Ministry of Energy,
Water and Communications

MEWC/PTM/DANIDA

Final Report –Activity 1.3 (a)

Study on Clean Development Mechanism Potential in the Waste Sectors in Malaysia

Renewable Energy & Energy Efficiency Component
(Sub-Component III: CDM Action Plan)

December 2004

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List of Abbreviations

ABC	Action Plan for a Beautiful and Clean Malaysia
DBKL	Dewan Bandar Kuala Lumpur (Kuala Lumpur City Hall)
BOD	Biochemical Oxygen Demand
BTU	British Thermal Unit
CAPEX	Capital Expenditure
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CHP	Co-generation of Heat and Power
COD	Chemical Oxygen Demand
CPO	Crude Palm Oil
DANIDA	Danish International Development Assistance
DBP	Development Bank of Philipines
DOE	Department of Environment
DVSAI	Department of Veterinary and Animal Industry of Sabah
EE	Energy Efficiency
EFB	Empty Fruit Bunch
EIA	Energy Information Administration
EQA	Environmental Quality Act
FFB	Fresh Fruit Bunch
FOD	First Order Decay
GEF	Global Environment Facility
GHG	GreenHouse Gas
GJ	Giga Joule
GoM	Government of Malaysia
GW	Giga Watt
GWP	Global Warming Potential
Hr	Hour
IC	Internal Combustion
IRP	Integrated Resource Planning
IRR	Internal Rate of Return
IPCC	International Panel for Climate Change
IWK	Indah Water Konsortium Sdn Bhd
JICA	Japanese International Cooperation Agency
JLSB	Jana Landfill Sdn Bhd
JPP	Sewerage Services Department

KL	Kuala Lumpur
KK	Kota Kinabalu
kW	Kilo Watt
kWh	Kilo Watt hour
LA	Local Authority
LACMIS	Landfill Closure Management Information System
LFG	Landfill Gas
MCF	Methane Conversion Factor
mT	Metric Tonnes
MB	Mass Balance Method
MEWC	Ministry of Energy, Water and Communications
MHLG	Ministry of Housing and Local Government
MIDA	Malaysian Industrial Development Authority
MJ	Mega Joule
MPOB	Malaysia Palm Oil Board
MS	Malaysian Standard
MSW	Municipal Solid Waste
MW	MegaWatts
NSP	National Strategic Plan for Solid Waste Management
OPEX	Operational Expenditure
PE	Population Equivalent
PFA	Pig Farming Area
POME	Palm Oil Mill Effluent
PORE	Palm Oil Refinery Effluent
PTM	Pusat Tenaga Malaysia (Malaysia Energy Center)
RDF	Refuse Derived Fuel
RE	Renewable Energy
RM	Ringgit Malaysia
ROE	Return of Equity
RRC	Resource Recovery Centre
SS	Suspended Solids
SBR	Sequencing Batch Reactor
SSA	Sewerage Service Act
SREP	Small Renewable Energy Programme
STP	Sewage Treatment Plant
TKN	Total Kjeldhal Nitrogen
TKO	Total Potassium

TPO	Total Phosphorus
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention for Climate Change
USEPA	United States Environmental Protection Agency
W.P.	Wilayah Persekutuan (Federal Territory)
WWTP	Wastewater Treatment Plant
Yr	Year

Executive Summary

Climate change has become an important international environmental agenda since the adoption of the Kyoto Protocol in 1997 made under the United Nations Framework Convention on Climate Change (UNFCCC). The Clean Development Mechanism (CDM) is a flexible financing mechanism introduced to assist committed developed countries to fulfil their climate change commitment while assisting the sustainable development of developing countries through investing in environmental friendly projects that lead to reducing global warming contribution.

Malaysia has shown its commitment by signing and subsequently ratified the Kyoto Protocol in 2002. Institutional set up has been established and the Malaysian National CDM Committee has identified several prioritised area where CDM projects should be prioritised. Waste sectors constitute one of these areas where significant potential of greenhouse gas emissions exist. This is particularly related to the anaerobic degradation of waste that resulted in methane emissions.

Potential of Methane Emissions from Waste Sectors

This study focuses on assessing the potential of CDM projects within the waste sectors in Malaysia. Focus was placed on fast methane emitting sources where energy recovery from the projects can be options for the renewable energy development in Malaysia. The result from the waste resources assessment indicates that the total methane emissions from the waste sectors analysed is approximately 1.3 million metric tons (mT) per year (compared to total methane emission in Malaysia of 2.2 million mT estimated in 1994). The most significant methane emission sources are landfill gas from municipal solid waste (53%), followed by biogas from Palm Oil Mill Effluent (POME - 38%). Less significant sources in terms of total potential include swine manure (6%) and industrial effluent (3%). The total carbon dioxide (CO_2) equivalent for methane emissions is estimated to be around 27 million mT, approximately 19% of the total greenhouse gas emission in Malaysia at 1994's level (total of 144 million CO_2 equivalent).

Minimum CDM Project Threshold

A screening process based on a pre-defined set of criteria has led to the selection of generic project types within two waste sectors (municipal landfill and palm oil mill) for further detail assessment. Detail assessments included financial analysis of the impact of CDM financing as well as detail assessment of additionality to be eligible for CDM. Generic project types based on a pre-determined minimum emission size of 30,000 mT CO_2 per year (the threshold value) were analysed.

Impact of CDM on Project Financing Viability

In general, the presence of CDM financing improves the financial performance of the projects analysed. Financial indicators including project internal rate of return (IRR) and equity IRR (ROE) were used. A financial internal rate of return (IRR) benchmark of 15% was set to determine the attractiveness of a project.

For the generic landfill gas recovery for energy project, the results indicate that the IRR (both equity and project) for projects above the minimum CDM threshold size are below the 15% benchmark set. With CDM financing, the IRR clearly improves from not financially attractive to attractive. Sensitivity analysis based on different size range of landfills indicated an improvement of IRR from a range between not feasible to 6% (without CDM) to a range of of 9 - 39% (with CDM). The IRR improves more with projects of larger scale. For flaring projects below the threshold, the projects are not feasible even with CDM support.

For generic POME biogas recovery for energy project, several technical options were analysed. Similar to landfill gas projects, for power generation options (gas turbines & gas engines), the results indicate the project return becomes attractive from unattractive (less than 15% ROE) with CDM financing. The equity IRR improves from a range of 7 -17 % (without CDM) to 17 to 29% (with CDM financing), giving improvement range of 10 -12%. Similarly, the project IRR also improves with CDM financing especially for the gas engine cogeneration and gas engine power generation options. All the power recovery options are feasible for off-grid connection. However, if grid-connected for SREP, the additional grid connection cost will reduce the attractiveness of the project. Generally, the project IRR and equity IRR are lower. This resulted in only gas engine options are feasible with CDM when grid connected, where ROE improves from 10 and 17% to 24 and 29%. For gas turbine option, only large scale mills seem to be able to be viable with CDM (equity IRR improves from 12% (without CDM) to 26% (with CDM)).

Sensitivity analysis based on sizes of palm oil mills indicated that CDM financing in general improves financing for all sizes of mills. However, for such small scale power production, gas turbine option was assessed to be less attractive compared to other options.

Additionality Assessment

In terms of additionality, the detail assessment for both project types indicates that the two selected project types in general fulfil the additionality assessment. In general, the barriers identified such as financing barriers (as seen in the financial analysis) and technological barriers seems to be removed with the implementation as CDM projects.

Other barriers such as policy barriers, awareness and unwillingness to change should be addressed with appropriate measures.

Potential Certified Emission Reductions (CERs) from Waste Sectors

The final evaluation concludes that the total potential certified emission reduction units (CERs) within the waste sectors analysed is between the range of 9 -10 million CERs per year. Among these potential CERs, POME biogas projects emerge as the most promising sector (52%) where landfill gas is second (38%). This is interesting since the baseline emissions from landfills are higher than POME but the recovery potential for CERs is proven to be less as compared to POME biogas.

In summary, the potential of CDM within the waste sectors is especially high within the palm oil mills and municipal landfills in Malaysia. It is recommended further detailed studies and efforts on CDM to be focussed in these 2 areas. Apart from financing, non-financial returns such as environmental benefits and socio-economic improvements can also be realised from implementing waste to energy projects.

1. Introduction

1.1 The Context: Clean Development Mechanism

Climate Change is one of the important environmental discussions among the international communities especially since the adoption of the Kyoto Protocol in 1997 under the United Nations Framework Convention on Climate Change (UNFCCC). Developed countries (commonly referred as Annex 1 countries) under the agreement must reduce their greenhouse gas (GHG) emission that contributes to climate change.

As a mean to support these commitments, three flexible mechanisms (Emission Trading, Joint Implementation and Clean Development Mechanism) were introduced internationally to promote cost-effective means of achieving these reduction commitments. Clean Development Mechanism (CDM) is a flexible financing tool designed to assist developed countries in the reduction of GHG emission while assisting developing countries meeting sustainable development goal. This translates to the implementation of environmental friendly projects that can lead to reduction of GHG that is additional with the project implementation.

Malaysia ratified the Kyoto Protocol on September 4, 2002 and subsequently the National Committee on the Clean Development Mechanism (CDM) was established to facilitate the implementation of CDM in the country[1]. Clean Development Mechanism (CDM) projects are gaining national the interest in Malaysia and a number of project developers are interested in CDM for their project activities.

Under the Malaysian-Danish Government Environmental Cooperation Programme (2003-2006), a component supporting the development of Renewable Energy and Energy Efficiency was initiated in early 2004. A sub-component (sub-component III) under the main component promotes the implementation of CDM action plans where the synergistic relationship of CDM and Renewable Energy/Energy Efficiency is to be explored.

It is believed that CDM could stimulate the implementation of RE and EE development. One of the main tasks of the CDM component is to provide the analytical background

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[1] Idris, Zukifli. (2003). Powerpoint slides: *Clean development mechanism Malaysia: Opportunities and priorities.* Conversation and Environmental Management Division, Ministry of Natural Resources and Environment Malaysia.

material for formulating Malaysian policies in the framework of the 9th Malaysia Plan[2]. Under the component, a number of studies and analysis for the different sectors for potential CDM will be carried out especially to assess the impact of CDM on the financial and economic performance of different types of projects (notably Renewable Energy/Energy Efficiency projects). This study will focus on the potential of CDM in the waste management sector.

1.2 CDM potential in Waste

The National CDM Committee has formulated some preliminary national criteria for CDM implementation and has identified several priority areas where CDM can be implemented. Waste management is one of these identified areas where a lot of governmental efforts are being concentrated at the moment.

Disposal of waste (specifically the organic fraction) presents one of the main anthropogenic sources of methane emission to the atmosphere. Methane emission contributes approximately 21 times more than carbon dioxide in terms of global warming potential. According to the 1st National Communication submitted by Malaysia to UNFCCC in 2000, methane constitutes around 33% of the Greenhouse Gas (GHG) emission in 1994[3].

Therefore it is strategic to focus on improving the management of organic waste which has high methane emission avoidance potential while at the same time, many other nuisance and environment issues e.g. fire risk, odour, pollution of waterways etc. related to the improper disposal can also be tackled.

The objectives and methodologies of this study will be further described in Section 2.

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[2] 9th Malaysian Plan is the 5 year overall development framework plans for the period between 2006-2010 by the Economic Planning Unit of the Prime Minister's Department, Malaysia.

[3] Ministry of Science, Technology and the Environment Malaysia. (2000). Malaysia Initial National Communication submitted to the United Nations Framework Convention on Climate Change.

2. Objectives and Methodologies

2.1 Objectives

With the background introduced in Section 1, the focus of this study was to assess the potential of energy recovery from waste resources while avoiding greenhouse gas emissions that contribute to global warming. The primary objectives of this study are two-fold:

- To assess the total potential of methane emission from prioritised waste sectors;
- To assess the significance of CDM on the overall economics and financing of select projects;

2.2 Methodologies

The approach of this study was formulated such that a quick assessment of the potential CDM projects within the waste sector can be used to provide guidance as to where policy should be focused for future CDM development. The following activities were carried out:

- Data collection of waste sources and existing management;
- Compilation and analysis of data;
- Deriving a long-list of potential projects from the data obtained above;
- Definition of key criteria for short-listing projects;
- Selection of 2 generic project types within selected waste sectors for detailed financial analysis to determine the significance of CDM on financing;
- Detail assessment of additionalities for the selected project types;
- Summarising the total potential of CDM in waste sectors.

In view of the short study period, a pragmatic approach was applied on data collection. The data collection was mainly based on a combination of secondary sources e.g. other studies, published information, experiences of consultants etc. In cases where data were not available, best estimates and relevant assumptions were made to derive the figures. In order to ensure reliability of information obtained, cross-checking and consolidation of data from different sources were done.

For compilation and analysis, in most cases where a variation of key figures were found, an average value was used and in some cases, best estimates and consultant's judgement was used to derive the results.

The screening of projects for detailed assessment was based on a list of criteria (described in detail in Section 4 below) defined by the study team. The economic analysis of the impact of CDM on project viability involved the use of a financial model developed from earlier CDM market study. Standard figures such as fuel prices, loan interest rate etc. were adopted from the Integrated Resource Planning (IRP) project (phase 2). Again, for the model input, where data is not available, best estimates and assumptions were made.

For the detailed additionality test, the standard tool for testing additionality issued by the UNFCCC CDM Executive Board was used (Section 5). The step by step approach involved alternatives identification, barrier analysis, common practices etc.

The total CDM potential in waste was finally presented based on results derived from the above analytic strategies.

3. Assessment of Waste Resources

3.1 Scope of Study

There are many possibilities within the waste sectors that could be interesting for CDM application. As mentioned in Section 1.2, significant potential for reduction of GHG emissions exists within the overall waste sector mainly due to the fact that many waste related projects will avoid methane emissions. Methane being a potent greenhouse gas with a Global Warming Potential (GWP) of 21 times more than CO_2 will have greater impact on GHG reduction initiatives.

Thus, the focus of this study was confined to those waste sectors where the current common treatment / disposal practices generate significant methane emissions. The waste resources addressed in this study included:

- Municipal solid waste (as methane emissions from MSW landfills);
- Domestic sewage in septic tanks (as methane emissions from existing anaerobic conditions);
- Livestock (swine) waste (digestion of manure in centralized swine farming etc.);
- Palm Oil Mill Effluent (POME);
- Industrial effluent (as methane emissions from existing anaerobic system, key sectors such as waste from crude palm oil processing, food and beverage processing etc.).

Details of each of the above waste resources will be elaborated in sections below.

3.2 Municipal Solid Waste (MSW)

3.2.1 Brief description of sector

In Malaysia, municipal solid waste (MSW) typically refers to all solid waste (often commonly referred to as garbage or rubbish) collected and managed under the municipality (city, municipal and district councils) waste management scheme. The municipalities are mandated to provide urban sanitation services as part of their social services. This includes solid waste collected from different sources such as residences, commercial establishments and industries (mostly non-processed waste[4]). In the case of process waste from industries, some are delivered separately by private contractors to

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[4] Non-processed waste typically refers to solid waste generated from the offices of the industries which does not include actual residues or by-products from the industrial manufacturing activities.

the same disposal facilities, such as landfills where these wastes are included as MSW. In some cases, these wastes are treated separately e.g. organic food waste for livestock fodder, wood waste for industrial boilers and so forth.

However, all landfilled waste in Malaysia is deposited in anaerobic landfills, with the exception of only several experiments with "semi-aerobic" landfills. Anaerobic landfills are deep enough to exclude air from permeating while the high rainfall, high MSW moisture content (about 55%) and consistent year-round high temperature (about 30 degrees Centigrade) create ideal conditions for anaerobic activity.

In recent years, the need for improvement in MSW management has being emphasized and the whole sector has and will continue to undergo many changes. Under the national privatisation policy, the development is such that MSW collection and treatment services are being driven towards full collection by contracted, private firms where, the role of local government will be to supervise and monitor the performance of its contractors[5].

A “National Strategic Plan for Solid Waste Management” (NSP) has been formulated and is currently being reviewed and awaiting the final endorsement from the federal cabinet. The NSP articulates the future directions of solid waste management including MSW practices of collection and disposal.

3.2.2 Regulatory and institutional framework

As in most countries, MSW management in Malaysia is traditionally a function of the local government (implemented through city, municipal and district councils). Under the Malaysian Local Government Act 1976, MSW in Peninsula Malaysia is managed by local government to ensure the cleanliness of public places under their jurisdiction. In Sabah and Sarawak, the same background governing principles apply but these two States have different regulatory and institutional setups. The relevant provisions are mandated via the Local Government Ordinance 1961 in Sabah and the Local Authorities Ordinance 1996 in Sarawak.

In Peninsula Malaysia, the various local councils are under the purvey of the Ministry of Housing and Local Government (MHLG) whereas, separate State Ministries in Sabah and Sarawak exist to perform the similar function as MHLG. In Sabah and Sarawak, two State agencies (Environmental Protection Department Sabah and, Natural Resources

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[5] Danish International Development Assistance (DANIDA). (2004). *Technical Working Paper for Solid Waste Management Component.*

and Environment Board Sarawak) were established to oversee environmental issues (including impact of solid waste).

Funding for MSW management is chanelled through both federal and local sources. In some States such as Sabah and Sarawak, funding for MSW can also be sourced from State Government. Under the Federal 8th Malaysian Plan (2001-2005), federal funding was assessed and allocated to the selected local authorities to establish treatment facilities that require a large capital investment. The daily collection, transportation and treatment services are normally financed through the local annual assessment rate (property tax). They are paid for through local authority general revenues, i.e. fees, licenses, rent and interest. Any shortfall in the revenue is then covered through a subsidy from the State Government.

In fact, the lack of funding seems to be one of the key constraints against improving management of the disposal facilities such as dumpsites where methane gas is emitted. Similarly, no proper funding mechanisms are in place for a safe closure and post management of old dumpsites[6]. MHLG, with the assistance of JICA has completed the draft final report "The Study on the Safe Closure and Rehabilitation of Landfill Sites in Malaysia", carried out by Yachiyo Engineering Co., Ltd. and EX Corporation. The report is composed of guidelines for safe closure, rehabilitation and long-term management, description of completed pilot projects, technical guideline on sanitary landfill design and operation, user manual of LACMIS (Landfill Closure Management Information System) and an inventory of data sheets for identified landfills. One strategic option that is being developed is to reduce methane generation by introduction of semi-aerobic landfills as a means of closure, i.e., conversion of existing anaerobic landfills to semi-aerobic, that would greatly reduce methane emissions from the closed landfills.

3.2.3 Assessment of waste amount and composition

Waste Amount

The assessment of the actual amount of MSW requires a review of the definition applied. As indicated in section 3.2.1, the MSW amount reported usually only includes waste actually collected and treated/disposed by the local government. Therefore waste not collected through the municipal collection scheme is not accounted for. Such waste

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[6] Yachiyo Engineering Co., Ltd., EX Corporation, & JICA. (2004) *The study on the safe closure and rehabilitation of landfill sites in Malaysia*. Draft Final Report, Volume 7. Ministry of Housing and Local Government in Malaysia,

could include that which is illegally dumped, collected for reuse and recycling, composted, burnt and so forth.

This study reports on both the amount registered by the local government as well as the total potential MSW generation. For the interest of CDM potential due to the collection and utilization of landfill gas, the actual amount landfilled will be more interesting but there are additional potentials for those wastes currently not being delivered to the designated treatment / disposal sites.

The waste amount presented here was compiled and estimated based on the available information generated from various studies undertaken earlier by both the Government of Malaysia and other sources such as international donor agencies (DANIDA, JICA etc.). Table 1 summarizes the amount of waste reported collected and landfilled at the official sites by the government (Ministry of Housing and Local Government, Malaysia) and also the total potential amount generated. Detailed distribution based on all individual States is attached as Appendix A.

Table 1 Total MSW Managed and Generated in Malaysia

Region	Waste collected and treated[a] (mT/day)	Total waste generated[b] (mT/day)
Peninsula M	14,809	18,511
Sarawak	1,659	2,072
Sabah	2,144	2,680
Total per day	**18,612**	**23,263**
Total per year	**6.8 mil mT**	**8.5 mil mT**

[a] Derived from figures reported by MHLG (2003)

[b] Reported by DANIDA Technical Working Paper on Solid Waste Management Component (2004)

It can be noted from Table 1 that approximately 20% of the estimated total MSW generated was estimated not to be collected for final disposal under the local government. When it comes to estimating the total maximum potential of methane emissions from landfills, only a certain percentage of this 20% not collected/managed waste could be taken into account based on the estimated composition elaborated below. It can also be noted that the NSP, while pending release, reportedly relies on achievement of a 20% recycling rate in Malaysia by 2020 from the current rate of less than 4% nationwide. It is likely that another goal of the NSP will be to increase the percentage of collected / treated waste which will offset reduction in collection achieved by recycling. Another factor that could be included in evaluation of total MSW is the increasing per capita generation rate that accompanies National development. When estimating the total maximum potential of methane emissions from landfills, the currently uncollected 20% of total waste was not taken into account.

Waste Composition

Waste composition of municipal solid waste has been studied in several cities and towns in Malaysia. Representative selections of results are tabulated in Table 2 below. For the estimation of the total methane generation potential from dumpsite disposal and landfilling of MSW, a national average composition was derived based on the various sources. The figures in the shaded column are compiled using the average of the figures of six studies across the country.

