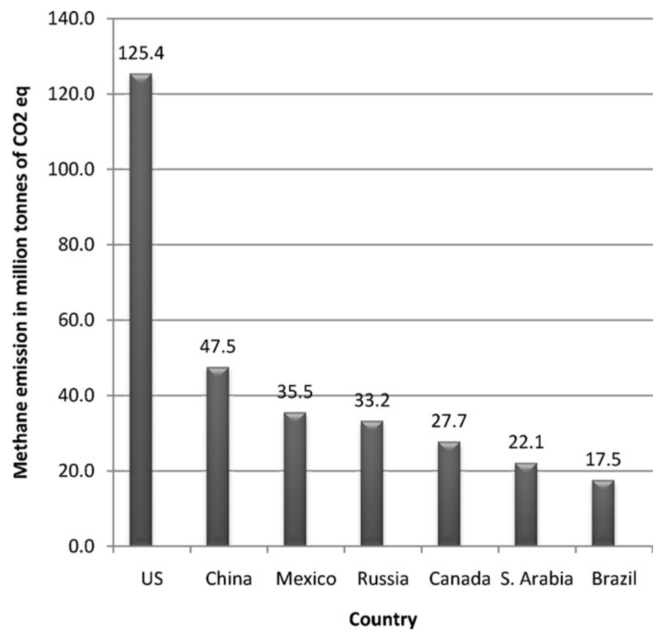

Fig. 1. Methane emission from MSW of world top 7 countries in 2010 [15].

6.1. *Estimation of methane emission from landfills by the IPCC method*

The anthropogenic methane emission from biomass by the anaerobic decomposition of various organic matters (i.e. kitchen garbage, paper and pulp, wood and leaf) can be estimated from a simple and straightforward method called the Intergovernmental Panel on Climate Change (IPCC) methodology [3]. By this methodology, methane emission from landfill is estimated using the following equation:

$$CH_4\ \text{emissions, tonnes} = MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times \frac{16}{12} \quad (5)$$

where MSW_T is the total MSW generated (tonnes), MSW_F is the fraction of MSW disposed of to landfills, MCF is the methane correction factor, DOC is the fraction of degradable organic carbon,

DOC_F is the fraction of total DOC that actually degrades, and F is the fraction of methane in LFG.

The default values (0.4–1.0) for MCF are dependent on the types of MSW landfill practices. If most of the landfills under consideration are unmanaged, a value of about 0.6 can be used [21]. According to IPCC, DOC ranges from 0.08 to 0.21 and is estimated from:

$$DOC = 0.4P + 0.15K + 0.3W \quad (6)$$

where P is the fraction of papers in MSW, K is the fraction of kitchen garbage in MSW and W is the fraction of woods/leaves in MSW.

Furthermore, the DOC_F should be considered because the biodegradation of DOC does not occur totally over a long period; therefore, a default value of 0.77 can be used.

Using the IPCC methodology [21], estimated methane emissions from MSW landfills in Taiwan during 1992–2003 to be around 360 thousand tonnes annually during 1992–1999, then decreased to approximately 103 thousand tonnes in 2003 due to the MSW recycling and incineration policies during this period.

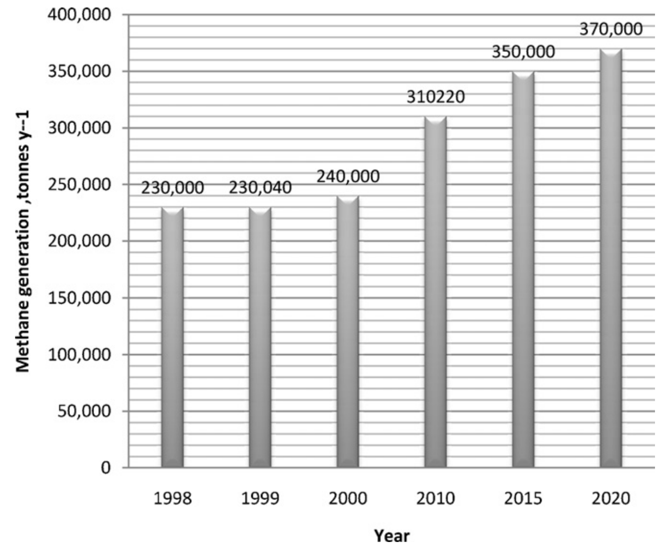

Fig. 2. Estimated methane emission in Peninsular Malaysia in tonnes/y.