Table 2 Typical Composition of Municipal Solid Waste in Malaysia

Waste Composition	Johor Bahru City Council	Kuala Terengganu Municipal Council	Petaling Jaya Municipal Council	Kuching[a]	Kota Kinabalu [b]	MHLG average[c]	National Average
Organic food waste	45	66	48	50	45	47	**50**
Paper and cardboard	19	15	24	15	25	15	**19**
Rubber and plastics	12	4	9	16	18	14	**12**
Metals	9	5	6	4	4	4	**5**
Glass/ Ceramic	3	1	4	5	4	3	**3**
Textile	5	1	4	5	2	3	**3**
Wood	7	3	5	-	1	-	**3**
Others	-	5	-	5	-	10	**3**

Source: MHLG, 1998, except:
[a] Trienekens, 1997 (based on landfill waste)
[b] Solid Waste Profile, Sabah, 2000
[c] Ministry of Housing and Local Government. (2004). Powerpoint Slides: "National Waste Recycling Program" presented at the *Seminar for the Study on National Waste Minimisation in Malaysia*, 16 September 2004.

Based on the various sources of information, it can be noted that the findings were quite consistent in terms of trends except Kuala Terengganu (which might not be representative of a typical city/town in Malaysia anyway). All studies showed a high percentage of organic food waste composition in the MSW. The composition of organic food waste from the various studies indicated that it comprises approximately 50% by weight of total MSW analyzed. For estimation in this study, a national average percentage organic food waste of 50% was used for the estimation of potential in CDM.

In fact, the contained fractions of paper and cardboard, rubber, textiles and wood are included as cellulose sources in methane production. These all contribute in the calculation of theoretical methane production which can be referenced in Tchobanoglous[7]. Table 3 below outlines the process used to calculate theoretical methane production based on the estimated waste characteristics presented in Table 2.

Table 3 Theoretical Methane Generation Potential of Malaysian MSW

Organic Fractions, %	**Malaysia Average**	**Fast Fraction**	**Slow Fraction**	**Unit**
Food	50	50		
Paper	19	19		
Wood	3		3	
Rubber	6		6	
Textile	3		3	
TOTALS	**81**	**69**	**12**	
Moisture Content	55			
ORGANIC Solid Content, % as dry weight	45	31.05	5.4	
Theoretical Rates, C H O N		0.8316	0.9504	m^3/kg ORGANIC
RATE FROM MSW (wet weight basis)		**0.258212**	**0.051322**	**m^3/kg MSW on a wet weight basis**
Period of Generation		5	15	years

In this study, generation rates of 80, 140 and 250 m^3/mT of MSW were compared. The theoretical calculation (Table 3) is 310 m^3/kg when rapid and slow degrading organic rates are summed. The study selected a rate of 140 m^3/mT as a slightly conservative approach and, for easier comparison with other applications of the first order decay model in the literature. The values for theoretical and obtainable generation rate range from 6.2 to 270 m^3/mT of MSW[8].

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[7] Tchobanoglous, G., Theisen, H. & Vigil, S. (1993). *Integrated solid waste management - Engineering principles and management issues*. McGraw-Hill Inc., International Editions.

[8] Stege, G.A. (2003), SCS Engineers for Landfill Methane Outreach Program, In *User's Manual - Mexico Landfill Gas Model Version 1.0*, USEPA, Washington, D.C.F

In an evaluation done by JICA[9], the contributing elements to methane generation included only food organics and yard wastes. However, food and yard waste were estimated to contain about 21% and 30% volatile matter respectively. JICA calculated a degradable organic fraction of 16% of landfilled MSW on this basis. The total tonnage waste disposed multiplied by this figure yields the available carbon to be transformed to methane which can then be converted to maximum methane yield with the multiplier of 16/12. The JICA calculation compares with a generation rate of 213 m^3/mT of MSW.

The other factor that is important to methane generation modelling by the first order decay equation is the methane generation rate constant, k. A high k value describes a fast rate of decay of organics within the landfill that would result in faster total methane generation and faster decline of generation rate after landfill closure. The magnitude of k usually depends on factors such as moisture content, nutrient availability, pH and temperature. Rainfall acts similarly to moisture content whereby anaerobic activity increases with moisture content in the landfill. As has been outlined, Malaysian conditions are tropical with ambient average temperature around 30 degrees Centigrade. Malaysian MSW has high moisture content due to rainfall averages above 2,000 mm/year in most locations. The range of k has been found empirically to range from 0.003 to 0.21, in the USA. Tropical conditions have been estimated to permit a rate as high as 0.4. In this study, values of 0.08, 0.12 and 0.4 were modelled and, results for k = 0.12 were used in financial modelling.

In landfilling MSW there are many factors that make the estimation of landfill gas emissions complicated and site-specific. These include MSW generation and collection rates and, MSW composition which may all change significantly over time and with geographical location. The LFG emissions also change with type of anaerobic landfill where depth impacts the degree of anaerobic degradation that occurs. The actual generation rate of methane from different substances, i.e., yard waste and food waste is quite different, whereby 10 years and 5 years respectively may be required for degradation to be completed[10]. The FOD model describes an approximation of the actual methane generation which may take place only one year or so after deposition, increases to a peak only after about 15 years and, drops rapidly upon closure.

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[9] Yachiyo Engineering Co., Ltd., EX Corporation, and JICA. (2004) The study on the safe closure and rehabilitation of landfill sites in Malaysia. Draft Final Report, Volume 7. Ministry of Housing and Local Government, Malaysia.

[10] Tchobanoglous, G., Theisen, H. & Vigil, S.A. (1993). *Integrated solid waste management - Engineering principles and management issues*. Pp 392-4, McGraw-Hill Inc.

3.2.4 Current treatment and disposal

The predominant treatment method for municipal solid waste in Malaysia is landfills and dumpsites. Most landfills are basically controlled or uncontrolled open dumps with the very minimum or no environmental control. Appendix B lists the assigned classes where records were obtainable for Malaysian Landfills. Zero is assigned to uncontrolled open dumps while 4 is assigned to sanitary landfills. Majority of mid-size and smaller landfills are mostly owned and operated by the respective local government or Local Authority (LA). In cases of some large landfills such as Taman Beringin in KL, Air Hitam landfill near Puchong in Selangor, Pulau Burung Landfill in Penang or, Matang dumpsite in Kuching Sarawak, the operation and maintenance of the facility is contracted to private companies by the local authorities for a sizable (15-25 years) concession period.

Information regarding all landfills / dumpsites existing, closed or planned was obtained from various secondary sources of information and is tabulated as Appendix B. These data include information obtained from governmental agencies (notably the federal Ministry of Housing and Local Government, the Natural Resources and Environmental Board of Sarawak, Environmental Protection Department of Sabah and various local governments). Other sources included a few recent studies conducted by DANIDA (notably the DANIDA Solid Waste Management Component preparation, Sustainable Urban Development Projects in Sabah and Sarawak) and JICA (Action Plan for a Beautiful and Clean Malaysia (ABC) and The Study on the Safe Closure and Rehabilitation of Landfill Sites in Malaysia).

Based on the above information, the following summarizes the current treatment and disposal of MSW using landfills/dump sites in Malaysia:

- Records are available for 247 landfills of which dated records were available for about 201. The database assembled is presented as Appendix B. Of the 201, 75 are recorded as closed. Table 4 below summarizes open and closed landfills by State.

Table 4 Summary of Landfill Distribution by State

State	Total	Closed	Unknown
Selangor	**16**	**5**	**0**
W.P. (DBKL)	**7**	**4**	**1**
Negeri Sembilan	**15**	**6**	**2**
Melaka	**8**	**6**	**0**
Johor	**32**	**11**	**6**

Pahang	**18**	**5**	**1**
Terengganu	**12**	**6**	**2**
Kelantan	**13**	**6**	**0**
Perak	**31**	**8**	**5**
Penang	**4**	**2**	**1**
Kedah	**14**	**2**	**0**
Perlis	**1**	**0**	**0**
Sarawak	**48**	**9**	**4**
Sabah	**28**	**5**	**5**
TOTAL	247	75	24

- Landfills in Peninsula Malaysia numbered about 145 with recorded Status (refer to Appendix A) of which < 1%, 7%, 9%, 17% and 67% were rated in Classes 0, 1, 2, 3 and, 4 respectively. In Sabah, only one sanitary landfill (Class 4) exists whereby the others are either controlled or uncontrolled open dumps. In Sarawak, there are 4 sanitary landfills and the rest are either controlled or uncontrolled open dumps. Figure 1 depicts a typical open dump, Class 0

Figure 1 Typical Open Dumps of MSW in Malaysia

∗ In Peninsula Malaysia, it was estimated that around 43% of existing landfills and dumpsites will exceed their capacity within the next 5 years[11];

∗ Although there are more and more sanitary landfills expected to be constructed in Malaysia in coming years, the highest standard of sanitary landfill (Level 4) neither specifically demands the recovery nor the utilization of landfill gas. The sanitary requirement is only to provide a gas-venting system where the methane may still be emitted to the atmosphere;

∗ Currently, there are only two landfills (Air Hitam Puchong, Selangor and Larkin, Johor) that recover landfill gas for power generation in Malaysia. The Air Hitam (near Puchong) landfill is operated by a private company (Worldwide Landfill Sdn Bhd) and a two MW plant burning landfill gas owned by Jana Landfill Sdn Bhd, a subsidiary of Tenaga[12], was installed in 2003. The power generated (2 MW capacity) is sold at 16.5 cents per kilowatt-hour for 15 years as a special arrangement under the Small Renewable Energy Programme (SREP). The Larkin landfill was closed in 1999[13] and the landfill gas project was initiated in 2001 as a pilot project with assistance through the utilization of a grant from the Commonwealth Government under its International Greenhouse Partnership Program. There are another two more known landfill gas recovery projects being planned e.g. the Krubong landfill in Melaka[14] and another in Johor[15]. In total, the number of landfills with landfill gas recovery is considered insignificant (2-3 %) if compared to the total number of landfills.

Apart from landfills, there are some places that utilize small-scale incineration systems. These are mainly on islands and hill resorts where land is not suitable for landfill, i.e. Pangkor Island, Tioman Island, Labuan Island and Langkawi Island. The total amount of waste incinerated is estimated to be relatively insignificant as compared to the total

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[11] Hamid, Ab Halim. (2003). “Towards Improvement of Landfill Sites in Malaysia”. Presented at the *Seminar on The Study on the Safety Closure and Rehabiltation of Landfill Sites in Malaysia*, 18-19th September 2003.

[12] Tenaga National Berhad is the main power producing company for Peninsula Malaysia.

[13] Falzon, J. (2002). Landfill gas – An Australian Perspective. Paper presented at the *1st Industrial Workshop on Landfill Gas: Issues and Opportunities*, Seberang Perai, 29 May 2002.

[14] Krubong Landfill Gas Project was officially submitted to the CDM Executive Board in September 2004.

[15] Personal communication with GasCon A/S. 4th September 2004.

amount of MSW. Existing incinerators have generally proven to be problematic and many require improvements especially since the moisture content of waste in Malaysia is very high. The incinerator built in Terengganu for a capacity of about 100 mT/day has failed mainly due to a lack of planning in delivery of the required waste quantity to the facility. Hence, the cost of cold starts and auxiliary fuel requirement made the operation uneconomical.

The government is also planning large scale, thermal treatment plants for the two main waste centres, Kuala Lumpur / Selangor and Penang. These are large cities without readily available land within close proximity available for landfills. The Thermal Treatment Plant at Beroga is proposed to treat municipal solid waste from the Federal Territory and the State of Selangor. The proposed plant is located in Sungai Lalang Forest reserve in Mukim Semenyih, Daerah Hulu Langat. The plant is designed to treat a maximum of 1,200 tonnes per day of the municipal solid waste and to use fluidized-bed gasification technology with an ash-melting furnace.

Under the innovation research of Malaysian Technology Development Corporation Sdn. Bhd. and the Malaysian Institute for Nuclear Technology Research, local technology provider Core Competencies Sdn. Bhd. has plans to build a 700 tonnes per day Resource Recovery Centre (RRC) / Refuse derived Fuel (RDF) / Waste to Energy Plant in Mukim Ulu Semenyih, Selangor. The refuse derived fuel will generate power on site with the bulk exported to the National grid.

Part of the NSP is expected to deal with division of the solid waste management privatization into at least 3 zones plus East Malaysia. A concessionaire will likely manage each zone with the responsibility of collection, transfer and disposal. Sub-contractors such as Core Competencies are expected to build more RRC, RDF and small-scale waste to energy plants but it is unlikely that these activities will be strongly mandated under the new plan, merely approved as an acceptable alternative to landfilling or mass burn incineration. Within each zone, the consolidation of landfills is expected to take place with many closures coming into effect within a short time frame. New landfills are expected to be large scale and, will be feasible through extensive use of transfer stations. Transfer station economics will rely on compaction and large transfer vehicles to avoid unacceptably increasing the overall costs of disposal.

3.2.5 Potential GHG (Methane) Emission

As discussed in section 3.2.3, MSW is a mixture of materials where the main biodegradable component is cellulose, found in food waste, animal waste, garden waste, paper and cardboard. When landfilled, anaerobic degradation takes place through a combination of biological and chemical action, resulting in landfill gas formation where methane is one of the main compositions. There are many researches and studies on the generation rate and composition of landfill gas. Both the generation and composition depends on factors such as the waste composition, climate and other conditions. It was reported that the gas generation for waste freshly landfill would take between 80-500 days to reach steady state where the gas generation will continue for 10-20 years[16]. There are also established methods (First Order Decay (FOD), Mass Balance (MB)) in estimating landfill gas production over a fixed period of time where the emissions will follow exponential decay pattern. Many empirical studies[17] over long term landfill operation have yielded formulae based on actual methane detected in collection pipes and correlated with waste deposition. JICA utilizes one such model established by Hydraulic and Sanitary Engineering Laboratory, Fukuoka University. For this study, the methane emission is projected using the FOD method which is today widely used, often in combination with other methods.

Typical generation rate and compositions of landfill gas published by various sources have been illustrated in Table 5 and Table 6 below:

Table 5 Typical Methane Generation Potential from MSW

According to	m^3 CH_4/mT of MSW
University of Malaya[a]	100 -150
Jenbacher[b]	150 - 250
GasCon[c]	100
Krubong Landfill Gas Project[d]	155
Calculated - Tchobanoglous[e]	310
USEPA[f]	170
SCS Engineers[g]	140
Used in this Study	**140**

[a] Brochures (no date) produced by Solid and Hazardous Waste Laboratory, University of Malaya Malaysia
[b] Wilfred B. (2002). Landfill gas: Issues and Opportunities. Paper presented at 1st Landfill Workshop at Seberang Perai, Penang, 29 May 2002

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[16] IEA Greenhouse Gas R&D Programme. (1998). Abatement of Methane Emissions.

[17] Laquidara,.M.J., Leuschner, A.P. and Wise, D.L (1986). Procedure for Determining Potential Gas Quantities in an Existing Sanitary Landfill. In M.E., Souza, F.G., Phland, & Pergamon, *Anaerobic Treatment in Tropical Countries*.

[c] GasCon Aps. (2003). Landfill Gas Utilization General Introduction.
[d] Yachiyo Engineering Ltd. (2004). Project Design Document for Krubong Landfill Gas Project.
[e] Calculation follows Tchobanoglous (1993)
[f] USEPA "Users Manual - LFG Emissions Model V.2.0", default value (February, 1998)
[g] USEPA "Mexico Landfill Gas Model V.1.0" (2003)

Table 6 Typical MSW Landfill Gas Composition

Sources	**Swedish Gas Centre**[a]	**Larkin Landfill**[b]	**Used in this Study**
Component	**% Concentration**	**% Concentration**	**% Concentration**
Methane	45-55	50%	50%
Carbon Dioxide	30-40	40%	40%
Nitrogen	5-15	10%	10%
Hydrogen Sulphide	50-300 ppm		

[a] Source: Swedish Gas Centre. (2003). Biogas: Potential in Energy Sector.

[b] Falzon John. (2002). Landfill Gas – An Australian Perspective. Paper presented at *1st Industrial workshop on landfill gas: Issues and opportunities*, Seberang Perai, Penang, 29 May 2002.

A potential summary of waste treatment from 2006 if only existing plans (pre-NSP) are implemented could be as presented in Table 7 below.

Table 7 Scenario of MSW Treatment and Disposal from 2006 in Malaysia

Types of treatment	**MSW (mT/day)**	**% Total**
Landfilled (potential emission)	15,500	83
Landfilled[a] (gas utilization)	1,550	8
Thermal Treated[b] / Incinerated	1,200	7
Refuse Derived Fuel	700	4
Small incinerators	Insignificant	0
Total (without uncollected MSW)	**18,600**	**100%**

[a] Air Hitam, Krubong and Larkin Landfill gas recovery projects
[b] Broga Thermal Treatment, Selangor

The impact of the above scenario on baseline emissions would appear to be minimal and explains the continued emphasis on major projects to be ushered in with the NSP.

JICA[18] has assessed landfill emissions using anaerobic landfills as the baseline and, calculated the accumulated amount of CH_4 estimated for years 2005-2020 is approximately 1,238,996 mT. The calculation of CH_4 for the years 2005-2010 is presented in Table 8 below.

Table 8 Accumulated GHG Emissions from Anaerobic Landfills

Year	2005	2006	2007	2008	2009	2010	Total (mT/yr)
CH_4	93,085	104,763	142,812	78,534	80,104	78,909	578,207

However, under the JICA proposed plan, for example, closure of landfills would be undertaken by converting them from anaerobic to aerobic, with an associated cost. In the equivalent period from 2005 to 2020, the anaerobic methane generation of 1,238,996 mT would be reduced by about 787,057 metric tonnes of methane due to the lower levels produced in the semi-aerobic landfills. The aerobic landfills replacing the anaerobic ones would also in turn generate higher total CO_2 by 2,709,159 metric tonnes in the same period. In total however, JICA calculates a net positive reduction of approximately 13,819,038 metric tonnes as CO_2 achievable through conversion of anaerobic landfills to semi-aerobic for 2005 and 2020.

As could be seen from Table 7 however, the Government of Malaysia (GoM) has maintained an open door to technologies, although with a limited number of implementations. Analyses of the economics of future proposals will likely drive developments to a large extent. Of the technologies applied, Waste to Energy with or without refuse derived fuel and, landfill gas extraction for power generation seem to hold out the most promise for improved economics.

The magnitude of potential emissions from MSW as CO_2 equivalent can only be approximated with more detailed modeling, preferably related to localized empirical data. The reasons for the limitations in estimating landfill gas production are explained in more detail in the latter part of this study. Essentially, because MSW degrades over a 25 year period (by some estimates), the ultimate effect in terms of emissions is felt over 25 years. Every tonne of MSW deposited to a landfill has an ultimate emission load that it will impose on the atmosphere over 25 years of anaerobic degradation. In Table 9

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[18] Yachiyo Engineering Co., Ltd., EX Corporation, and JICA. (2004) The study on the safe closure and rehabilitation of landfill sites in Malaysia. Draft Final Report, Volume 7. Ministry of Housing and Local Government, Malaysia.

below, ultimate emissions associated with the annual tonnage of MSW deposited to Malaysian landfills are summarized. These numbers do represent an accurate approximation of the actual emissions from total landfill area in Malaysia since:

- the deposition takes place every year;
- the deposition process has been taking place for 25 years and will continue for more than 25 years from present;
- the running average from 25 years will sum to approximately the ultimate emission from annual deposition.

On the other hand, the estimation suffers inaccuracy due to the rapid increase in per capital MSW generation rate has been taking place for rapidly-developing nation such as Malaysia.

Table 9 Total CH_4 and CO_2 Equivalent Emissions from MSW Landfills in Malaysia

Region	Total Landfill area (hectares)	mT of MSW per year as reported	Ave. mT CH_4 / year[a]	Ave. mT CO_2/ year
Peninsular M	**1242.9**	**5.405 million**	**544,824**	**11,441,300**
Sarawak	**117.6**	**0.6055 million**	**61,034**	**1,281,720**
Sabah	**507.3**	**0.7826 million**	**78,886**	**1,656,610**
Total	**1867.8**	**6.804 million**	**685,843**	**14,402,700**

[a] based on L_0=140 m^3 CH_4/mT MSW with density of 0.72 kg/m^3 for CH_4

Some observations on the above table include that waste estimation by landfill area would not appear to be sufficiently accurate for the purpose of methane generation calculations and, that conversion of methane by power generation could achieve significant CO_2 emission reductions that would, however, be dependent on collection efficiency for the theoretical methane produced.

3.3 Domestic Sewage in Septic Tanks

3.3.1 Brief description of sector

Domestic sewage commonly refers to wastewater generated from daily human activities from residences, commerce, public institutions establishments etc. In Malaysia, insuffient treatment of sewage is a common problem that leads to pollution of waterways as well as creating various types of nuisances. Unlike other developed countries, in most cities/towns, large scale centralized sewers and sewerage systems are not in placed.

In general, the most common treatment systems, especially for blackwater[19] generated are septic tanks (sometimes referred to as cesspits). This system type can include individual tanks (typically for individual households) as well as communal or imhoff tanks shared among several polluters. The basic function of a septic tank is basically for the retention of significant suspended solids to avoid discharging to surrounding perimeter drains or land. The conditions in the tank are anaerobic and therefore methane gas will be generated and emitted to the atmosphere.

In recent years, the use of communal sewage treatment plant (STP) has increased. Most of these plants employ biological and mechanical processes where aerobic treatment (activated sludge, aerated lagoons etc) is the most commonly used system. These systems significantly reduce the methane emission potential and thus will not be considered in this study. Another source of methane emission may be from the management of sludge, which usually involves anaerobic technologies. However, methane emissions from sludge treatment will not be included in this study.

Why is CDM interesting for emerging wastewater systems?

For developed countries with centralized sewer and conventional mechanical treatment plants, the relevance of CDM might not be obvious. However, emerging wastewater systems such as the ecological sanitation (eco-san) concept will definitely bring in the potential of CDM especially for developing countries without proper sewerage systems[20]. The eco-san approach can include the collection of sewage (blackwater) to a centralized, highly controlled biogas facility for energy and nutrient recovery. This system would be a means of supporting additional methane emissions avoidance and thus could qualify for CDM. A pilot project introducing such a system is currently being implemented in the City of Kuching, Sarawak of Malaysia[21].

3.3.2 Regulatory and institutional framework

Sewage management in Peninsula Malaysia prior to 1993 was under the jurisdiction of local authorities. In 1993, the Sewerage Service Act (SSA) was enacted in 1993 to

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[19] Blackwater refers to all waste discharged from toilet bowls which typically compose of a mix of faeces, urine, toilet paper and flush water.

[20] Bruijne, Gert and Dulac, Nadine. (2003). EcoSan - Clean Development Mechanism under the Kyoto Protocol. Paper presented at the 2nd *International symposium on ecological sanitation*, Luebeck Germany, April 2003.

[21] Personal communication with Mr. Chong Ted Tsiung, Controller of Environmental Quality, Natural Resources and Environment Board Sarawak, 14 September 2004.

empower the Federal Government to regulate the sewerage industry. As a step by the government to upgrade the general sanitation level, a private company, Indah Water Konsortium Sdn Bhd (IWK), was appointed in 1994 as the concessionaire to undertake the management of sewerage services in Peninsula Malaysia (except Johor Bahru and Kelantan). IWK was officially taken over by the Ministry of Finance a few years ago. A Sewerage Services Department (JPP) currently under the Ministry of Energy, Water and Communication was established with the purpose to supervise and regulate the concession agreement with IWK[22].

In relation to guidelines, the Malaysian Standards (MS1228:1991 Code of Practices for Design and Construction of Sewerage System) is commonly used as the overall guidance for wastewater management. In addition to this, the Sewerage Services Department has also published a series of guidelines (5 volumes) targeted towards the housing developers who are obliged to include wastewater treatment system for the facilities they build. Such guidelines include for example the design and construction of septic tanks for single development of less than 150 population equivalent (PE)[23].

In Sabah and Sarawak, there are no dedicated regulations and authorities established to oversee sewage management. Thus, the local governments (municipalities) in both states are responsible to provide sanitation services as part of their mandate.

3.3.3 Current treatment and disposal

In Malaysia, the domestic sewerage treatment system can be classified into 4 main types:

- Septic / Imhoff tanks;
- Oxidation ponds;
- Aerated lagoons;
- Mechanical Sewage Treatment Plants;

In Peninsula Malaysia, approximately 60% of the total sewage treatment system is based on communal and imhoff tanks. However, as these tanks mainly used by individual dwelling, the total population served is only around 9%[24]. In contrast, the

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[22] Hamid, Haniffa and Narendran M. (2004). Getting to Know the National Sewerage Concessionaires (Series 1). *Buletin Ingenieur, Vol 22*, June-August 2004.

[23] Sewerage Services Department, Malaysia. (1999). *Guidelines for Developers*: Volume 5 Septic Tanks.

[24] Hamid, Haniffa and Narendran M. (2004). Getting to Know the National Sewerage Concessionaires (Series 1). *Buletin Ingenieur, Vol 22*, June-August 2004.

majority of the population (58%) in Peninsula is served by mechanical sewage treatment plants that mostly utilize aerobic treatment process and thus significantly reducing methane emissions. Thus, these sewage plants are not interesting for CDM consideration.

In contrast, for Sabah and Sarawak, due to the abundance of land and low population density, it is not surprising that most population is served by septic tanks. For this study, it is assumed that approximately 60% of population in both Sabah and Sarawak are using septic tanks. This is assuming the population concentrated in larger cities, districts and towns will have septic tanks as part of their housing development. Out of the remaining 30%, apart from the occasional use of small scale sewage treatment plants and oxidation ponds, the rest can be assumed to be directly discharging to the environment e.g. hanging latrines along the rivers.

Figure 2 Typical Septic Tanks Used in Malaysia

According to a study which assesses the types, performance and status of septic tanks in use carried out by the Municipal Council of Kuching South in 1997, most of existing septic tanks are not in good condition and most are not properly maintained[25]. Further studies by others, for example the Sustainable Urban Development project in Sabah (2001) and Sarawak (2000) both confirmed this fact. A study carried out by IWK in Ulu Langat Selangor in year 2000 indicated the effluent quality from septic tanks on average is around 100 mg/L BOD and 150 mg/L Suspended Solids (SS)[26]. Combining information from the above studies, it can be noted that the quality of treatment of septic

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[25] Kuching South City Council. (1997). Study on the Existing Septic Tanks in Kuching.

[26] Hoh, Choon Yee. (2003). Overview of local experiences in the Malaysian context: From indah water to Matang sewage sludge treatment. Paper presented at the *Seminar on sustainable urban wastewater management*, Kuching, Sarawak, Malaysia, 10-11 June 2003.

tanks indeed varies significantly depending on the conditions and maintenance of the septic tanks but most of the discharge is not meeting the discharge standard allowed (EQA Effluent Quality Standard A or B).

There are no known cases to this study of significant recovery and utilization of biogas from sewage treatment plants in Malaysia. There is however a proposal to upgrade a sludge treatment facility in Kuching, Sarawak into biogas recovery system. This project is still under evaluation.

3.3.4 Assessment of waste amount and composition

The assessment of sewage amount or tariff is especially interesting for those serviced by septic tanks, for the reason explained in section 3.3.1. Several assumptions have to be made in this estimation due to the lack of information. The overall estimation will be based on extrapolation from information available from widely known sources.

The following assumptions were made:

- ∗ Assuming 10% of the population in Peninsula Malaysia and 80% of the total population in East Malaysia are using septic tanks;
- ∗ Assuming each individual house will have a septic tank and the average occupancy rate of 5 persons per households;
- ∗ Total population in Peninsula Malaysia is approximately 20 million with an additional 3.4 million in Sabah and 2.2 million in Sarawak.

Based on the above information, the following estimations can be made:

Table 10 Estimated Amount of Septic Tanks in Malaysia

Region	Population served by septic tanks	Total Number of Septic / Imhoff tanks estimated
Peninsula M	2,000,000	400,000
Sabah	2,040,000	408,000
Sarawak	1,320,000	264,000
Total	**5,360,000**	**1,072,000**

In summary, approximately 5.4 million people (around 20% of total population) in Malaysia are served by septic tanks. Using a standard, per capita sewage (blackwater) generation amount of 13 m^3 per year[27], this would correspond to approximately 70 million m^3 of domestic sewage to be treated per year in approximately 1.1 million septic tanks. This figured is comparable to an estimate that there are around 1 million septic tanks in Malaysia through a press article released on 24 October 2004[28]. The same press article also estimated approximately 4.2 million m^3 of sewage sludge in Malaysia.

For this study, the composition of domestic sewage used is based on relatively standard wastewater design parameters obtained from the feasibility study of an integrated wastewater management system in Kuching City 2003 commissioned by the State Government of Sarawak[29]. The study recommends the following:

Table 11 Estimated Organic (BOD and COD) Loading in Septic Tanks in Malaysia

Pollutants	Concentration in raw sewage (mg/L)	Total loading per year (mT/year) to septic tanks in Malaysia
BOD_5	200	14,000
COD	440	30,800

(Source: Adopted from the State Government of Sarawak (2003). Feasibility study on Wastewater Management System for Kuching, Sarawak)

It can be assumed that the composition of raw sewage is similar throughout the country.

3.3.5 Potential GHG (methane) Emission

Estimation of methane emissions from septic tanks is not very straight forward since it depends very much on the extent of the anaerobic digestion that take place which of course depends on various factors related to design, retention time etc. In general, the emission rate has not been a popular study area and therefore not much information exists.

Thus, for this study, methodology used for estimating methane emission from anaerobic treatment of wastewater was used as the best estimates. Three sources of information were adopted for the estimation of methane emissions from septic tanks in Malaysia:

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[27] Assuming 70% of time presence, 5 person family and based on a 7-9 L flush toilets. (Adopted from the integrated wastewater framework plan by DANIDA Urban Environmental Management System Project)

[28] China Press. (24 October, 2004). *Appropriate sludge management: Avoid pollution to water sources*, Malaysia.

[29] Sarawak Government. (2003). *Feasibility study on centralized wastewater management system in Kuching*.

- The first estimate uses the recommended method of the revised 1996 International Panel for Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories which sets the emission rate at 0.25 kg methane per kg of COD[30];
- The second uses a methane emissions factor recommended by the United States Environmental Protection Agency (USEPA) of 0.6 kg methane per kg of BOD;
- The third uses an emission rate per septic tank derived from a study carried out by the Department of Energy of USA on GHG emission from septic tanks.

According to the CDM Approved Methodology (AM013), IPCC Guidelines, CH_4 emissions from wastewater are calculated as follows:

CH_4 emissions (kg/yr) = Total COD (kg COD/yr) x Bo (kg CH_4/kg COD) x MCF
Where
COD = Chemical Oxygen Demand of effluent entering lagoons (measured)
Bo = Maximum methane producing capacity
MCF = Methane conversion factor (fraction)

Using the yearly COD loading (30,800 mT/yr) obtained from Table 11, a maximum methane producing capacity of 0.25 kg methane/kg COD and MCF of 1 for anaerobic conditions, a total potential methane generation is 7700 mT methane/year. An assumption of 50%[31] of these would be emitted, gives 3850 mT methane per year or 81000 mT CO_2 per year[32].

If we use the BOD based calculation (using 0.6 kg methane/kg BOD), the total potential methane emissions was calculated to be 8400 mT / year. Halving this will gives approximately 4200 mT methane /yr or 88,000 mT CO_2 per year.

For the third method, the emission rate per septic tank suggested by the US Department of Energy (study on GHG emissions) is 0.005 m^3 of methane per year. Applying this estimate to the total number of septic tanks estimated in Table 10 gives a total methane

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[30] This is also adopted by the UNFCCC CDM Approved Methodology for Estimation of methane emission from open anaerobic wastewater lagoon (AM 013) based on a project in Malaysia.

[31] A rough estimate of methane emission from anaerobic system by NIRAS A/S, 2004.

[32] Using a Global Warming Potential of 21 for methane gas

emission of 5,360 m^3 of methane per year. If we use a density of 0.7 kg/m^3, then approximately 3,750 tonnes of methane or equivalent to approximately 79,000 mT of CO_2 equivalent per year.

In summary, the estimated methane emissions from septic tanks based on the three methods are:

Table 12 Total Estimated Methane / GHG Emissions from Septic Tanks in Malaysia

Estimated GHG emissions	IPPC method	USEPA method (IPPC)	US Dept. of Energy GHG study	Adopted for this Study
Total MT methane/year	3850	4200	3750	4,000
Total CO_2 equivalent per year	81,000	88,000	79,000	84,000

The estimation based on the 3 methods (mostly all based on IPPC guidelines) is within similar magnitude but the overall contribution of the GHG emissions is relatively insignificant. If we compared the magnitude of emissions with septic tanks emissions in USA (Table 13) which is approximately emitting 30 times more than Malaysia!

Table 13 Comparison of Methane Emission from Septic Tanks in USA and Malaysia

Country	Number of septic tanks	mT of methane / yr
USA[33]	25 million	130,000 mT
Malaysia	1.1 million	4,000 mT

Methane emissions from other sewage sources

It must be noted that the emissions from other sources within the sewerage sector were not covered in this study. These include methane emissions from sludge treatment (e.g. sludge digesters, drying bed), some anaerobic systems used in STP and also emissions from untreated discharged.

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[33] US Department of Energy. *Release of methane from US Septic tanks: An insignificant contribution to the global warming effect of US Greenhouse gases.*

Based on information obtained from existing sludge handling facility[34] and a press article[35], sewage sludge collection and treatment is still relatively undeveloped. In fact, as most septic tanks are often not maintained, sludge is accumulated and separated in the various septic tanks. The press article estimated more than 65% of septic tanks are not desludged. The article also stated that sludge collected from septic tanks and those from sewage treatment plants, they are often either dried using sand based drying bed before landfilled or directly disposed to land. For few sludge treatment plants, solid-liquid separators are used. Indah Water Konsortium is currently collaborating with research institutions such as local university to research the use of treated sludge for use as fertilizer in forestry and agricultural sectors.

For centralized sludge treatment plants, oxidation process such as the use of sequencing batch reactor (SBR) of effluent from the solid-liquid separation will significantly reduce the methane emission to the atmosphere. In summary, since the treatment of sludge are currently handled mostly in a decentralized manner where existing practices would not give rise to significant methane emission where CDM may be interesting; it is justifiable that these area are not included in this study.

CDM potential will exist for centralized treatment where open anaerobic treatment using digesters (open anaerobic digestion) and further studies are recommended.

3.4 Livestock Waste – Swine Farming

3.4.1 Brief description of sector

Apart from feeding the country's population, the livestock industries represent a significant contributor to Malaysia's export earnings. In view of this significance, the government has recently shown strong interest and determination to improve the development of agricultural sectors, including the livestock sub-sector. Under the National Agricultural Policy (1992-2010), the government is driving towards a more commercial, modern, efficient, competitive and sustainable sector[36].

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[34] Personal communication with plant manager, Matang Septic Sludge Treatment Plant, 15 October 2004.

[35] China Press. (24 October, 2004). *Appropriate sludge management: Avoid pollution to water sources*, Malaysia.

[36] Department of Veterinary Services Malaysia. (2003). *Malaysian Livestock and Veterinary Industries Directory 2001/2002.* Department of Veterinary Services, Ministry of Agriculture, Malaysia and Trans-Event Sdn. Bhd.

The output values of the various livestock industries in Malaysia include those in Table 14:

Table 14 Gross Output Value of Different Sub-sector of Livestock Industries in 2000

Types of Livestock	Gross Output Value (RM million)	% Total
Poultry	4008	76.78%
Swine (Pigs)	906.8	17.37%
Buffalo	248.7	4.76%
Cattle	43.5	0.83%
Sheep	12.9	0.25%
Total	**5220**	**100.00%**

(Source: Department of Veterinary Services, Malaysia. (2003))

Although the poultry sub-sector dominates both in population and the total output value in the market, when it comes to export market, the swine industries contribute more.

Table 15 Export Value of Livestock Commodity in Malaysia in 2003

Commodity	Value (RM Million)
Swine	94.12
Broiler Duck	65.32
Day Old Chick	3.95
Chicken Egg	2.36
Chicken meat	0.26

(Source: Department of Veterinary Services, Malaysia (2003))

In recent years, the livestock industries are facing many challenges. The top issues include high import bills, environmental issues and diseases. Disease incidents such as the Nipah Virus on swine industries, Avian flu on poultry industries has significantly affected these respective industries.

Environmental issues are also an increasing demand on farmers. The increase in demand on better waste management from livestock industries may have implications in methane emissions. For example, the wide used of open anaerobic ponds as retention especially for the swine industries before discharge has become a source of methane emissions to the atmosphere.

In contrast, the poultry sub-sector is not obvious when it comes to CDM potential. This is due to the fact that the current waste management (chicken dung) of poultry farming is well taken care off for use in fertilizer production for farming use. Hence, as chicken dung will not be considered for CDM in this study here are however some new initiatives in the upgrading of chicken dung using palleting technologies which would improve the fertilizing effect but this is unlikely to significantly improve the CDM potential of chicken dung.

Similarly, ruminant livestocks (cattles, buffaloes, goats) are also not considered in this study mainly due to the farming practices where ruminants are left grazing in open spaces. Thus, the waste generated are in general widely distributed and left to degrade naturally. Only some dairy industries and feedlot cattle farms (intermediate rearing before slaughtering) that house the animals within a fix area where the waste will be concentrated and collected. Due to the spreading of these farms across the country and in general not very large scale, methane emission from cattle waste is not covered in this study.

Why are swine industries interesting for CDM?

Swine farming, the second largest gross output contributor in the livestock sector, is the only sub-sector that is interesting for CDM projects due to the following reasons:

- The fact that these livestocks are housed and their waste collected and in most case anaerobic digested in open lagoons before discharging to waterways. The effluent discharge is considered the most polluting livestock activities which often give rise of public complaints and degradation of water quality;

- Under the National Agricultural Policy in controlling swine farming pollution, swine farming activities have been driven towards the formation of a permanent production area (refer as Pig Farming Area (PFA)) where high intensity of swine population will be established within a designated area. Due to the various challenges faced by smaller swine farming holders, the trend of domination by large companies (industry consolidation) will further reduce the number of smaller farms[37].

In view of the above reason, the following assessment will only focus on assessing the potential of CDM in the swine industries within the livestock sectors.

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[37] DANIDA - DVSAI. (2004). *Draft feasibility study of partnership development between Danish and Malaysian companies for the pig farming area at Telipok, Sabah*.

The current distribution of swine population in Malaysia in 2002 is tabulated below. Detail distribution according to States is tabulated in Appendix C. A total of approximately 2 million swine was record in 2002. Since the recovery from the Nipah virus epidemic in 1998, the total population has been stable and some signs of increasing but still far from the population level before the Nipah virus which recorded to as high as 2.5 million swine.

Table 16 Distribution of Swine Farms According to States (2002)

State	Total Population	% Total
Peninsula Malaysia	1,399,935	72.2
Sarawak	427,695	22.0
Sabah	112,224	5.8
Total	**1,939,854**	**100**

(Source: Department of Veterinary Services, Malaysia (2003), State Veterinary Authority Sarawak (2003), Department of Veterinary and Animal Industry Sabah (2003))

3.4.2 Regulatory and institutional framework

The regulation of swine farming activities is different among Peninsula Malaysia, Sabah and Sarawak. The regulation of swine farming activities has been strengthened in recent years especially due to the concern over the pollution from the activity and disease control. Specific discharge quality limits are set and enforcement is being stepped up throughout the country. The regulation of swine farms in Peninsula is mainly governed by Federal legislatures where the Department of Veterinary Services under the Ministry of Agriculture Malaysia and Department of Veterinary Services under the various States play the vital role in regulating the swine farming industries. The main ordinance is The Animal Ordinance 1953. It is being scheduled to be replaced by newly proposed Veterinary Act and The Animal Feed Act. Subsidiary legislations made under this ordinance include The Animal Rules 1962 among others. There are also other relevant Federal laws such as the National Livestock Development Authority Act 1972, the Veterinary Surgeon Act 1974, Abattior (Privatization) Act, 1993 and so forth[38].

In Sabah and Sarawak, swine farming is governed by existing regulations under the Sabah and Sarawak State Government legislature.

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[38] Department of Veterinary Services Malaysia. (2003). *Malaysian Livestock and Veterinary Industries Directory 2001/2002.*

In Sabah, the main regulatory framework is the Animal Ordinance, 1962 and the Conservation of Environment Enactment, 1998. Under these two main legislations, subsidiary legislations specifically targeted to regulate swine farming include The Animal Ordinance (Control of Livestock Activities) Rules, 2004 (Draft) and Conservation of Environment (Control of Pig Farming Pollution) Rules, 2004 (Draft). Both rules are expected to be endorsed and implemented sometime this year (2004). The main authority under the new rules will be the Department of Veterinary and Animal Industry of Sabah (DVSAI).

In Sarawak, the main regulatory framework on swine farming include the Sarawak State Veterinary Ordinance, 1999 and the Natural Resources and Environment (Control of Livestock Pollution) Rules, 1996. The State Veterinary Ordinance empowers the State Veterinary Authority under the State Department of Agriculture to regulate via licensing swine farms in Sarawak. The Natural Resources and Environmental Board Sarawak on the other hand ensures the discharge from this sector does not pollute the natural environment.

Apart from governmental institutions, within the swine farming industries there are several livestock breeding associations, which combine the key players in the industries.

3.4.3 Assessment of waste amount and composition

Waste generations from swine farming mainly consist of a mixture of:

- Livestock manure – commonly consist of wash-water and raw animal excreta (faeces and urine) or feed/bedding material mixed with excreta, etc.;
- Dead animal carcasses/solid – may be infectious that must be treated separately;
- Abattoir waste – waste generated from abattoir operation;
- Others – e.g. packaging of fodder etc. manure, wash water, etc.

Livestock manure is a very high strength biological waste (with average BOD concentration of 5000-10,000 mg/l for example), which is a potential significant source of organic pollution. Research indicated that livestock manure such as pigs contributes many times more in pollution loading compared to human sewage. Thus, if not properly collected and treated, the manure would cause serious degradation to the environment, including emissions of GHG especially methane to the atmosphere.

Similarly, the waste from abattoirs (slaughtering process) is also high in organic content and thus would be interesting for CDM consideration. However, waste from abattoirs are not included in this study as currently they are operating as a separate industry and commonly widely distributed. However, studies[39] had shown that most of these facilities usually use lagoon system which will emit methane to the atmosphere. It would be highly possible to combine the waste management when the concept of PFA is implemented, where waste from the farming and slaughtering are treated under an integrated system utilizing technology such as controlled anaerobic digestion system. In such case, the methane emission avoidance could be realized from both the manure and the abattoir waste.