7. Estimation of methane emission from landfills in Peninsular Malaysia

The amount of methane generated from MSW landfills in Peninsular Malaysia was estimated using the IPCC methodology [3]. Table 6 shows the amount of methane generated for 2010 by states in Peninsular Malaysia.

The values in the table were generated by substituting values into Eqs. (5) and (6). Total waste generated, MSW_T in 2010 was used for the estimation. Ref. [5] discovered that 80% of the total MSW in Malaysia was land filled, thus the value of waste fraction, MSW_F was taken as 0.8. Furthermore, MCF has a default value ranged between 0.4 and 1.0 depending on the type of landfill practices [21]. In Malaysia, since most of the landfills were unmanaged [6] a value of 0.6 was used. Also, according to the methodology a default value of 0.08–0.21 is allowed for DOC based on the result obtained from Eq. (6). Substituting values from Table 2 into Eq. (6) gives DOC of 0.14. In addition, biodegradation of DOC does not occur to completion, for this reason the same value ($DOC_F = 0.77$) as employed by [21] was used in this work. Moreover, a conservative value of 0.55 was used for F based on characterization of [11].

Similar estimations were done based on total MSW generated in Peninsular Malaysia from 1998 to 2020 and the corresponding methane emission is shown in Fig. 2.

A total of 310,220 tonnes of methane was generated in 2010 in Peninsular Malaysia and this value is expected to reach 350,000 tonnes/year and 370,000 in 2015 and 2020, respectively. These values resulted in the methane emission rate of 0.05 tonnes of methane/tonnes MSW or 70 Nm^3 of methane/tonnes MSW. (Taking the density of methane as 0.714 kg/Nm^3.) This value is in close agreement with the experimental values presented by [17–19]. Moreover, the 2010 methane estimation (310,000 tonnes) agrees with the estimation of [2] (318,800 tonnes) for the whole of Malaysia in 2009.

Comparing methane emission in states in Peninsular Malaysia, their generation is proportional to MSW generation. Selangor state was the highest generator of methane in 2010 followed by Johor then Kuala Lumpur with methane emissions estimated at 60,370 tonnes/y, 52,800 tonnes/y and 45,500 tonnes/y, respectively.

7.1. Environmental and economic benefits of methane capture

Landfill methane is a potential resource, but allowing its release into the environment has a lot of environmental implications. Methane, apart from its global warming potential also contributes in depleting the ozone layer. Therefore, the capturing and positive utilization of the biogas is not only environmentally beneficial but also economically attractive. The environmental and economic benefits of methane capture are shown in Table 7.

Equivalent CO_2 reduction was estimated by multiplying annual methane emission by 21 as methane has about 21 times global warming potential than CO_2 [1]. The values shown for CO_2

Table 6
Estimated methane generated from landfills in Peninsular Malaysia in 2010.

State	MSW_T tonnes/y[a]	MSW_F	MCF	DOC[b]	DOC_F	F	16/12	CH_4 tonnes/y[c]
K. Lumpur	1,202,000	0.80	0.60	0.14	0.77	0.55	1.33	45,500
Selangor	1,595,000	0.80	0.60	0.14	0.77	0.55	1.33	60,370
Pahang	250,000	0.80	0.60	0.14	0.77	0.55	1.33	9460
Kelantan	87,000	0.80	0.60	0.14	0.77	0.55	1.33	3290
Terengganu	155,000	0.80	0.60	0.14	0.77	0.55	1.33	5870
N.Sembilan	411,000	0.80	0.60	0.14	0.77	0.55	1.33	15,560
Melaka	310,000	0.80	0.60	0.14	0.77	0.55	1.33	11,730
Johor	1,395,000	0.80	0.60	0.14	0.77	0.55	1.33	52,800
Perlis	34,000	0.80	0.60	0.14	0.77	0.55	1.33	1290
Kedah	941,000	0.80	0.60	0.14	0.77	0.55	1.33	35,620
Penang	833,000	0.80	0.60	0.14	0.77	0.55	1.33	31,530
Perak	983,000	0.80	0.60	0.14	0.77	0.55	1.33	37,210
Total	8,196,000							310,220