There are several previous studies on the waste generation amount from swine farming in Malaysia. As the swine farming practices in Malaysia are in general less modern and due to the abundance of water resources, the amount of waste manure generated per swine is relatively high. A commonly used estimate is between 30-40 litres of manure per swine per day (including faeces, urine, wash water for cooling and cleaning etc.). For this study, an average of 35 litres (0.035 m^3) is used. Out of this, approximately 5 litres are faeces and urine[40]. Adopting the population from Table 16, the following waste amount can be estimated:

Table 17 Estimated Total Amount of Swine Manure in Malaysia

State	Total Population	Total Amount of Manure (m^3/ day)
Total Peninsula M	1,399,935	49,000
Sarawak	427,695	15,000
Sabah	112,224	4,000
Total	**1,939,854**	**68,000**

(Source: Own Calculations)

When it comes to composition and loading of waste, the following can be adopted for this study:

Table 18 Typical Composition and Loading from Swine Manure

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[39] DANIDA-Sarawak Government. (2004). *Study on organic waste from food manufacturing and processing industries*. Implementation of an Urban Environment Management System Project, Kuching, Sarawak.

[40] DANIDA-Sarawak Government. (2004). *Surveys on plantations and other potential users for organic fertilizer and on potential sources of organic waste in the vicinity of Matang Septic Sludge Treatment Plant in Kuching, Sarawak.*

Parameters	**Avg. Load (kg/swine/d)**	**Total Loading (mT/d)[41]**
Biological Oxygen Demand (BOD)	0.13	**260**
Chemical Oxygen Demand (COD)	0.32	**640**
Total Solids	0.45	**900**
Total Kjeldhal Nitrogen (TKN)	0.016	**32**
Total Phosphorus (Phosphate - TPO)	0.01	**20**
Total Potassium (TKO)	0.005	**10**

(Sources: Adapted from the Feasibility Study for Development of Pig Farming Area at Pasir Puteh, Samarahan Sarawak (2004))

3.4.4 Current treatment and disposal

The discharge of swine waste has been highlighted in recent years as indicated earlier. Since the strengthening of regulatory requirement on the discharge control, today the most common minimum requirement of having ponds/lagoons prior to discharging is required. These are also considered the least costly option considering most farmers have sufficient land area for the lagoons.

The fundamental principle of this treatment technique is providing ample settling and detention time for the denser particle within the wastewater to sink onto the bottom of the ponds to further decompose thus becoming sludge. These ponds mostly decompose under anaerobic conditions where methane emissions are inevitable. Consequently, the lighter liquid portion of the wastewater is allowed to flow into consecutive lagoons (sometimes up to 4 ponds) undergoing the same process of detention and degradation before discharging into the drain/stream nearby the various farms.

Based on studies carried out by Department of Veterinary Services as well as by the Natural Resources and Environment Board Sarawak and Environmental Protection Department Sabah, it can be safe to indicate that between 80-90% of the swine farms in Malaysia are using the lagoon system to different levels. Some farms have more lagoons than others while most of these ponds are not lined and therefore there are still concerns of contamination via the ground water. Other concerns include odour emission, vector spreading and sludge disposal.

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[41] Based on approximate total population of 2,000,000 for Malaysia

Only a small percentage (less than 10%) of these ponds area lined with concrete. Some farms are also assessing new techniques to improve their waste system. Systems such as the use of solid-liquid separator for more efficient solid removal, the use of farm scale biogas system and bioreactor aerobic system were reported in various sources. Farm scale biogas systems are found in for example in Kuching, Sibu (Sarawak) and KK of Sabah are all using low technology dome digesters. The biogas is used for running small generator sets for running cooling fans and other internal farm use. The extent of biogas generation is however relatively small compared to the total swine population today.

Figure 3 Typical Unlined Anaerobic Lagoons in Swine Farms in Malaysia

3.4.5 Potential Greenhouse Gas (Methane) Emission

As mentioned in section 3.4.4, majority of existing methane emissions within the swine farming comes from the anaerobic lagoons used for as waste detention system. Without reliable number of ponds throughout Malaysia, the estimation for this study will be based on potential emission per swine instead. This is of course making an assumption the all lagoon systems are approximately the same conditions and the waste generation amount per swine is consistent throughout Malaysia.

There are several sources of methane emission estimation per swine. These are summarised below:

Table 19 Comparison of Methane Emission per Swine from Various Sources

Sources	Methane emissions per	Methane emissions per swine (kg/day)[b]
Development Bank of Philippine[a] (DBP)	0.15	0.11
Department of Veterinary and Animal Industry, Sabah[c]	0.096	0.07

Ecosecurities[d]	0.12	0.087
Adopted for this study	**0.14**	**0.1**

[a] Development Bank of Philipines. (n.d.). Cost Estimation of Biogas Plants in Piggeries.
[b] Based on a standard methane density of 0.72 kg/m
[c] Eli, N., Kasim, A. and Khong, W. (2002). *Waste management in livestock farming.* Paper presented at the 2nd Sabah-Sarawak Environmental Convention, Kota Kinabalu, Sabah.
[d] Personal communication with Mr Jan Willem, Ecosecurities, 15 Sept 2004.

Applying the above methane emissions to the population distribution in Malaysia gives the following:

Table 20 Estimated Total Methane Emissions from Swine Farming and Lagoons

State	Total Swine Population	Total methane emission potential (mT / year)	Total CO_2 equivalent per year (mT/year)
Total Peninsula M	1,399,935	51,100	1,073,100
Sarawak	427,695	15,700	329,700
Sabah	112,224	4,130	86730
Total	**1,939,854**	**70,930**	**1,489,530**

3.5 Palm Oil Processing: Palm Oil Mill Effluent (POME)

3.5.1 Brief description of sector

Malaysia is the largest producer and exporters of palm oil in the World today. A total of 12,248,000 mT of palm oil was exported from Malaysia in 2003, representing approximately 58% of the total world market. In 2003, there are approximately 370 palm oil mills in operation in Malaysia and there are additional 40 mills currently under planning or construction. Thus, based on the on-going trend, the industry is set to expand further[42].

When it comes to potential of CDM due to methane avoidance, the Palm Oil Mill Effluent (POME) will be the main discussion. This is due to the fact that POME is managed using anaerobic ponds which emit methane to the atmosphere. This study will only focus on the potential of methane emissions from POME. Biomass related potential such as the use of EFB as fuel for co-generation will not be covered.

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[42] Malaysia Palm Oil Board. (2004). *Malaysia Palm Oil Statistic 2003*.

The discharge from palm oil refinery mills was not assessed in this study. In the refinery, the industry has to contend with treating the palm oil refinery effluent (PORE). The characteristics of PORE are very much dependent on the types of refinery process. It was reported that a cost effective and common system for treatment of refinery effluent is the sequencing batch reactor (SBR) process. Such systems employ aerobic treatment and thus less attractive for methane avoidance. However, further research is recommended. Based on information provided by the Malaysian Palm Oil Board, there are 47 palm oil refineries in operation with a processing capacity of 16 million mT in 2003. A further 11 is under planning.

3.5.2 Regulatory and institutional framework

The regulation of palm oil mills in relation to waste discharge is mainly government by the Environmental Quality Act 1974. As early as 1978, a specific regulations made under the EQA was enacted to control palm oil and rubber industries. Realizing the potential impacts of the rapid expansion of palm oil industries, the Department of Environment (DOE) has set a specific discharge standard before discharging to waterways. Under the regulation, it is mandatory for palm oil mills to construct their own treatment system and submit reports to DOE. However, it is not mandated under the law what kind of technologies to be used and resource recovery is not compulsory.

The palm oil industries have developed rapidly over the last 2 decades in Malaysia. With this fast expansion, the impacts of the activities on the environment are also becoming increasingly important. With the increasing attention, several research organizations (Malaysia Palm Oil Board, Palm Oil Research Institute of Malaysia (PORIM), SIRIM Environment and Bioprocess Technology Centre, Malaysia Palm Oil Promotion Council, Malaysia Energy Centre etc.) are indeed very active in palm oil waste related research. The research involves finding ways and opportunities of better utilizing waste from palm oil industries as resources. These include the use of empty fruit bunch (EFB) as mulch or as fuel for waste to energy plants. Similarly, the use of palm oil kernel cake for animal feed, promotion of timber products from palm oil tree trunks etc. are all on-going efforts.

3.5.3 Assessment of waste amount and composition

POME is one of the main by-products from crude palm oil (CPO) mill operations. The total generation amount and typical composition of POME are tabulated below:

Table 21 Total Amount of Fresh Fruit Bunch Produced and POME Generated in Malaysia (2003)

State	Total Fresh Fruit Bunch Processed	POME generated (mT)	% Total
Total Peninsula M	42,293,805	25,376,283	63%
Sarawak	4,164,855	2,498,913	6%
Sabah	21,151,499	12,690,899	31%
Total	**67,610,159**	**40,566,095**	**100**

(Source: Malaysia Palm Oil Board. (2004). *Malaysia palm oil statistics 2003*.)

It can be noted that the distribution is almost equally distributed between Peninsula Malaysia and East Malaysia. Sabah is the largest producer today but the development in Sarawak is on-going while Sabah has reached its capacity. Detailed distribution (based on Fresh Fruit Bunch Produced) according to States can be found in

Appendix D. The distribution in 2003 is approximately 60% in Peninsular and 40% in Sabah and Sarawak.

POME is a high-strength pollutant with the following typical characteristics:

Table 22 Average Composition of Raw POME

Parameter*	Mean
pH	4.0
Biochemical Oxygen Demand (mg/l)	25000
Chemical Oxygen Demand (mg/l)	51000
Total Solids (mg/l)	40000
Suspended Solids (mg/l)	18000
Oil and Grease (mg/l)	6000
Ammoniacal Nitrogen (mg/l)	35
Total Nitrogen (mg/l)	750

(Source: Ma. A.N. (1999). Management of palm oil industrial waste in Malaysia. Paper presented at the *Seminar on integrated waste management in Sarawak*. Kuching, 28-29 July 1999.)

3.5.4 Current treatment and disposal

There are several methods used in managing POME today. The most common and less costly solution used by palm oil millers is the use of a series of lagoons/ponds as retention. The principle is exactly the same as for the swine waste. A typical lagoon system used for POME is shown in Figure 4.

(Source: MPOB)

Figure 4 Typical Anaerobic Ponds for Treating POME

In 1999, it was estimated that around 85% of the mills in Malaysia adopted the ponding system[43]. The situation today is estimated to be the similar. Apart from ponds, open tank digesters with extended aeration as well as closed tank digesters with biogas recovery were also introduced. However, the extent of digesters usage, especially the more advantage closed digester system with biogas recovery is not very common. There are only a few reported (Tennamaram at Batang Berjuntai, Selangor, Keck Seng in Johor, etc.)[44]. The Tennamaram mill for example, has 4 digester tanks and produces average 10,000 m^3 of biogas per digester each day[45]. The biogas is used to generate power. For the case of Keck Seng, the biogas is mainly utilized for heat recovery: steam generation. Other new packaged systems utilizing the closed digesters with extended after treatment concepts such as "Zero Ponding" POME treatment system was also introduced by a local private companies, Sustainable Wastewater Engineering Sdn Bhd.

3.5.5 Potential Greenhouse Gas (Methane) Emission

The potential methane emission from POME can be estimated based on some established key figures. There are many researches and experiences in estimating the methane emission rate per POME production and a comparison of the various sources is shown below:

Table 23 Comparison of Biogas Production Based on POME

Sources of Information	Methane Emission Rate (m^3 biogas/m^3 POME)
Malaysia Energy Centre	28
Malaysia Palm Oil Board	28
Golden Hope Plantation	25
Forest Research Institute Malaysia	28
SMART Research Institute	28

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[43] Ma. A.N. (1999). Management of palm oil industrial waste in Malaysia. Paper presented at the *Seminar on integrated waste management in Sarawak*, Kuching, 28-29 July 1999

[44] Yeoh, B.G. (2004). A Technical and Economic Analysis of Heat and Power Generation from Biomethanation of Palm Oil Mill Effluent. Paper presented at the *Electricity supply industry in transition: issues and prospect for Asia conference*.

[45] Malaysia Energy Centre (PTM). (2000). *Feasibility Study on Grid Connected Power Generation Using Biomass Co-Generation Technology*.

Adopted for this Study	**28**

This key figure is used in estimating methane emissions from POME:

Table 24 Estimated Total Methane Emissions from POME in Malaysia

State	POME[46] (m^3/yr)	BIOGAS[47] (m^3/yr)	CH_4 (m^3/yr)[48]	CH_4 (mT/yr)[49]	mT CO_2 equiv./yr[50]
Peninsula M	25,376,283	710,535,924	426,321,554	306,952	6,445,982
Sabah	2,498,913	69,969,564	41,981,738	30,227	634,764
Sarawak	12,690,899	355,345,172	213,207,103	153,509	3,223,691
MALAYSIA Total (rounded)	**41 mil**	**3,100 mil**	**682 mil**	**0.5 mil**	**10.3 mil**

The total methane emission from POME of 500,000 mT is relatively higher compared to the estimates by Yeoh[51] (2004), which only amounts to 225,000 mT per year in 1999. However, the difference can be explained considering the fast development rate over the last five years (almost 50% increases in 2003 as compared to 1999 level). The basis of calculating methane emissions is also slightly different. Yeoh (2004) used an average emission based on m^3 methane per kg of BOD. An average yield of 0.5 m^3/kg BOD added to the anaerobic pond was used and a density of 0.6 kg/m^3 (compared to 0.72 used in this study). It is believed that these figures are on the conservative and low side.

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[46] Using an average 0.6 m^3 POME produced per FFB processed

[47] Using an average potential production of 28 m^3 / m^3 POME

[48] Using an average methane composition of 60% volume

[49] Using an average density of 0.72 kg/m^3 for methane

[50] Using a GWP of 21

[51] Yeoh, B.G. (2004). A Technical and Economic Analysis of Heat and Power Generation from Biomethanation of Palm Oil Mill Effluent. Paper presented at the *Electricity supply industry in transition: issues and prospect for Asia conference.*

A quick check using the UNFCCC Approved Methodology AM013 for methane emissions estimation from open lagoon wastewater systems (refer to 3.3.3) can be done. The baseline is based on IPCC guidelines used earlier in methane estimation from sewage where:

Total CH_4 emissions = Total COD x B_o X MCF (see Section 3.3.5 for details)

By using an average COD concentration of 50,000 mg/L and a total of 41 million m^3 of POME generation per year (see Table 24), a total COD loading of 2050 million kg per year is estimated. Entering this into the IPCC method, using a default IPPC value of 0.25 kg methane/ kg COD for B_o, methane conversion factor (MCF) of 1 gives a total methane emissions of 512,500 mT per year.

Another source[52] estimated the total POME production in Malaysia is around 39 million m^3 (as compared to 41 in this study) and the total methane emissions is 707 million m^3/yr (compared to 682 million by this study).

The results derived in this study are well comparable to the estimates made both using the IPCC guidelines and the estimates made in report by Hashim et al (2004). Since it is within the same magnitude, the estimate of 500,000 mT methane is used for rest of this study.

3.6 Wastewater from Other Industries

The industrial sector in Malaysia was defined by survey data obtained from the National Statistics Department and the Malaysian Industrial Development Authority (MIDA). The sector can be referred to as the manufacturing sector and value of sales in 2003 were RM310.8 billion. The enormity of the sector results in an equivalent amount of data.

Appendix F provides the Statistics Departments Industry List summarized to reveal the base categories within the manufacturing sector. A reduced version of is then presented as

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[52] Hashim, M. et al. (2004). Palm Oil Biomass for Electricity Generation in Malaysia. Feature in *Jurutera – The Monthly Bulletin of the Institution of Engineers Malaysia*. No. 11 November 2004.

Appendix G to present a reduced set of industries that produce wastes containing high levels of organics. Table 25 below further eliminates biomass waste producers that do not generate the general type of liquid waste amenable to anaerobic treatment. Palm oil refinery is included as it is distinguished from crude palm oil (CPO) mills dealt with elsewhere in this study. Palm oil refineries do not produce palm oil mill effluent (POME) as POME is defined as being a product of CPO mills. Refineries carry out advanced processes such as hydrogenation, etc. using crude palm oil as a substrate.

Table 25 Industries with Probability of Anaerobic Strength Organic Wastes

INDUSTRY	Production		
	No. of sites	Sales ex-factory, (RM '000)	Product, (mT)
All processed aquatic products (excluding raw fish production)	35	994734	47729
Other fats	9	724432	80348
Oleochemical (palm refinery)	42		1700000
Other food	31	1269604	
Fruits			1349000
Meat (red + poultry)			110000
Beverages	10	608397	524748
Synthetic textile	9	2554364	
Tannery / Leather	7	51778	
Pulp, paper, paperboard	12	1465891	
Boxes	81	2011285	
Other paper / paperboard items	35	1025876	
Rubber remill	55	4001186	1135637
Other rubber product	190	5860453	
latex products (glove, catheter, thread)	138		342000

3.6.1 Regulatory and institutional framework

The principle body regulating waste generated by Industry is Department of Environment (DOE). While the Environmental Quality Act has been in place for some 30 years, there have been and continue to be wastes generated by industry that do not receive treatment to the National discharge Standard.

However, industries out of compliance are provided with only a limited period under a Contravention License in which to upgrade their effluent treatment facilities. If industries are unable to comply within the allotted time frame, closure is meant to be the next step. In practice there are industries which are allowed longer time frames when economics or practicality demonstrate that additional time is required to develop a suitable solution.

Industries with anaerobic ponds or tanks without roofs are notoriously out of compliance. The logic of this observation is that most anaerobic treatment systems are difficult to maintain and, the effluent from them requires additional treatment to meet discharge Standards. Therefore, such systems are necessarily complex and expensive to operate. In turn, expense and complexity are the main causes of non-compliance.

Compliance is measured against two sets of Standards for liquid effluent. Standard A is for effluent discharged directly to a receiving water body or in an area having a close upstream effect on a water body utilized for drinking water supply. Standard B is for general discharge of effluent to non-critical water bodies or, to storm drains in non-prescribed areas. Indication of organic waste in effluent is generally measured as Biochemical Oxygen Demand (BOD) or Chemical Oxygen Demand (COD).

Because Environmental regulation under the Environmental Quality Act 1974 & Subsidiary Legislation is consistent in its treatment of industry with the exception of crude palm oil and rubber processing, all industries except CPO mills and rubber processing operations must meet either Standard A or B. As a result the application of CDM is unlikely to be successful for industrial wastewater.

3.6.2 Assessment of waste amount and composition

Appendix **G** and Table 25 extract the number of sites, factory sales value and, product (metric tonne produced ex. factory) in Malaysia for the selected range of industrial activities.

The wastes generated by industry applicable to this study exclude solid wastes as these are routinely sent to landfill. In addition, this study has eliminated biomass wastes from its scope to focus on methane generation. As a result the wastes focused on are primarily liquid effluents carrying high levels of organic contamination.

For the cases selected in Table 25, a manufacturing output level has been selected for a case study. Research has been carried out to obtain engineering references for wastewater characteristics and generation rates for each industry. A wastewater mass output has thus been estimated. The total available substrate for methane generation has been calculated based on estimated COD levels. The same engineering references provide guidelines for the generation capacity of methane from a given mass of COD. The case studies, parameters and results of this broad-based analysis are summarized in

Appendix G.

3.6.3 Current treatment and disposal

The effluents from industries included in Table 25 are considered either potential substrates for anaerobic digestion or, are already treated in effluent treatment plants that include or would benefit from including anaerobic treatment. Nonetheless it is acknowledged that effluent treatment is mandated by current legislation.

3.6.4 Potential Greenhouse Gas Emission

A simple rate of methane available through anaerobic digestion of wastewater containing COD, considered as being generally achievable has been applied to all cases. The actual rate is a highly variable function of treatment methodology and some factors of treatability of the waste products that are beyond the scope of this study. Methane generation is then converted to a CER by application of a factor of 21 to CH_4 produced, yielding a potential metric tonnage of CO_2 emission per year.

Some general assessment has been performed by senior environmental engineers who are familiar with the industrial wastewater context in Malaysia and who have first hand experience of many representative industries in the various categories. Their contribution is to provide a simple assessment of the likelihood of each case of industry having a full wastewater treatment Plant (WWTP) facility. In addition, an evaluation is given of the likelihood of the WWTP incorporating anaerobic treatment at this point in time (existing anaerobic facility) and of the likelihood that gas is generated and flared where an anaerobic facility exists.

The industry types that indicate a potential for generating more than the cut off criteria of 30,000 mT CO_2/year include:

1. red meat process and packinghouse (swine)
2. poultry processing

Additional industries might qualify where some form of bundling could take place or, where one party dominates production in the sector. Bundling is not applicable to the industrial sector in general due to the lack of feasible cooperation between industries. However, there are many cases where only a few corporations control the vast majority of market share in a particular sector. In these instances, average production is insufficient. Some knowledge of the specific corporations involved in a sector is required to determine the extent of dominance and hence capacity and potential for waste generation. The general cases where some potential for this condition to take place exists are thought to be:

3. ethanol distillery (sugar cane molasses fermentation)

4. waste paper mill

Appendix H provides the details of case studies for methane generation from waste for the industries and GHG productions summarized in Table 26.

Table 26 Presentation of Potential GHG Production

INDUSTRY	CH_4 conversion		
	COD mass, mT/yr	(0.3m^3/kg COD; 0.6 kg/m^3; 1000kg/mT) mT/year	CO_2: CH_4 = 21
case: fish processing[a]	3.14E+02	56	1186
case: oleochemical (palm refinery)[b]	4.07E+02	73	1540
case: animal rendering[c]	2.50E+01	5	95
case: fruit[d]	1.89E+02	34	714
case: red meat slaughterhouse[e]	3.53E+04	6359	133544
case: process & packinghouse[e]	5.11E+04	9198	193158
case: poultry[e]	9.07E+03	1632	34266
case: brewery[f]	2.70E+02	49	1021
case: ethanol distillery (cane molasses)[f]	2.39E+03	430	9023
case: soft drink[f]	2.56E+03	460	9658
case: synthetic Rayon[g]	3.36E+03	605	12701
case: Tannery[h]	3.42E+02	62	1293
case: waste paper mill[i]	4562.5	821	17246
case: latex products (glove, catheter, thread)[j]	3.29E+02	59	1242

case: Natural rubber[k]	1.66E+03	299	6278

References:
a: (Battisoni et al), (Mendoze et al); b: (Agamuthu, P.); c: (Racault, Y.); d: (Austemann-Haunn et al); e: (Barnes et al); f: (Souza et al); g: (Schlesinger C. et al); h: (Ates, E. et al); i: (Kroiss et al); j: (Selper); k: (Mott McDonald)

At present, the criteria for selection of industries for CDM include the necessity for those industries to have anaerobic lagoons as part of their treatment process. In Table 27 the process of elimination is continued. Of the listed industries where potential for anaerobic lagoons exists at sufficient capacity to qualify for CDM, none appear to exhibit evidence that any of these industries are in fact using anaerobic lagoons in Malaysia.

Table 27 Evaluation of Relevant WWTP Status

INDUSTRY	Wastewater Treatment		
	Likelihood of full WWTP	**Likelihood of anaerobic treatment**	**Flaring?**
case: fish processing	low	low to none	NA
case: oleochemical (palm refinery)	high	some	yes
case: animal rendering	medium	low	NA
case: fruit	low	low to none	NA
case: red meat slaughterhouse	medium	low to none	NA
case: process & packinghouse	medium	low to none	NA
case: poultry	high	low	NA
case: brewery	high	high	yes
case: ethanol distillery (cane molasses)	high	high	yes
case: soft drink	high	low	NA
case: synthetic Rayon	medium	low	NA
case: Tannery	medium	low	NA

case: waste paper mill	high	low to none	NA
case: latex products (glove, catheter, thread)	high	some	yes
case: Natural rubber	medium	medium	yes

Those industries known to include anaerobic treatment are summarized in Table 28 below:

Table 28 Industries Employing Anaerobic Treatment Facilities

Industry	Type of Anaerobic Treatment
Oleochemical palm oil refinery	anaerobic digester - open to atmosphere
Poultry secondary waste processing	anaerobic digester probable venting to atmosphere
Brewery	anaerobic digester with planned energy recovery
Distillery	anaerobic lagoons
Latex product manufacturing	anaerobic lagoons and anaerobic digesters with flaring
Natural rubber processing	anaerobic lagoons and anaerobic digesters with flaring
Chemical industry	anaerobic digester - open to atmosphere

From the tabulated industrial estimates recorded in Appendix G, a very approximate estimate of potential GHG emissions is produced that records emissions only for industries where data has been generated (refer to Table 26 and Table 27).

Again referring to Appendix H, parameters that include an average production per industrial site and the number of sites in each relevant category are estimated. The methane calculation derived from COD load is converted to CO_2 and both the average and total CER are presented for each category in Table 29, below. The total estimated CER from all industrial wastewater categories is calculated as 832,180 mT/yr CO_2.

Table 29 Estimated total GHG Emissions from Methane Generation Potential

Industry	No. sites	Product, (mT)	Ave Case CO_2 (mT/yr)	Category Total CO_2 (mT/yr)
Canned pineapple	3	18,897	714	2,142
All process aquatic	35	47,729	1,186	41,510
oleochemical (palm refinery)	42	1,700,000	1,540	64,680
Other food	31			
fruits		1,349,000	714	0
meat (red + poultry)		110,000	34,266	0
Beverages	10	524,748	9,658	96,580
Synthetic textile	9		12,701	114,309
Tannery / Leather	7		1,293	9,051
Pulp, paper, paperboard	12		17,246	206,952
latex products (glove, catheter, thread)	138	342,000	1,242	171,396
natural rubber	20	850,000	6,278	125,560
Total				**832,180**

3.7 Summary of Total Potential Methane Emissions

Based on information presented above, a summary of GHG emission potential from the various waste sectors analysed are presented below:

Table 30 Total Methane and CO_2 equivalent Emission Potential within Waste Sectors in Malaysia

Waste Sectors	mT Methane / year	mT CO_2 eq/ year	% of Total
MSW Landfill	685,843	14,402,700	52.7
Sewage (Septic tanks)	4,000	84,000	0.3
Swine farming	70,930	1,489,530	5.5
Palm Oil (POME)	500,000	10,500,000	38.4
Other Industries (Wastewater)	39,628	832,188	3.1
Total Emissions	**1,300,400**	**27,308,400**	**100**

The methane emission distribution by sectors can be illustrated in Figure 5 below:

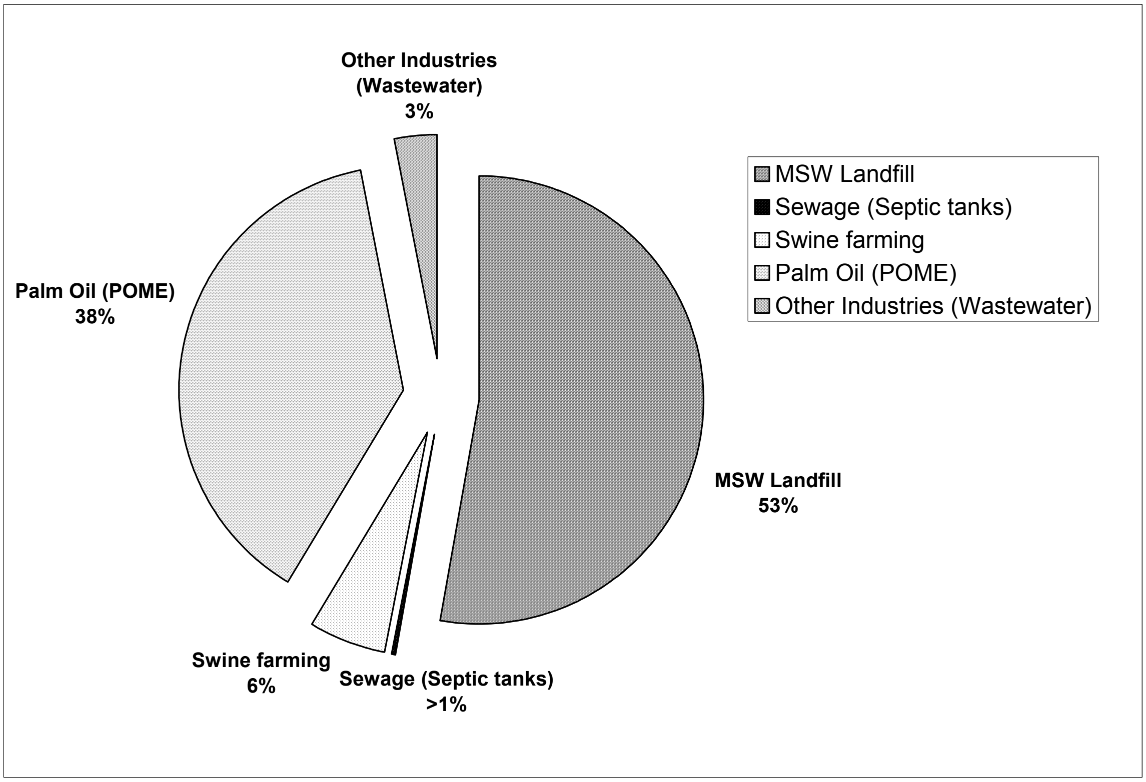

Figure 5 Distribution of Methane Emissions Potential by Waste Sectors

The total **methane emissions** estimated from the waste sectors assessed are approximately ***1.3 million mT*** per year. The results from this study indicate that the most prominent methane emissions source in the waste sector comes from MSW landfill gas (53%). This is followed by POME emissions from the Palm Oil Industries, which contributes to approximately 38% of the total methane emissions from waste resources assessed. The rest of the sectors are less significant in terms of total methane potential.

In terms of distribution of potential among the waste sector, it is interesting that the above result (trend) in the CDM potential is reflected also from the existing CDM projects proposed in Malaysia. Until October 2004, the following CDM project distribution was reported[53]:

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[53] CDM Energy Secretariat: Malaysia Energy Centre. (2004). Country Presentation – Malaysia. In *Asian regional CDM investors forum*, Manila, The Philippines, 27-29 October 2004.

Table 31 Types and Distribution of CDM Projects Proposed in Malaysia

Waste Sectors emitting Methane (MT/yr)	No. of projects	% of Total
MSW Landfill	3	30%
Livestock farming	1	10%
Palm Oil Processing (mostly biomass)	6	60%
Others	-	-
Total	**10**	**100%**

(Source: Malaysia Energy Centre, 2004.)

It can be noted that where 90% of the projects are MSW landfill gas and palm oil mill related. The projects related to Palm Oil Industries are mostly biomass projects (e.g. EFB for power and heat) rather than biogas from POME.

In terms of the amount of total methane and CO_2 emission potential, the results can be compared and reviewed against other estimations made earlier. This is tabulated in Table 32 below:

Table 32 Comparison of Methane Emissions Estimates from Various Studies

Waste Sectors emitting Methane (mT/yr)	Total CH_4 Potential: This Study	Malaysia National Communication (1994 level)	Potential CER : CDM Potential Study in 2003 (DANIDA/PTM)
MSW Landfill	685,843	1,043,000	
Swine farming	71,000	75,000	
Other Industries (Wastewater)	39,628	224,000	
Palm Oil Processing (POME)	500,000	Not studied? Or included in industrial	
Total methane	**1,296,470**	**1,342,000**	
Total GHG (mT CO_2 eqv.)	**27.2mil (only waste sectors)**	**144 mil (all sectors)**	**13 mil (for all sectors excluding landfills and POME)**

In fact, if we compared the total methane emission potential from waste of this study (1.3 million mT/year) to the estimates in the Malaysia Initial National Communication submitted to the United Nations Framework Convention on Climate Change (level in 1994) of approximately 1.34[54] million mT, it is within the same magnitude. In terms of total CO_2 equivalent, the estimated 27.2 million mT per year from waste sectors are almost comprising 20% of the 144 million mT total GHG (CO_2 equivalent) estimated by the Malaysia Initial National Communication at 1994 level. By adjusting to the total GHG emissions in Malaysia today, it could be relatively safe to conclude that the total methane emissions from ***waste sectors*** constitute between ***15-20%*** of the **total GHG emissions** in Malaysia.

Inevitably, the total emission reduction that would be eligible for Certified Emission Reductions (CERs) via CDM would be confined by various limitations and factors. This report only provides an overview of the baseline emissions. The actual baseline emissions and reduction for CDM projects will vary from project to project.

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[54] Summing methane emitting sources related to waste: landfill, livestock, wastewater in the 1994 Malaysian National Communication report. Total methane including all sectors = 2.2 mT.

4. Screening of CDM Potential Projects

4.1 Introduction

Section 3 has indicated that there is indeed significant potential in developing CDM projects that could reduce methane emissions within the different waste sectors in Malaysia. However, it is understandable that not all these potentials could be qualified as CDM projects due to the various CDM modalities. For example, the value of CER from a project must exceed process transaction cost of carrying through CDM applications, additionality considerations, economic of scale considerations etc. Therefore, it is necessary to define a set of screening criteria in order to generate a prioritised list of generic CDM project types within the waste sector that has realistic chances to be developed, validated and certified.

This section defines and elaborates a set of criteria (size, additionality, replicability, expected feasibility, and availability of data) for potential CDM projects within the waste sector in Malaysia. Utilizing these criteria, a list of potential CDM project types within the waste sectors was established particularly based on the information presented in section 3. Details of screening are discussed below:

4.2 Screening criteria and methodology

4.2.1 Screening Criteria

It must be stressed again that this study focused on waste types that have high potential of anthropogenic methane emissions within the waste management sector. There are certainly other applications such as biomass to energy, composting projects etc. that could also qualify for CDM but are not included in this study.

Within the waste sectors in this study, there are many possibilities that could be justified for CDM application. Therefore it is necessary to derive certain criteria specifically for the prioritization of CDM identifications. Criteria identified and used for scoping CDM projects within the waste sector for this study are tabulated in Table 33 below.

Table 33 Basic Screening Criteria for CDM Projects within the Waste Sector in Malaysia

Criteria	Description
Size & Distribution	In CDM terms, this is defined by the total CO_2 emission reduction which would be the basis to qualify for Certified Emission Reduction. For this study, a minimum threshold of 30,000 mT CO_2 reductions per year was used to qualify CDM projects. In addition, projects within the range of 10,000 – 30,000 mT CO_2 per year, where bundling is geographically and administratively possible are also considered to qualify. Projects with less than 10,000 mT CO_2 per year were not considered to be interesting for CDM considerations at this stage.
Additionality (legislation, common practices etc.)	This is an important criterion in relation to eligibility of CDM projects. In principle, the proposed project is considered additional if the project will provide additional GHG emission reduction as compared to the baseline emissions (i.e. as compared to situation without the project). The proposed project must conform to all governmental legislation including the environmental laws in Malaysia. The proposed project would not provide additional emission reduction should it be mandatory under the law or already a common practices (in say >25% of instances). A consolidated tool for assessing additionality (refer to Appendix I) was prepared by the UNFCCC CDM Methodology Panel and will be used to assess selected projects in Section 5.
Replicability	The proposed project should ideally be possible to be replicated for wide implementation over the country. This is a representation of the significance and representativeness in relation to total GHG reduction that is relevant to each type of project assessed.
Economic & Technical feasibility	Proposed project must be both economically and technically feasible to ensure sustainability of the project and successful emission reduction over the crediting period (typically 7-10 years).
Data availability	Availability of data is crucial for the detailed assessment of projects in relation to CDM potential. Projects with readily

	available data will be given priority especially in short-listing projects for further, detailed financial analysis.
Others	CDM projects must conform with national criteria (see below).

National CDM Criteria in Malaysia

Beside the basic screening criteria listed above, the assessment also included considerations of the criteria indicated by the National CDM committee of Malaysia[55]. These criteria included the following issues:

∗ In accordance with sustainable development policies and direct benefits towards achieving sustainable development;

∗ Conform to conditions as laid down by UNFCCC CDM Executive Board;

∗ Bilateral in nature i.e. must involve participation of Malaysia and Annex 1 Party/Parties;

∗ Transfer of technology: Emergence of new technology instead of conventional one or improvement of existing technology;

In addition, criteria for small-scale energy projects (which many of the waste management sector CDM projects will fall under e.g. landfill gas for power etc.) include[56]:

∗ Project shall in accordance to one or more of the sustainable development strategies of energy sector in Malaysia (include environmental considerations, promote utilization of gas and renewable energy etc.);

∗ Conform to the environmental regulations of Malaysia;

∗ Utilizes the best available technologies, including local technologies;

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[55] Idris, Zukifli. (2003). Powerpoint Slides on *Clean Development Mechanism Malaysia: Opportunities and priorities*. Conversation and Environmental Management Division, Ministry of Natural Resources and Environment Malaysia.

[56] CDM Energy Secretariat: Malaysia Energy Centre. (2004). Country Presentation – Malaysia. In *Asian regional CDM investors forum*, Manila, The Philippines, 27-29 October 2004.

- must justify their ability to implement the proposed project based on the following:

  - locally incorporated company;

  - minimum paid up capital of RM 100,000;

  - likely sources of financing for the project;

4.3 Methodology and Results of Screening

4.3.1 Preliminary Screening

The results from Section 3 indicates that emissions from MSW landfills and POME treatment are the two largest potential areas for developing CDM in terms of total size of emissions. As indicated in Section 3, the potential CDM projects submitted for national approval have also reflected this importance.

As the total emissions from the swine farming waste, domestic sewage (septic tanks) and wastewater from industrial sources (except POME from palm oil processing industries) were relatively insignificant when compared to the other sectors analyzed, these sources would not be included in the detail screening below.

Swine farming can be interesting mainly due to the government's effort to centralize swine farming in concentrated or dedicated areas throughout the country under the Malaysian National Agriculture Policy. This would greatly increase the intensity of single source or bundled methane emissions and increase the potential of developing emission reduction projects. With the recent approval of cabinet to establish these proposed PFA[57], the potential of CDM would definitely be enhanced.

The sewage and wastewater industries are bounded by environmental regulations where most sites are equipped with commercially available wastewater systems which are mostly based on aerobic treatment e.g. aerated ponds, thus reducing the potential of methane emissions. In addition, these two sectors are also in general widely distributed in both geographical terms and ownership, therefore less attractive for CDM considerations. However, there might be a few exceptions where CDM projects could be developed e.g. wastewater from breweries, sugar factory etc. where high organic loadings of wastewater are produced.

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[57] Sin Chew Daily News. (7 Oct 2004). *Cabinet endorsement to establish & privatise pig farming area.*

In general, the waste sectors elaborated in Section 3 were assessed using the criteria mentioned above. The screening methodologies include:

Qualitative assessment – screening of the waste projects against the criteria as specified in Section 4.2. Information based on those collected in section 3, published information, personal communication with relevant stakeholders and professional knowledge and experiences of consultants in the field;

Quantitative assessment – this is particularly applicable for screening projects according to the minimum CDM qualifying "threshold". Generic project conditions representing a "typical and average" project within individual waste sector were used and the emissions estimated using established methodologies or models e.g. for landfill gas, where the first order decay model was used.

Discussions of the individual sectors against specified criteria are described below:

4.3.2 MSW Landfill

4.3.2.1 Size & Distribution

As indicated in Section 3, there are approximately 145 active landfills and around 75 closed landfills in Malaysia of a variety of sizes and ages. Due to poor accessibility of data and since there is not yet a complete and official national inventory or registration of all active and closed landfills or dumpsites in Malaysia, a database of these landfills with respective information regarding the location, size and, ages was derived from various previous studies, publications, personal communications and seminar material (refer to Appendix B). There are also many cases of data records obtained from different sources containing confilicting information for certain geographical areas. Therefore, there are some unavoidable and unverifiable deficiencies in the data record that is presented and analysis has been confined to best assessment of records with data, without approximations. Conficting data was occasionally rationalized and, some data was logically deduced from available information such as in the case of landfill lifespans.

It is obvious that not all of the landfills will be interesting for CDM application so there is a need to develop a screening methodology to determine a minimum "threshold" in relation to size of landfills which would be likely to indicate eligibility for CDM.

For the calculation of minimum "threshold" for CDM projects, average size representation for landfills can be reflected by the following:

- Daily waste amount received;

- ∗ Accumulated waste amount (reflecting landfill age).

There are some complications when calculating thresholds for landfills however. Firstly, the deposition of MSW to a given landfill may change over its life-span. After a landfill is created, it requires about 10 years of deposition before gas generation reaches about 85% of the maximum landfill gas production rate. Maximum will be achieved in about 20 to 25 years assuming that deposition is constant over the period. The maximum gas production will be maintained thereafter as long as deposition continues at the same rate. Once a landfill is closed, gas production is predicted to drop over the years, for example to 55% of generation at closure in only 3 years.

For these reasons, landfills achieving the cutoff criteria of 30,000 mT/yr of CO_2 equivalent emissions during a ten year lifespan are considered to exceed the threshold. The first order decay model is applied to increments of MSW deposition of 25 mT/day until the model indicates that landfill size crosses the threshold. All landfills with ten years of lifespan or more remaining that receive more than the threshold tonnage of MSW deposition will be considered for evaluation.

Landfill gas (LFG) recovery projects are currently popular amongst the various types of CDM projects internationally. In the majority of cases, prediction of gas generation is through use of the first order decay model as in this study. However, historical records and observation of existing facilities is used to verify assumptions, which is not possible at present in Malaysia.

Evaluation of projects to collect and combust landfill gas in power generation equipment will generally allow for some element of flaring of excess gas. In this way, the project benefits from power generation can be estimated in a conservative manner satisfactory to the investment partners while combustion of all collected gas is guaranteed while payment of CER credits will be based on actual, monitored gas flows.

Worldwide applications of landfill gas combustion include flaring, leachate evaporation, steam or medium BTU gas production and, generation of electricity. This study is confined to flaring and electricity generation. For electricity generation the study also confines itself to generator modules in increments of 1 MW. This condition reflects the reality of any LFG project where actual gas flows are not already being monitored at the particular landfill. There cannot be a perfect match of electrical generation capacity and LFG flow.

To support the model of CDM potential of LFG to electricity projects in Malaysia, the landfill database was analyzed for major size classes. Appendix J selects landfill classes of > 400, 300-400, 150-300, and < 150 mT/day. Also attached to Appendix J is statistical analysis of the landfill database for average lifespan, average dormancy of closed landfills and, average operating years of open landfills. While the average operating years of open landfills was 14 years, the study modelled landfills that had been open, accumulating MSW, for 10 years. The average lifespan of existing landfills was calculated as 17 years but the study modelled landfills that would remain open for 10 years after project initiation. Thus modelled landfills had a total lifespan of 20 years representing 10 years of operating history plus a remaining 10 years of useful life. Since only landfills above150 mT/day would be likely to meet the criteria for an electricity generation project, these assumptions were considered reasonable to demonstrate the scope of application in Malaysia. Larger landfills are generally more recently implemented and, also tend to have a longer lifespan. A summary of open landfills in the selected size Classes for modelling is provided as Table 34 below.