[a] From Table 1.
[b] Calculated from Eq. (6).
[c] Calculated from Eq. (5).

Table 7
Environmental and economic benefits of methane biogas capture.

Parameter	2010	2015	2020
Estimated methane emission	310,220 tonnes	350,000 tonnes	370,000 tonnes
[a]Equivalent CO_2 emission	6,514,620 tonnes	7,350,000 tonnes	7,770,000 tonnes
[b]Revenue from carbon credit	[c]RM257,978,952 (US$85,992,984)	[c]RM291,060,000 (US$97,020,000)	[c]RM307,692,000 (US$102,564,000)
Equivalent electricity generation	1.9×10^9 kWh	2.2×10^9 kWh	2.3×10^9 kWh
Revenue from electricity sale	RM570,000,000 (US$190,000,000)	RM660,000,000 (US$220,000,000)	RM690,000,000 (US$230,000,000)

[a] Methane is 21 times more potent than CO_2.
[b] US$13.2/tonnes of CO_2.
[c] Based on US$1 = RM3.0.

reduction equivalent in 2010 for instance (6,514,620 tonnes) are over 13% of the total carbon emission in Malaysia [22]. If the methane emitted were captured and used in a Clean Development Mechanism (CDM) project or any other renewable energy scheme, the carbon reduction could attract revenue from carbon credit of 257 million Malaysian Ringgit (85 million US dollars) in 2010 based on US$13.20/tonnes of CO_2. In addition, equivalent electricity generation of 1.9, 2.2 and 2.3 billion kWh is achievable in 2010, 2015 and 2020, respectively, based on methane calorific value of 55,530 kJ/kg and Gas Engine efficiency of 40% [1]. The estimated equivalent electricity generation in 2010 of 1.9×10^9 kWh is about 1.5% of the total electricity consumption in Malaysia or equivalent to electricity needs for 420,000 Malaysians. Furthermore, based on RM0.30/kWh the electricity thus generated could be sold to attract revenue of up to RM570 million (US$190 million), RM660 million (US$220 million) and RM690 million (US$230 million) in 2010, 2015 and 2020, respectively.

8. Conclusions

In 2010, 2015 and 2020, the MSW generation in Peninsular Malaysia was projected to be 8,196,000, 9,111,000 and 9,820,000 tonnes, respectively. These values were based on MSW average increase rate of 2.14% from 1998 to 2000. This resulted in methane emission of 310,220 tonnes in 2010 and a value of at least 370,000 tonnes is expected in 2020. These in terms of carbon dioxide emission are 6,514,620 tonnes and 7,350,000 tonnes for 2010 and 2020, respectively. This is a serious environmental pollution which if left unchecked could contribute to the environmental degradation experienced globally. On the other hand this can be utilized as a renewable energy source. Based on 2010 estimate, up to 1.9 billion kWh of electricity can be generated worth over RM 570 million (US$190 million) with additional carbon credit of over RM 257 million (US$85 million).

In addition, Landfill is one of the most environmental friendly and cheapest means of waste disposal, it is also the main MSW disposal means in Malaysia therefore government should encourage and indulge in sustainable landfill management. This is achievable by partnering with private bodies to up-grade the existing landfills in at least states with higher landfill sites, like Johor, Selangor, Pahang and Perak for LFG capturing and utilization especially for power generation, fuel or as feedstock. This will go a long way in reducing the MSW management problems and at the same time helping to achieve the nation's quest for development of green energy.

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