Table 34 Summary of Open Landfills in Selected Size Classes in Malaysia

Size Class of Landfill	400 mT/day or greater	300 mT/day or greater (< 400)	150 mT/day or greater (< 300)
Numbers Currently Open in Size Class	**8**	**7**	**6**
Peninsular Malaysia	**7**	**3**	**6**
Sabah	**0**	**2**	**0**
Sarawak	**1**	**2**	**0**

Modelling of landfill gas generation was carried out for a selection of methane generation rate constants and generation rates to evaluate the corresponding magnitude of changes resulting in potential electrical power generation. The cases analyzed are presented in Appendix K. These results are considered external to the study and are included in support of more research and an effective monitoring program of landfills in Malaysia. They establish the sizeable difference in the potential of LFG conversion to energy under different generation scenarios, which should be supported with more empirical data.

For purposes of financial modelling of the above sizes of landfill, the results from model runs using a rate constant (k) of 0.12 and methane generation rate (L_o) of 140 m^3 - CH_4/mT were used. The approximation is tabulated in Table 35 below as deduced from the results in Appendix K.

Table 35 Basis for LFG to Power Generation Financial Model Inputs

k (= 0.12)	**Lo (= 140)**	**MW**	**>400 mt/d,**	**>300 mt/d,**	**>150 mt/d,**
			Yrs	**Yrs**	**Yrs**
		3	10	**-**	**-**
		1	**-**	**-**	10

Finally, the GHG emission reduction potential of each of the sizes can be reviewed. For a 150 mT/day landfill, 54,750 mT/year of MSW are deposited. As per the modelling inputs, the waste deposited will ultimately produce 140 m^3 CH_4/mT MSW but the generation will occur over the subsequent 10 to 25 years. Thus, it is necessary to differentiate between the total estimated GHG production from MSW summarized in Section 3 and, the accessible portion of GHG that can be effectively reduced by application of LFG collection and conversion to electricity at a particular site.

Complications to the analysis of annual GHG emission reductions for landfills include:

- The life of a project may be confined to between 7 and 21 years under CDM but, the methane generation from a landfill may exceed that period;
- Electrical generation will not perfectly match landfill gas production and, the excess gas produced by the landfill should be flared. Electrical generation will always be sized conservatively so that the equipment is always supplied with 100% of its gas requirements;
- Every landfill is different with respect to degree of management, site characteristics such as depth and exposure and, quality and consistency of waste;
- Landfills may require 10 years of deposition before 87% of steady-state methane output is achieved;
- Landfill methane output may reduce to 55% within 3 years of closure.

As a result of these and other complications, the assessment of landfill projects with respect to meeting the criteria for CDM requires case by case analysis. In this study, a generic project was assumed.

As shown in modelling results, landfills below 150 mT/day were unlikely candidates for power generation. However, Table 36 below describes the ultimate output of smaller landfills in terms of CH_4 and CO_2 equivalents in mT/yr at year 20 of operation. Landfills of 25, 50 and 100 mT/day meet or exceed the threshold emission of 20,000 to 30,000 mT/yr even when 50% collection efficiency was imposed on the results. Therefore, landfills of 25, 50 and 100 mT/day, while not meeting the criteria for > 1 MW of electrical generation, will be considered as candidates for flaring under CDM.

Table 36 GHG Generation in Year 20 for Individual Smaller-scale Landfills

mT/d ->	25	50	100
CH_4, Year 20, (mT/year)	1,777	3,554	7,108
CO2 equivalent, (mT/year)	37,317	74,634	149,268
CO2 equivalent, (50% collection efficiency) (mT/year)	18,659	37,317	74,634

Suitable landfills from each state are summarized in Table 37:

Table 37 Currently Open Landfills 25-149 mT/d Recorded by State

State	Number Open with Capacity between 25 and 150 mT/d
Selangor	2
Negeri Sembilan	8
Melaka	2
Johor	8
Pahang	5

Terengganu	3
Kelantan	3
Perak	7
Kedah	3
Penang	1
Sarawak	3
Sabah	4
Total	**49**
Total Peninsular Malaysia	**42**

Selection for Financial Analysis

The electrical generation candidates of 150, 200, 300 and 400 mT/day are subsequently selected for financial analysis in Section 5 with predicted electrical outputs of 1, 2 and 3 MW respectively for 10 years as per Table 35. Table 34 describes the breakdown of 21 landfills in this category 16, 2 and 3 of which exist in Peninsular Malaysia, Sabah and Sarawak respectively.

25, 50 and 100 mT/day landfills are selected for financial analysis under a flaring-only option and Table 37 shows a total of 49 recorded open landfills with capacity between 25 and 150 mT/d, 42, 3 and 4 of which exist in Peninsular Malaysia, Sabah and Sarawak respectively.

4.3.2.2 Other Criteria

Sustainable Development Policies

Landfill gas recovery is also consistent with the Malaysian Government's sustainable development policy especially stated through the national energy policy, national environment policy and waste management policy.

In terms of energy policy, specifically under the fifth fuel policy, landfill gas utilization will be in line with the development of small renewable energy sources in the country. This has already been demonstrated with the support of a special programme known as the Small Renewable Energy Programme (SREP).

Under the environmental policy, the conformance of reducing methane emissions will be in line with government's direction to fulfil its international commitments such as the ratification of the United Nations Framework Convention on Climate Change and Kyoto Protocol.

In general, the utilization of waste is also in line with the call for reduction of environmental impacts from urban activities as well as plans to improve the fundamental health and sanitary aspects of landfill management.

Replicability

When it comes to replicability, apart from a few newly established sanitary landfills, it is believed that the situation of landfills across the country is similar and thus the project scenarios are replicable for the respective size Classes analyzed.

Data availability

As mentioned in Section 3, landfill gas recovery and utilization projects are one of the popular CDM project types in Malaysia currently. Therefore, data is foreseen to be available. In addition, with two existing landfill gas recovery projects having already been implemented, data should be available, although not easily available.

Summary of results

∗ Minimum "threshold" determined to be daily waste amount received of 150 mT/day for electrical generation exceeding 1 MW and of 25 mT/day for flaring;

∗ Minimum waste in place does not apply to flaring as collection and flaring can begin within one year of startup. 10 years of waste in place provides 87% of peak gas generation. By using smaller increments of generator, it would be possible to begin gas conversion to energy with gas generation at say 50% of peak in about year 5 of operation. Additional power generation would be implemented as an additional 50% in year 10 under such a scenario. This study is confined to energy generation at a single, sustainable output with no incremental module additions;

∗ Based on the results, 29 Malaysian landfills meet the criteria of currently operating and receiving > 150 mT/day for electrical generation. 24, 2 and 3 of these were found in Peninsular Malaysia, Sabah and Sarawak respectively (refer to Table 34). 49 landfills meet the criteria of currently operation and receiving >

25 mT/day (and < 150 mT/d) for flaring. Of these, 42, 4 and 3 were each found in Peninsular Malaysia, Sabah and Sarawak respectively (refer to Table 37).

- Screening of Technical Options:

  Based on the above assessment, generic CDM project types for landfill gas include:

  - Capturing and flaring ;
  - Capturing and power generation.

Co-generation with heat recovery will not typically be applicable unless there is a need of heat (typically steam) nearby. However, this is rare as most landfills are sited relatively far from other activities in Malaysia.

4.3.3 Palm Oil Processing: Palm Oil Mill Effluent (POME)

4.3.3.1 Size and Distribution

Information on palm oil production and processing is relatively complete and accessible compared to landfills and other sources of waste. The main source of information was obtained from the Malaysian Palm Oil Board. In addition, numerous research and publications were obtained with regard to the palm oil industries.

For the calculation of minimum “threshold” for CDM projects, average size representation for palm oil industries can be reflected by the following:

- Minimum POME production;
- Minimum Fresh Fruit Bunch Processed;
- Minimum planted land area.

The following were assumed:

- 60% weight of Fresh Fruit Bunch processed ends up as POME[58];
- Average methane generation rate of 12 kg per mT of POME[59];

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[58] Derived from Malaysia Palm Oil Board Statistics, 2003.

- Average Fresh Fruit Bunch production of 20 mT per hectare/year.

Based on a minimum “threshold” emission of 30,000 mT CO_2 per year, this will corresponds to approximately 4000 kg CH_4 per day[60]. Thus dividing this minimum by the average 12 kg CH_4/ mT of POME will gives the minimum processing rate of approximately 333 mT of POME/ day or 25 mT per hour[61]. Using an average rate of 60% POME from FFB, a daily minimum of approximately 555 mT (approximate 43 mT FFB/hr) or a yearly production of 200,000 mT FFB. Comparing this to estimates made by another SIRIM study[62], it was estimated approximately 30,000 mT CO_2 per year can be achieved by a palm oil mill with a production size of 30 mT FFB per hour. Thus, the threshold minimum of 43 mT FFB per hour derived for this study can be considered relatively conservative.

If we use the third assumption above, the average plantable area of 10,000 hectares per year will be the minimum for CDM qualifications.

In total, there are 370 palm oil mills with POME treatment system in Malaysia in 2003. In addition to these existing mills, another 40 mills are either currently being constructed or under planned. In relation to distribution of palm oil processing mills, these are concentrated in States that are active in Palm Oil Industries in Malaysia. These include:

Table 38 Major Distribution of Palm Oil Processing Mills in Malaysia 2003

States	Number of Mills
Sabah	98
Johor	67
Pahang	66
Perak	45
Selangor	26
Sarawak	26

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[59] Assuming 60% methane in POME biogas and a density of 0.72 kg/m^3.

[60] Using a GWP of 21 for Methane

[61] Based on an average 400 operating hours per month (4700 operation hours a year) reported by Malaysia Palm Oil Board in 2003.

[62] Yeoh, B.G. (2003). Biogas Projects and CDM. Presentation Slides at *European Commission-Asean COGEN Programme Phase III*.

Total	**328 (89% of total)**

(Source: Malaysia Palm Oil Board. (2003). *Malaysia palm oil statistics 2003*.)

In terms of palm oil mill size distribution, Table 39 indicates the latest (until 2004) distribution of palm oil mills according to size in Malaysia. It can be illustrated that 230 (60%) out of 380 palm oil mills have a capacity more than 40 mT FFB / hr which is meeting the minimum threshold sizes (around 43 mT FFB/hr) to be attractive for CDM applications.

In terms of geographical distribution, Table 39 illustrates that most of the large plants (>60 FFB mT/hr) are located in the States of Sabah and Johor. These two States constitute more than 60% of the large mills.

Table 39 Distribution of Palm Oil Mill According to Sizes in Malaysia (2004)

STATES	**FFB/hr**						
	< 20	**20 - 29**	**30 - 39**	**40 - 49**	**50 - 59**	**> 60**	**TOTAL**
JOHORE	0	8	10	18	15	16	67
KEDAH	0	1	1	1	1	0	4
KELANTAN	0	3	1	3	1	1	9
MALACCA	0	0	1	2	0	0	3
N.SEMBILAN	0	4	2	1	4	3	14
PAHANG	1	8	19	8	26	4	66
PENANG	0	0	3	0	0	0	3
PERAK	1	14	8	8	5	9	45
SELANGOR	1	14	4	3	2	2	26
TERENGGANU	0	2	3	0	4	3	12
P.MALAYSIA	**3**	**54**	**52**	**44**	**58**	**38**	**249**
SABAH	0	13	14	26	13	35	101
SARAWAK	1	2	11	4	9	3	30
SABAH/SARAWAK	**1**	**15**	**25**	**30**	**22**	**38**	**131**
MALAYSIA	**4**	**69**	**77**	**74**	**80**	**76**	**380**
% total	**1**	**18**	**20**	**19**	**21**	**20**	**100**

(Source: Malaysia Palm Oil Board, 2004)

By using an average production between the ranges, a total palm oil mill average of 45 mT FFB / hr was obtained. In order to get a feeling of the changes in average size and size distribution of palm oil mills throughout Malaysia, a list of existing palm oil mills, especially those studied by the Malaysia Energy Centre in 2000 were tabulated below:

Table 40 List of Average Size of Some Palm Oil Mills in Malaysia

Palm Oil Mill	FFB (mT/yr)	POME[63] (mT/d)
Snerting	215,000	369
Sungai Buloh	90,000	154
Batang Berjuntai	280,000	480
Kuala Langat	185,000	317
Dengkil	240,000	411
Sepang	96,000	165
Labu	143,000	245
Bidor	300,000	514
Beaufort	70,000	120
Lahad Datu	200,000	343
Average	**181900**	**312**

(Source: Malaysia Energy Centre (PTM). (2000))

The rough average of 40 mT FFB/hr in 2000 can be comparable to the average of 45 mT FFB/hr in 2004. There seems to be a slight increase in the overall plant production size.

The estimated threshold is compared to other studies and tabulated below:

Table 41 Comparison of Results on POME & GHG Reduction Potential

Details	CDM Threshold determined in this Study	Average sizes based on MPOB[a]	Average estimated by Yeoh[b]	Bjoern's Working Paper on CDM Potential[c]
POME	120,000	126,900	113,400	136,500

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[63] Based on average POME/FFB of 60%.

production (mT/yr)				
FFB Proc. (mT/yr)	200,000	211500	200,000	145,000
FFB Proc. (mT/hr)	43	45	43	31
mT of CH_4 / yr	**1,440**	**1,507**	**1286**	**1324**
mT CO_2 / yr	**30,200**	**31,650**	**27,000**	**27,820**

[a] MPOB.(2004). Personal communication with Director of Industry Development Unit, Malaysia Palm Oil Board, 30 November 2004.

[b] Yeoh, B.G. (2004). A Technical and Economic Analysis of Heat and Power Generation from Biomethanation of Palm Oil Mill Effluent. Paper presented at the Electricity Supply Industry in Transition: Issues and Prospect for Asia conference.

[c] Sawilla, Bjorn. (2003). Working Paper: CDM Potential from Biogas Recovery in the Palm Oil Industry. Unpublished.

Discussion

The comparison in Table 41 shows that the results and estimates from various sources of information are within the same magnitude and similar trend. The difference can be attributed to the different operating hours used to compute the information and also year where information was obtained.

In summary, it can be concluded that the average production size of palm oil mills that is likely to be eligible for meeting the minimum CDM "threshold" of 30,000 mT CO_2 is approximately 200,000 mT of FFB per year or 120,000 mT POME per year. Comparing this to the national average palm oil mill FFB production of say 200,000 mT/yr (POME of 20,000 mT/yr), it can be articulated that the potential of CDM eligible projects in terms of size is promising especially for those mills above average size. It is also interesting to note that the potential is especially promising since it is common that a single site has more than one palm oil mills which belongs to same company.

4.3.3.2 Other Criteria

Summary of results

Minimum "threshold" determined to be 200,000 mT of FFB per year or 120,000 mT POME per year per palm oil processing mill.

- It is articulated that most projects above the average sized of 200,000 mT FFB productions would have the potential of developing eligible CDM projects. This is especially promising since it is common that a single site has more than one palm oil mills which belongs to same company.

- Screening of Technical Options: Based on the above assessment, generic CDM project types for POME biogas include:
  - Capturing and flaring ;
  - Capturing for heat production;
  - Capturing for heat and power production.

Unlike landfill gas applications, co-generation will typically be applicable especially for palm oil mills due to their need for heat in the form of steam in various processes.

4.3.3.3 Potential CDM Integration of Other Palm Oil Waste

Apart from POME, the palm oil industries also produce substantial amount of other types of waste (commonly refer to biomass) which is posing a great challenge to the industries. Waste originated from the processing includes empty fruit bunch (EFB), palm kernel, shells, fibres etc. These wastes were not included in this study primarily due to the fact that they are not immediate sources of methane production. However, the current treatment of such waste such as open burning, disposal on land would inevitably lead to greater GHG emissions.

For most palm oil mills, part of the solid fuel e.g. palm shells, kernels are burned on site in biomass boilers where heat and power are generated for meeting own mill demand. It was reported that most of these facilities today are very inefficient and contribute to local pollution[64]. In Malaysia, there are only 3 modern biomass fuelled co-generation plants proposed in 2004. Out of these, 2 will utilise palm oil biowaste and another proposed for 2005 up to date. These plants are designed to cater a total output of 23.5 MW[65].

In view of the inefficient and polluting biomass energy recovery system installed in most palm oil mills, power and heat generation from biogas from POME presents an interesting alternative. In the case where energy supply is substituted by biogas, the

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[64] Hoi, Why Kong and Koh, Mok Poh. (2002). Renewable Energy in Malaysia: A policy analysis. In Energy for Sustainable Development. Vol VI No.3, September 2002.

[65] Journal on Cogeneration & On-site Power Production. September – October 2004. James and James Ltd, London, UK.

biomass e.g. palm kernel shell can be considered for other recovery utilisation. Examples could include production as animal feed which is already commercially implemented in some places.

On the other hand, should it be required for both biogas and biomass energy recovery system, the energy supply planning can be integrated with grid-connection systems where a flexible energy supply system can be established.

4.4 Summary: List of Potential Generic CDM project types

4.4.1 Summary of Thresholds and Project types

The minimum emission "threshold" calculated for the various waste sectors can be summarized in the following table:

Table 42 Minimum "Threshold" For Qualifying CDM Projects & Identified Project Types

Waste Sectors	Indicative key figures for threshold calculations	CDM Project Potential Threshold based on 30,000 mT CO_2 per year	CDM Project Potential Threshold based on 10,000 mT CO_2 per year (with potential of bundling)
Landfill	mT waste landfilled per day	> 25 mT/day flaring > 100 mT/day power generation	>25
POME	Fresh Fruit Bunch	>200,000 mT / yr	>66,000 mT / yr
	POME generation[a]	>120,000 mT / yr	>40,000 mT / yr
	Planted area	>10,000 ha / yr	>3,300 ha / yr

[a] based on avg. 350 operating days and 4700 hours per year

4.4.2 Generic CDM Project Types in Waste Sectors

Based on the assessment and screening above, the following project types are determined to be generic CDM projects that has higher chance of materialising into actual project. Among these two waste sectors, the following generic project types are derived:

Table 43 Generic CDM Projects Types Studied in Greater Details

Waste Sectors	Types of CDM Projects
MSW Landfill	Landfill gas recovery and flaring ;
	Landfill gas recovery & utilisation;
POME Treatment	POME biogas recovery and flaring ;
	POME biogas recovery for heat production (steam boilers) only;
	POME biogas recovery for power only
	POME biogas recovery for heat and power production (co-generation)

4.4.3 Selected CDM Projects for Financial Analysis

The list of potential CDM project types generated above include those (capturing for flaring) that are not interesting in the context of renewable energy from waste. However, these projects are eligible for CDM applications since they constitute an option in reducing the methane release from landfilled waste which would otherwise be released without the project.

As this study concerns, CDM projects with energy production potential, the project types selected for detailed assessment of CDM impact on the overall financial performance of the individual projects were:

- Landfill Gas Recovery and Utilization;
- POME Biogas Recovery and Utilization;

Details of technical and financial assessment of these selected project types are discussed in the following section (Section 5).

5. Financial Analysis and Additionality of CDM Projects

Selected projects from Section 4.4.3 were analysed in greater detail in this section. In particular, the impact of CDM financing on the overall project financial viability was assessed. In addition, detail assessment of additionality of these selected projects was done in greater detail to assess the actual potential of CDM projects development and thus elaboration of the total potential of CERs within these sectors in the next section.

5.1 Methodology

5.1.1 Derivation of Generic Projects for Selected Cases

In order to analyse the financial impact and additionality of CDM on selected projects, it was necessary to establish a "representative" (typical) CDM project for the elaboration of the total potential in the next section. As a point of departure, the basis of this typical project is based on the minimum "threshold" size for eligible CDM project derived from section 4. Other considerations such as the representativeness, potential of replication were also considered in deriving this generic project case.

5.1.2 Financial Analysis

A financial analysis of the impact of CDM financing on the overall project viability was carried out for the selected generic projects. A benchmark of 15% Financial Return on Investment (in real terms) is used as criterion for an investment to be attractive.

A standard financial model developed by the MEWC/PTM/DANIDA "CDM Market Study in Malaysia" (January 2004) was adopted as the basis for the financial assessment in this study. Additional details were included with some minor modification of the original model.

Some standard figures such as loan interest rate, fuel prices etc. established by the Intergrated Resource Planning (IRP) Project were adopted in the financial models for this study. For project related figures, a combination of information sources were used, including personal communications with suppliers, experts, derivation from published sources (e.g. research studies, reports etc.). In case where data was not available, best estimates and judgement of consultants were used.

5.1.3 Additionality and Non-Financial Return

Comprehensive assessment of additionality for the selected projects was performed based on the "Tool for demonstration and assessment of additionality" approved at the 16th UNFCCC CDM Executive Board Meeting. The step by step additionality scheme is attached as Appendix I.

5.2 Landfill Gas Utilisation

5.2.1 Description of Generic Cases

The generic case for detailed financial analysis is based on the minimum threshold criteria (150 mT waste/day received) presented in earlier sections. Two technical options included were the landfill gas to power option and flaring of landfill gas for small landfills. Generic cases of different landfill sizes were developed and analysed as sensitivity analysis.

Charts of the results from FOD Modelling have been presented in Appendix L and Appendix M. The values used in FOD Modelling include the model constants derived earlier and a collection efficiency assumption of 50% of produced gas. Heat Rate is the assumed energy input required to generate a unit of electric power and was selected as 11,383 kJ/kW-hr (10,800 BTU/kW-hr). In the later financial analysis, the energy produced is used to calculate the amount of landfill gas consumed by the internal combustion engine generator and a Heating Value of 26,163 kJ/kg of LFG is used. The composition of LFG is assumed to be 50% methane.

Models of 150, 200, 300 and 400 mT/day deposition rate landfills are presented in Appendix L. These landfills are large enough to produce gas that is in excess of a 1 MW generation capacity cutoff set in this study to reflect practicality in installations. The charts present the year of operation as the x-axis. For the first 10 years of landfill life, each model assumes that the project is not in place. Many open landfills have already been operating for 10 years so that this segment is completed and in the past for such landfills. The model assumes that upon installation of gas collection (at year 10) that 50% of the generated landfill gas is recovered in the collection system. Because power generation capacity is selected in 1 MW modules, the total methane that continues to escape to atmosphere is the sum of the 50% that is not collected and, the excess of the collected amount beyond that required by the generator engine. The chart shows the exact conversion of collected methane to energy as kW-hrs. The quantum of excess gas that would be flared in the cases studied averages about 7% of peak gas production over the 10 years of recovery.

Models of 25, 50 and 100 mT/day deposition rate landfills are presented in Appendix M. These landfills are not large enough to produce gas that is in excess of input required for 1 MW generating capacity. However, it was shown that they produce amounts of methane that could exceed the cutoff equivalent of 30,000 mT/year of CO_2. Flaring was proposed for these three options with CDM as the only revenue scheme.

The CO_2 emission avoidance from these projects assumes that LFG combustion is carbon neutral or in other words that MSW is a renewable resource. As long as landfills exist as one of the main MSW disposal routes, it would appear reasonable to make the renewable resource assumption. If LFG combustion is not carbon neutral it is still an improvement over fossil fuels and leakage would be minimized as a result.

5.2.2 Technical Description

Flaring options contribute only to GHG emission reduction while energy generation options also contribute to achieving the Malaysia 5th Fuel Policy. The generic layout of landfill gas-to-energy and flaring project opportunities appears as Figure 6 below.

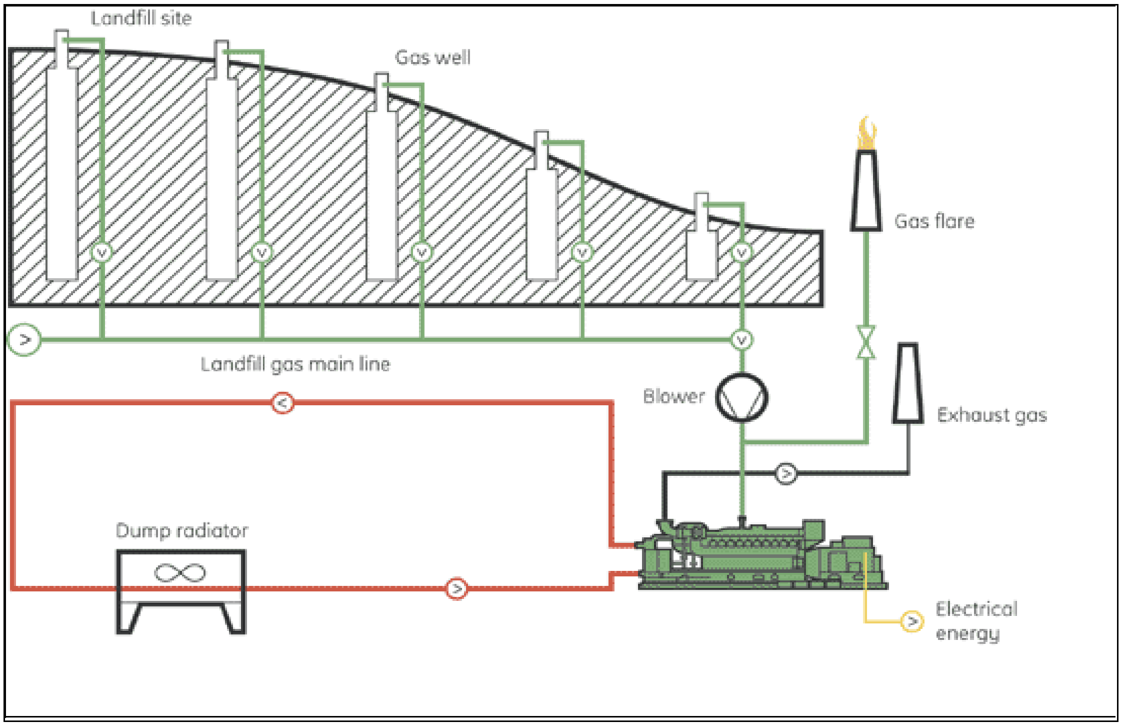

Figure 6 Generic Schematic of a Landfill Gas to Power Project

(Source: GE Jenbacher website (2004))

Gas recovery and conversion investment includes the following equipment:

- gas collection network of vertical and/or horizontal permeable and transport pipes, blowers for suction extraction, leachate removal pumps to clear extraction system;
- gas dewatering, gas scrubber (optional) and storage with pressure modulation, i.e., gas dome;
- gas engines or turbines;
- high temperature LFG flare either as post IC engine or as a stand alone flare;

- electrical transformer and grid connection.

5.2.3 Financial Analysis

Elements of costing were generated through review of estimates produced by SCS Engineers, USEPA and the Energy Information Administration (EIA) all for projects in the USA and quotation and discussion of costs of local implementation and equipment supply with local waste-to-energy consultants.

Costing in general was based on the 1 MW electrical generation module as all sources recorded data for this configuration and economies of scale were not predicted to be significant over the project range evaluated.

Costing was assumed to be linear for equipment purchase required for gas collection while modular 1 MW generator engines were used to fulfill requirements for IC engine generator sets. Locally obtained quotations for biogas generator sets were significantly lower than the cost of higher end systems typically quoted in North America and through the same companies' distributors overseas. The technology for biogas power generation has been addressed in recent years by a larger number of suppliers supporting lower generator equipment cost. Engineering, planning, operation and maintenance were related to equipment capital cost. Relevant economic assumptions are described in Table 44 below.

Table 44 Assumptions for 150 mT/day Landfill Example

Operating Assumptions	
Waste in Place (mT)	0. 548 million
Collection Efficiency (%)	50
Sustainable LFG for power (m^3/hr)	681
LFG calculation method	First Order Decay model
Electric Output Calculation	kW-hr = m^3 x kJ/m^3 / kJ/kW-hr
Electric Heat Rate of LFG (BTU / kW-hr)	10,800
Heating Value of LFG (kJ/kg)	26,163
Annual Capacity Factor (%)	80
Annual full Load Operating Hours (hr)	7708
Capital Cost Assumptions	
Energy conversion system cost includes IC engine/generator, auxilliary equipment, interconnections, blower and construction costs (where energy conversion is applied).	

A 1 MW system capital cost of RM2,593,000 was applied. An additional charge of RM1,000,000 is applied to estimate a 1 kilometer grid connection cost.	
LFG collection system includes collection wells and blower and flare system. A 1 MW system capital cost of RM1,140,000 was applied.	
Engineering and Planning were fixed cost averages of reviewed costing (to include legal, insurance, etc.). Engineering was scaled to plant size while planning was held as a constant across the cases studied. Engineering for a 1 MW project was estimated as RM473,000, while planning was estimated at RM114,000. Contingency was applied as 10% of Capex minus planning. Maintenance estimate was 10% of capex minus planning and engineering. Manpower was calculated from a staff estimate with a rising pay scale towards larger projects.	
Cost of Electricity	
Electricity Sales Tariff	RM 0.167 / kW-hr
Project life	10 years
Interest on debt	7 %
CDM Revenue	
CER price	USD 5.00 / tonne
CDM Transaction Costs	15% of CDM revenue

Financial model

Results of financial modelling, recorded in spreadsheet format for the major cases in Appendix N, are reported in Table 45 below.

The results indicate that CDM can bring about a required 15% return in all cases except for 150 mT/day providing 1 MW power generation and, 25 mT/day as a flaring option. These cases achieved a project IRR of 13.2% and 9.4% respectively. Without CDM incentive, the projects would all be considered not feasible. In the case of power generation projects studied, CDM might improve the financial performance even further if recovered gas surplus to that consumed in electrical generation were flared with credit obtained from the flared gas. The average flared gas quantum over 10 years is estimated to be about 7% of the gas consumed by the generator set.

Table 45 Results of Financial Impacts of CDM on Landfill Gas Projects of Various Sizes

Project (mT/d MSW to landfill)	Output	Capex, (RM)	Opex, (RM)	Lifetime, (yrs)	Methane in Power / Flare, (mT/yr)	CDM Credit Value, (RM)	Electrical Power Value, (RM)	Return on Equity with-out CDM, (%)[a]	Return on Equity with CDM, (%)[a]	IRR with-out CDM, (%)	IRR with CDM, (%)	CDM Price to Achieve IRR = 15%, (USD)
25	Flare	689,700	135,267	10	716	285,684	N/A	N/A	N/A	N/A	9.4%	5.69
50	Flare	1,316,700	168,267	10	1432	571,368	N/A	N/A	N/A	N/A	22.9%	4.2
100	Flare	1379400	234,267	10	2864	1,142,736	N/A	N/A	N/A	N/A	39.4%	3.05
150	1 MW	5,840,930	529,430	10	1525	608,295	1,170,336	N/A	22.4%	1.6%	13.2%	4.35
300	2 MW	10,357,860	982,960	10	3049	1,216,591	2,340,672	**N/A**	**31.4%**	**4.8%**	**16.8%**	2.75
400	3 MW	14,874,790	1,443,090	10	4574	1,824,886	3,511,008	**2.2%**	**34.6%**	**5.9%**	**18.1%**	2.23

Note: Interest Rate of 7% on debt financing of 70% of Capex applied

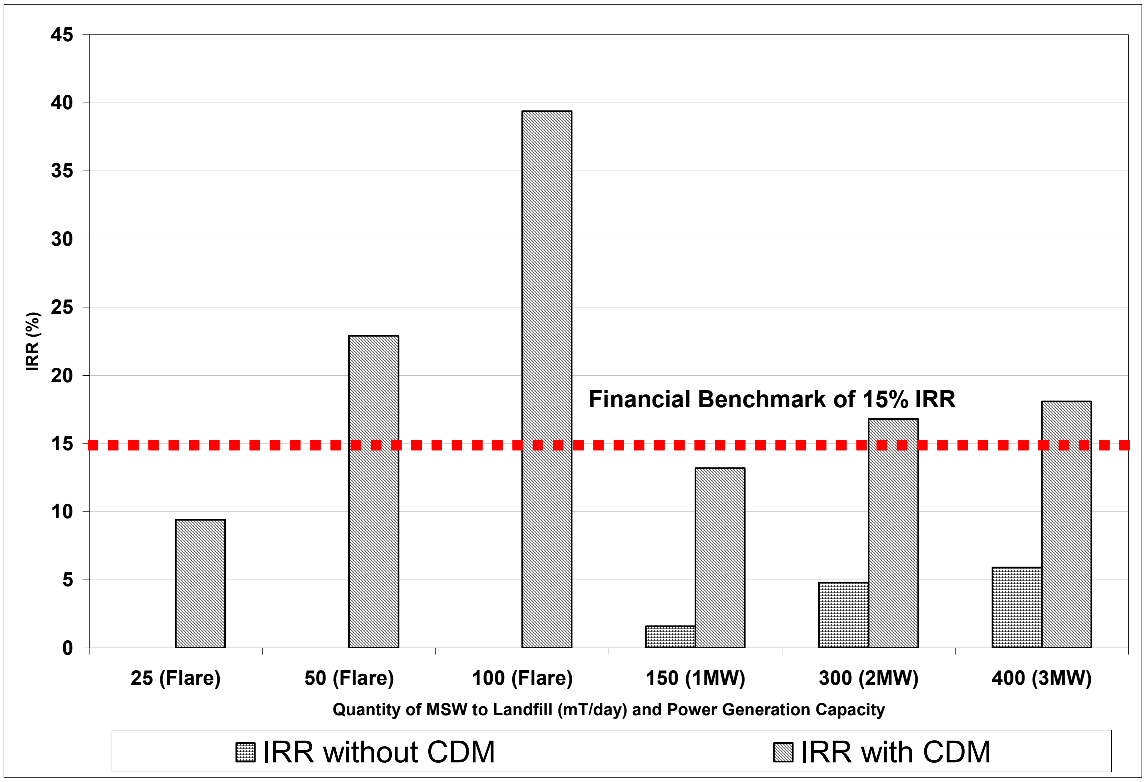

Figure 7 Financial Models for Landfill Gas Recovery Projects (Flaring and Power Generation)

Flaring

Table 37 showed 49, 42, 3 and 4 open landfills as the National, Peninsular Malaysia, Sabah and, Sarawak totals respectively in the size class of 25 to 150 mT/day. An average of the methane conversion from 25 to 150 mT/day is estimated using the data presented in Table 45. An average landfill of 62.5 mT/day in this category is calculated to generate 4442.5 mT/day of methane. 50% of that amount is assumed to be collectable. This number is used to calculate an average of 2,2,221 mT of methane conversion avoidance per landfill per year, whereby a total avoidance potential of 108,829 mT/year of methane results. The figure translates to 2,285,409 mT/year of CO_2 emission reduction. Table 46 provides a regional estimate of distribution of this CER. Again, these estimates are for the portion of landfills assumed to be currently open.

Table 46 Regional Distribution of Flare-only Potential Projects

Result	Peninsular Malaysia	Sabah	Sarawak
Nos of flare-only landfill option	42	3	4
mT/yr Methane avoidance	93,282	6,663	8,884
mT/yr CO_2 avoidance	1,958,922	139,923	186,564

Recovery and Energy Generation

The energy generation methane reductions do not include additional flaring that could be carried out in conjunction with energy generation. The prospective numbers of 150, 300 and 400 mT/day open landfills were presented in Table 34. The methane avoidance results were presented in Table 45. Avoidance potentials of 9,150, 21,343 and, 36,592 mT/year of methane resulted for the listed 150, 300 and 400 mT/day landfills respectively. Total methane avoidance if all projects were undertaken would then be 67,085 mT/year. The figure translates to 1,408,785 mT/year of CO_2 emission reduction. Table 47 summarizes the regional distribution of the projects. Again, these estimates are for the portion of landfills assumed to be currently open.

Using Appendix K, a range of power generation potential is predicted and included in Table 47. The range of generation results from changes in model prediction of methane production when model parameters are adjusted.

Table 47 Regional Power Generation Distribution and Potential Installed Capacity

Landfill Scale	Peninsular Malaysia	Sabah	Sarawak	Total
> 400 mT/day	7	0	1	7
3 - 400 mT/day	3	2	2	6
150 - 300 mT/day	6	0	0	6
Low Estimated Power Potential	18	3	4.5	
Modelled	34	4	7	45

Power Potential				
High Estimated Power Potential	78	9	17	

Outside of the gas generation constants used in modelling, effects that would bear most strongly on the electrical generation outputs include:

- increase in collection efficiency;
- ability to provide extra modular generator capacity or to remove it when it is not required.

These two effects could be altered by GoM and private initiatives to develop better local equipment and systems designed to work with the local conditions and, coordinated planning of multiple projects, similar to bundling, under a form of Regional initiative.

5.2.4 Assessment of Additionality

The assessment of additionality using the "Tool for demonstration and assessment of additionality" (Appendix I) was carried out. The assessment steps covers:

- Step 0 - Project starting date;
- Step 1 - Identificiation of alternatives;
- Step 2 - Investment analysis;
- Step 3 - Barrier analysis;
- Step 4 - Common practice analysis.

Step 0 – Project starting date

Based on the information presented earlier, landfill gas recovery project is considered rare (only 1 commercial and 1 pilot projects). Thus, the assumed CDM projects can be regarded as not started.

Step 1 a - Identificiation of Alternatives

As the assessment in this section is based on a generic landfill gas project, it must be noted that the assessment was carried out based on broader context and potential representative conditions. When it comes to assessing additionality for individual projects, the assessment will be very much dependent on case to case situation.

Apart from the landfill gas recovery and utilization projects investigated, the following alternatives were identified:

- No CDM project;
- Recovery and flaring;
- Conversion to Aerobic landfill; and,
- Industrial medium BTU gas or steam energy to industry;

Neither recovery for an electrical generation project nor recovery for flaring is a feasible investment and there is no incentive to carry either project out without CDM.

No return exists for the predictably expensive route of conversion of landfills to aerobic design, hence this option is not feasible.

Local industry is typically capital investment shy and does not have access to ready financing for such a project as capturing medium BTU gas or producing steam with same from a landfill. Infrastructure is unstable and there is no provision for a private pipeline for transmission of either gas or steam from a landfill to even a nearby industry.

The true alternatives are the examined alternatives of LFG recovery (for power generation or flaring-only) with CDM or, no project at all. The projects therefore pass a preliminary screening for additionality.

Step 1 b - Enforcement of laws and regulations

An evaluation of enforcement issues by definition of any legally binding regulation pertaining to the project(s) and alternatives was carried out. As indicated in Section 3, the baseline scenario for landfill gas is based on emissions from typical open dumpsites. Currently, there are no legislations that deal specifically with the design requirement of landfills in Malaysia, including the necessity to recover landfill gas. However, non-legal binding guidelines specifically pertaining to the different sanitary level of the landfill have been developed by the Ministry of Housing and Local Government. Principle development of all new landfill is to achieve higher sanitary level (sanitary level 3-4). However, the highest level (sanitary level 4) only requires leachate treatment and gas venting but not gas recovery and/or utilisation. Thus landfill gas recovery projects as CDM projects can be considered additional from the regulatory standpoint.

Step 2 – Investment Analysis

The financial analysis demonstrated that an effective economic / financial benchmark cannot be met without CDM incentive. CDM will alleviate the financial constraint and extract the following benefits and incentives:

- Anthropogenic GHG emission reduction;
- Revenue to the developing nation in sellilng CERs
- Encouragement of competitive technology providers, foreign and local to enter the scene;
- Reduction of inflation / exchange risk improving attractiveness for investors;
- Establishment of a financial record for such activity as a precedent to future investments;
- Provision of a tropical climate case history of an implemented project together with its incrementally increasing monitoring database thus improving technical and scientific knowledge in the field;
- Improvement of landfill management and by extension creating a management precedent.

As the assessment clearly passed step 2, the analysis continues to Step 4.

Step 4 - Common Practices

Landfill gas recovery and utilization is definitely not common as indicated in Section 3. Apart from the 2 existing projects (of around 190 total landfills in the country) at Air Hitam, Puchong and Larkin in Johor, there are merely a few such as the Krubong in Melaka in the proposal stages. Thus, CDM projects on landfill gas recovery can be considered additional under the common practice assessment.

Step 5 - Impact of CDM Registration

The economic feasibility of landfill gas projects is reported to be in general not feasible or marginally feasible with subsidies. This is mainly due to the high cost of technology involved such as the gas engines where elements of foreign technology are required. The economic assessment of the landfill gas recovery project proposed at Krubong Landfill, Melaka indicated a negative project internal rate of return (IRR)[66].

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[66] Kajima Corporation and Yachiyo Engineering Co. Ltd. (2004). *Project design document for Krubong Melaka LFG collection and energy recovery CDM project*, July 2004.

Another assessment[67] carried out at the Kayu Madang landfill in Sabah indicated that the economic feasibility of a landfill gas recovery and utilization project will be feasible especially with heat recovery. However, the use of heat (steam) at and around landfills is not very likely to be applicable in general in Malaysia. Thus, when it comes to assessing investment and technical barriers, the role of CDM financing is interesting to enhance the "bankability" of such project. The financial model employed utilizes a 7% interest rate on borrowed funds and examines IRR for the various project cases selected against a desired IRR of 15% both with and without CDM financing. Return on equity is also examined. As strongly evidenced in Table 45, the projects are viable only with CDM financing but, at reasonable CER rates and inclusive of transaction costs in adminstration of CDM funding. Thus, the primary hurdle to the projects being considered additional is overcome as the impact of CDM is positive and necessary to implementation.

In conclusion, the projects are able to pass the additionality assessment proposed within the boundaries and parameters outlined.

5.3 POME Biogas to Energy

5.3.1 Description of Generic Cases

Inevitably, deriving a generic project that can be used to represent a typical crude palm oil mills in Malaysia is not an easy task since individual mills differ in sizes, operations, geographical distributions etc.

However, for this section, a generic case is required for detail analysis. Assumptions and derivation of figures for this generic project is derived based on Section 4.3.3 earlier. The following summarises the key description of the project:

Production of the Mill

- Average production capacity = 200,000 mT FFB / yr [68];
- Average FFB processing capacity = 43 mT / per hour[69];

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[67] DBKK/DANIDA. (2001). *Economic assessment for utilisation of landfill gas at the Kayu Madang Landfill*. Sustainable Urban Development Project Sabah.

[68] This figure is defined according to the CDM Threshold predefine in Chapter 4 above and it is agreeable with the average palm oil mill processing capacity of 205,000 FFB per year throughout Malaysia

[69] Using a mill operation of 4700 hours per year, derived from information published by MPOB, 2003

- Average POME generation = 120,000 ton/yr or 26 mT/hr[70].

POME & Biogas Generation

- Average digestion temperature = 55 °C
- (Thermophilic condition as studied by Yeoh (2004)[71] which can yield more biogas in shorter time and lower H_2S content thus can minimise the scrubbing process[72]);
- Average biogas production of 28 m^3 per m^3 of POME;
- Average biogas yield per year = 3,360,000 m^3;
- Methane generation from POME = 2,000,000 m^3/yr or 1,440 ton/yr;
- Heating Value of biogas[73] = 23.9 MJ/m^3;
- Average mT CO_2 reduction = 30,200 mT / year.

Power and Heat Demand of the Mill

- According to PTM[74], power consumption of the mill size of 40 ton FFB/hr will be 16 -17 kWh/ton FFB. However, another source[75] estimates an average 25 kWh power required every mT of FFB processed. As this figure includes other usage such as mill lighting, etc. therefore it was adopted for this study. Thus, for the generic project, a total power requirement of 5 million kWh per year is required for this generic project and this corresponds to a power generation capacity of approximately 720 kW[76];

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[70] Based on 60% weight of FFB processed ends up as POME.

[71] Yeoh B.G. (2004). A Technical and Economic Analysis of Heat and Power Generation from Biomethanation of Palm Oil Mill Effluent.

[72] PTM (2000). Feasibility Study on Grid Connected Power Generation Using Biomass Cogeneration Technology.

[73] Derived from Methane's heating value of 55.4 GJ/ ton and methane density at 0.72 kg/m^3.

[74] Malaysia Energy Centre (PTM). (2000). Feasibility study on grid connected power generation using biomass cogeneration technology.

[75] Wambeck, Noel. Oil palm process synopsis: Volume I – Oil palm mill, systems and process. (Unpublished).

[76] Based on power generating capacity factor of 80% i.e. 7008 hours per year.

- Heat is required in the form of steam and hot water palm oil mill. The steam is mainly used for sterilisation process and process heating. Estimation of 615[77] to 660 kg[78] steam required to process every mT of FFB. In this study, a higher estimate of 660 kg is used. The annual heating demand will be approximately 3.4 million kWh or equivalent to 4 million Litre of diesel[79] fuel by assuming the boilers' efficiency at 85%.

Table 48 Summary of Generic Case Description

Description	Amount
Total Power plant operation[80] (hr/yr)	7008
Average FFB input (mT/hr)	43
Annual capacity (ton FFB/yr)	200,000
Daily POME generation[81] (mT/d)	345
Total POME generation (mT/yr)	120,000
Average Biogas Yield (m^3/yr)	3,360,000
CH_4 generation (m^3/yr) (mT/yr)	 2,000,000 1,440
CO_2 equivalent reduction (mT/yr)	30,200
Yearly power demand (kWh)	5 milion
Yearly diesel required for steam generation (L/yr)	4 million

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[77] Environmental Management Guideline for the Palm Oil Industry, Thailand (1997).

[78] Wambeck, Noel. (1999). Oil palm process synopsis: Volume I – Oil palm mill, systems and process. (Unpublished).

[79] According to Yeoh, B.G. (2004), heating value of diesel is 34.5 MJ/L.

[80] 80% plant capacity as assumed by IRP study.

[81] Base on mill operation of 350 days and 4700 hours per year, hence daily operation of about 13.5 hours.

5.3.2 Comparison of Technical Options

As summarized in Section 4.3.3.2, three generic CDM projects types have been identified for POME biogas. These include capturing and flaring, capturing for heat generation and capturing for heat and power generation. Among these, the later two are more technically sound as the waste (biogas) are utilized and converted into energy. At the same time this can help to achieve the target of Malaysia Fifth Fuel Policy where biogas from waste is used as fuel to produce renewable energy as well as UNFCCC and Kyoto Protocol which emphasis on the GHG reduction.

In this section, further discussion on the technical and financial aspects will be concentrated on the latter two options which are biogas from POME for heat generation and biogas for both heat and power generation. For heat generation only option, steam boiler was the technology analysed and both gas turbine and gas engine were compared for the co-generation and power only options. Heat generation is interesting for the palm oil mills since there is internal demand for steam in the process.

5.3.2.1 Grid Connection: Biogas Vs Biomass

When it comes to power production and demand, two alternative scenarios (off-grid system and grid connected system) were analysed. This is due to the fact that some of the mills are accessible to nearby grid (mostly in Peninsula) where excess power generated can be sold while some mills that are located relatively far away from nearest grid connection (mostly those in East Malaysia) where grid connection is hardly feasible. The interest in grid connection also owes to the fact that most mills today already utilises biomass generated from process for meeting both internal power and heat demand and therefore excess power will be available for sale.

As discussed in section 4.3.3.3, most of the biomass plants were reported to be inefficient and polluting. Therefore, there exist potential of substituting these plants with biogas systems whereby the biomass can be utilised for other purposes e.g. palm oil kernel for animal feed, processed further and transported as other fuel sources. With this substitution, there will be an improvement to local environment with the reduction of odour from POME ponds while the air pollution from inefficient boilers is also avoided.

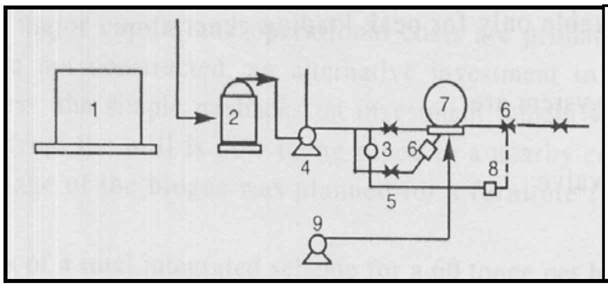
In the case for grid-connected mills where biomass to energy is desired, excess power can be sold to grid with modernisation of biomass power plants. Modern cogen biomass plants are far more efficient and an integrated waste to energy system can be established where CDM will apply to both POME and biomass.

5.3.2.2 Steam Boilers (Heat Generation)

Biogas produced from the anaerobic digester can be piped and combusted directly to produce heat. In this case, biogas can act as substitute to diesel, where 1.54 m^3 of biogas can replace 1 L of diesel. The efficiency of energy conversion is depending on the types of boiler used and is normally high at 80-90%[82].

The main components for heat generation by biogas system are anaerobic digester, biogas storage tank, biogas boiler, and some other facilities (valve, switch, fan, air blower and such). A schematic diagram of biogas utilization for heat generation using boiler is shown in Figure 8.

The advantages of this heat generation are the lower installation cost yet high efficiency. However, the heat produced from burning of biomass (EFB, Palm kernel, etc) can basically sustaining the heat requirement for palm oil mill. Therefore the extra heat generation from the biogas is not necessary unless there are other factories situated near by which need biogas for burning and heating.



1. Anaerobic digester
2. Biogas holder
3. Pressure switch
4. Booster fan
5. Solenoild valve
6. Pilot
7. Boiler
8. Alarm
9. Combustion air blower

Figure 8 Schematic Diagram of Heat Generation by Burning Biogas in Boiler

(Source: PTM (2000). Feasibility study on grid connected power generation using biomass cogeneration technology)

5.3.2.3 Gas Engine

5.3.2.4 Power Generation

Beside heat generation with boilers, other option of biogas utilization is to generate power. By installing a gas engine system, electric can be produced from biogas as direct fuel. Electric is the main product for gas engine system. The electric efficiency of gas engine that only produces electric without heat is high at about 40%. The advantage of power generation over heat generation is that the electric produced can support the power demand of the mill so that purchasing of electric can be minimised. The main components are anaerobic digester, scrubber/gas treatment facility, and gas

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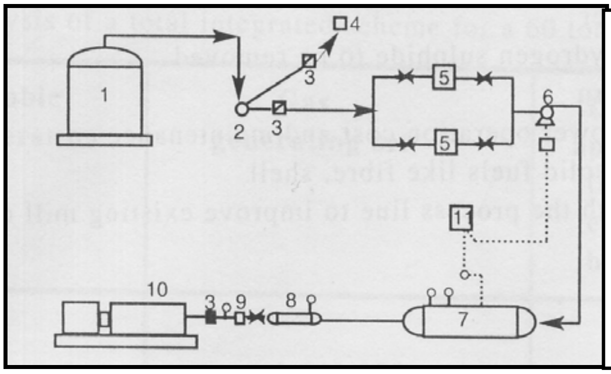
[82] Pusat Tenaga Malaysia (2000). Feasibility Study on Grid Connected Power Generation Using Biomass Cogeneration Technology.

engine, as shown in Figure below. Operation of gas engine system is reliable under regular maintenance schedule.

Heat and Power Co-Generation

Heat can be recovered from the high temperature exhaust gas yield from gas engine by installing some necessary facilities including heat exchanger system. By making such modification, gas engine can provide co-generation of power and heat. The basic of gas engine cogeneration is similar to power generation. However, the efficiencies[83] of power generation decrease to about 26-36 % but the overall efficiencies are still high at 76-86%.



1. Anaerobic digester
2. moisture remover
3. Flame arrester
4. Waste gas boiler
5. H_2S scrubber
6. Biogas compressor
7. Biogas storage
8. Biogas receiver
9. Line regulator
10. Electricity generating set
11. Switch board
12. Pressure switch

Figure 9 Schematic of Biogas Engine Electricity Generation System

(Source: PTM (2000). Feasibility study on grid connected power generation using biomass cogeneration technology)

5.3.2.5 Gas Turbine (Heat and Power Co-Generation)

Another option for utilising biogas is cogeneration which can product combination of heat and electric. In our study, cogeneration of heat and power using gas turbine would be adopted as the technology is more locally available. The main components of a cogen system using gas turbine are gas compressor, pressure vessel, waste heat boiler, gas damper and miscellaneous as shown in Figure below. Biogas is combusted in a pressurised combustion chamber using combustion air supplied by compressor. The gases produced will rotate a turbine to generate electricity. The hot exhaust gases escaping from turbine are tapped to waste gas boiler for heat recovery. The efficiency[84] of overall cogen plant is 74-81% and the efficiency for electrical conversion is 24-31%.

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[83] Mathias, A.J. (2004). Presentation slides: Overview of cogeneration technologies and applications. Presented in *2004 Cogeneration Week in the Philippines*.

[84] Mathias, A.J. (2004). Presentation slides: Overview of cogeneration technologies and applications. Presented in *2004 Cogeneration Week in the Philippines*.

The efficiency can be increased to 85% by using high efficiency components. It is efficient in heat and power recovery for palm oil mill.

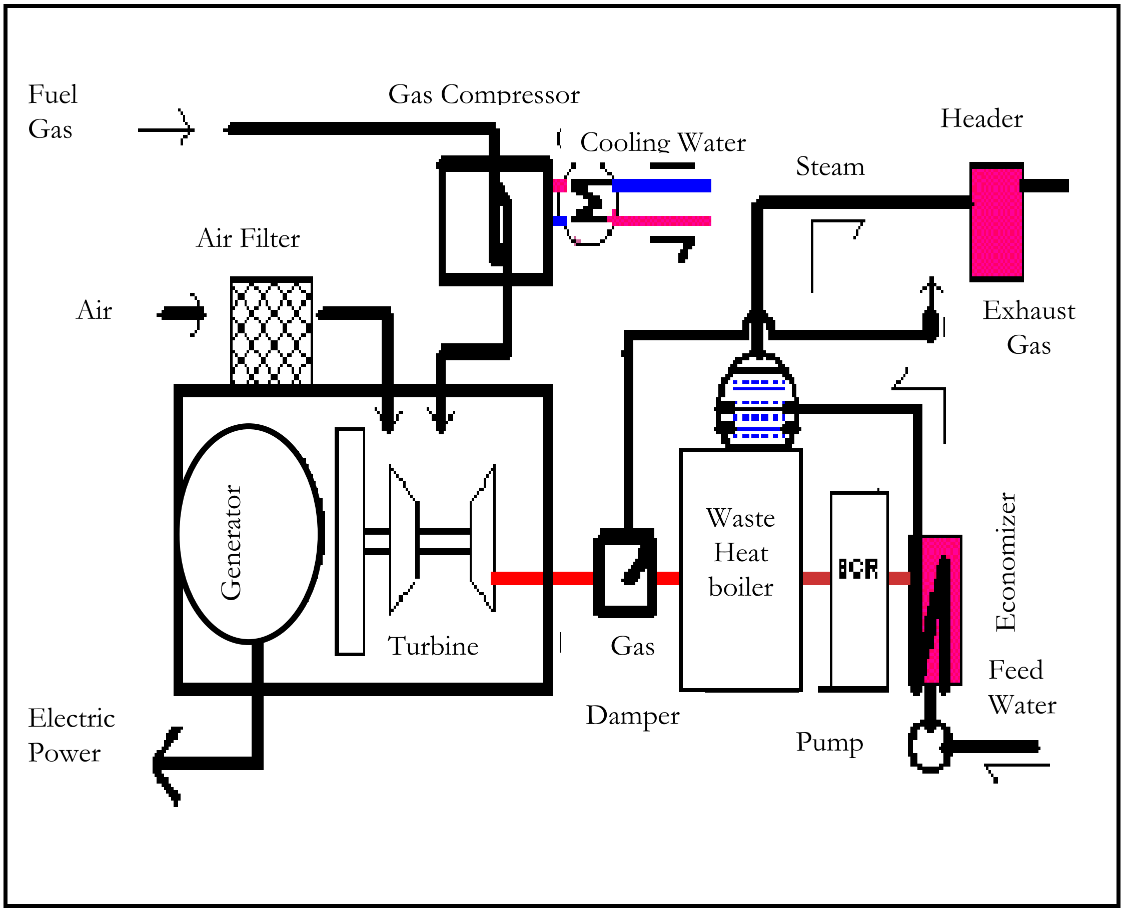

Figure 10 Schematic Diagram of Gas Turbine Cogeneration System

(Source: Euro-power website)

5.3.3 Description for Technical Options

Some of the real cases and previous studies for the technology for biogas recovery from POME are reviewed. The specification and financial costing of those technologies are summarised in Table 49 below as reference to our study:

Table 49 Selected Projects and Their Financial Costing for the Cacilities Installed

Specification	**Keck Seng's[85] (only heat generation)**	**Tennamaram/ Sime Darby Plantation (Heat and Power)**	**Yeoh (2004)[86] (only power generation)**	**PTM[87] / (Soeren/Bjoern's) (only power generation)**
Operation				
Mill Operation	24hr/d 300 d/yr 7,200 hrs/yr		350 hr/mth	4,416 hr/yr
FFB input	30 ton/hr	90 ton/hr	45 ton/hr 189,000 ton/yr	60 ton/yr
POME generation	400 m^3/d	150,000 ton/yr	240-450 m^3/d	32.5 ton/hr 143,520 ton/yr
Biogas Generation	3.36 $x10^6$ m^3/yr[88]	4.2 x 10^6 m^3/yr	3.94 $x10^6$ m^3/yr	4,8018,560 m^3/yr
CH_4 generation	2,072,000		2.56 $x10^6$	2,612,064 m^3/yr[90]

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[85] Keck Seng (M) Berhad Intergrated Palm Oil Processing Complex – Maximising Renewable Energy Sources, Highlighting Biogas.

[86] Yeoh, B.G. (2004). A Technical and Economic Analysis of Heat and Power Generation from Biomethanation of Palm Oil Mill Effluent.

[87] Varming, S. (2004). CDM Potential in the Energy Sector. PTM. Final Workshop on 15 January 2004.

[88] Biogas production at 11,200 m^3/d and mill operation at approximately 300 day/year.

Specification	**Keck Seng's[85]** **(only heat generation)**	**Tennamaram/** **Sime Darby Plantation** **(Heat and Power)**	**Yeoh (2004)[86]** **(only power generation)**	**PTM[87] / (Soeren/Bjoern's)** **(only power generation)**
	m^3/yr 1,407 mT/yr		m^3/yr[89]	1854 ton/yr
CH_4 Heat Value			22.4 MJ/m^3 (Biogas)	55.4 x 10^3 MJ/ton @ 102,711,600 MJ/yr
Energy Generation				
Power Capacity	No power generation by biogas	250 kW (use only 20% of biogas)	950 kW	2 x 1065 kW elec.
Power generation	No power generation by biogas	1.44 x 10^6 kWh	7.88 x 10^6 kWh/yr (8300 Operation hrs)	41,084,640 MJ/yr @ 11,421,529 kWh/yr[91]
Efficiency	Boiler efficiency[92]: 83%	Gas engine: 28-36% Boiler:80-90%		Gas Engine: 40%
Heat	Steam:	Estimated[93]:	If all the biogas	no heat recovery

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[89] Base on mean methane content of 65% in the biogas produced

[90] Base on 65% methane of biogas produced.

[91] conversion coefficient = 0.278 kWh/MJ

[92] PTM (2000). Feasibility study on grid connected power generation using biomass cogeneration technology.

[93] Based on 2.78 x 10^6 m^3/yr of biogas as boiler fuel, 85% (average) boiler efficiency and 23.9 MJ/m^3 heating value of biogas derived previously.

Specification	**Keck Seng's[85] (only heat generation)**	**Tennamaram/ Sime Darby Plantation (Heat and Power)**	**Yeoh (2004)[86] (only power generation)**	**PTM[87] / (Soeren/Bjoern's) (only power generation)**
Generation	1) 33.6 M kcal/d. 70 bar, 320 °C 2) 30 MT/d, 10 bar, 180 °C	5.6 x 10^7 MJ/yr	is burnt for heat[94]: 8.8 x 10^7 MJ/yr	
Capital Cost	Anaerobic digester (7500m3, Constructed in 1984) = RM 1.6 mil Biogas boilers: Geka Boilers (2 unit, 1985) = RM 360,000 Mechmar Boiler (1 unit, 1979)	Anaerobic digester (Constructed in 1984) = RM 1,401,000 Biogas boilers: = RM 300,000 Gas engine = RM 584,000	Anaerobic digester = RM 977,094 Biogas storage system = RM 809,552 If gas-engine to be installed: 950 kW gas engine = RM 3.61 mil	Anaerobic digester system = RM 2.2 mil (maintenance cost 3%) Gas treatment facility = RM 304,000 (maintenance cost 5%) Jenbacher Gas engine x 2 = RM 2.3 mil x 2

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[94] Biogas Heating Value = 22.4 MJm^{-3} is used by Yeoh.

[95] This price is rather low, some how the inflation rate has no been accounted into.

Specification	**Keck Seng's[85] (only heat generation)**	**Tennamaram/ Sime Darby Plantation (Heat and Power)**	**Yeoh (2004)[86] (only power generation)**	**PTM[87] / (Soeren/Bjoern's) (only power generation)**
	1979) = RM 200,000 **Total[95]:** **RM 2.1 mil**	**Total:** **RM 2.28 mil**	**Total:** **RM 4.62** **(heat only)** **RM 5.43 mil (electric)**	Installation & operation cost = RM 92500 (2% of gas engine) **Total:** **RM 7.2 mil**
O & M Cost	Anaerobic digester = RM 50,000 Biogas boilers: Geka Boilers (2 unit, 1985) = RM 10,000 Mechmar Boiler (1 unit, 1979) = RM 10,000 **Total[96]:** **RM 70,000/yr**	Anaerobic digester = RM 51,000 Biogas boilers: = RM 47,990 Gas engine = RM 24,094 **Total:** **RM 123,084/yr**	Anaerobic treatment = RM 20,660 Biogas handling = RM 16,340 Electricity generation = RM 66,450 **Total:** **RM 37,000/yr (heat only)**	Anaerobic treatment digester system = RM 64980 Gas treatment facility = RM 15,200 Jenbacher Gas engine = RM 138,624 **Total:** **RM 218,804/yr**

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[96] The maintenance cost is estimated at 3 % of instrument cost as suggested by Yeoh (2004).

Specification	Keck Seng's[85] (only heat generation)	Tennamaram/ Sime Darby Plantation (Heat and Power)	Yeoh (2004)[86] (only power generation)	PTM[87] / (Soeren/Bjoern's) (only power generation)
			RM 103,450/yr (electric)	

In order to study the feasibility of heat, power as well as power and heat recovery for POME biogas, four types of technology as mentioned in above section (technical description) are proposed. These are heat generation using boilers, electric generation using gas engine and heat and electric cogeneration using gas engine and gas turbine. Gas engine is chosen for electric generation due to its higher efficiency in power generation yet available in small capacity size that accommodates generic base case's biogas production, gas turbine and steam turbine are not efficient for electricity generation alone in small scale[97]. However, gas turbine is very effective in heat recovery and some portion of electric generation as bonus. Therefore for cogeneration, gas turbine and gas engine are chosen for comparison. Steam turbines are normally found at larger size which is above 10 MW[98] are not suitable for this small scale biogas plant.

The main components for each option in biogas recovery and utilization are listed below:

5.3.3.1 Biogas Production and Handling

The biogas production and handling are general components for all the technology options (heat, power, heat and power), therefore it is reasonable to assume that all the technology options install the same equipment.

The main component for biogas production is anaerobic digester. The biogas produced is stored in biogas storage system which comprise of pressurised storage vessels, scrubbers, compressors, piping and housing.

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[97] Personal communication with Sesco's senior manager.

[98] Mathias, A.J. (2004). Overview of cogeneration technologies and applications. 2004 Cogeneration Week in the Philippines.

The designation size for anaerobic digester is about 6,500 m^3 to cope with POME production of 400 m^3 per day and 18 retention days for the digestion.

The size of biogas storage system should be able to accommodate the annual biogas production of 3,360,000 m^3.

5.3.3.2 Heat Generation Option

The main component of the heat generation option is basically the boilers which are used to burn the biogas and produce steam for processes in the mill. The thermal efficiency of boilers is assumed at 85%.

The total boilers' capacity estimated

= (annual biogas heating energy x Thermal efficiency) ÷ Mill operating hour per year

= (8×10^7 MJ x 0.278 kWh/MJ x 0.85) ÷ 4700

≈ **4 MW**

5.3.3.3 Power Generation Option

The main components installed for power generation using gas engine plant are gas treatment facility and gas engine generator. The gas treatment facility is used to scrub the H_2S from the biogas before combusting in the gas engine generator to prevent the corrosive H_2S from eroding gas engine. The power efficiency of gas engine used is assumed as 40%.

The estimated power for gas engine

= (annual biogas heating energy x power efficiency) ÷ power plant operation hour per year[99]

= (8×10^7 MJ x 0.278 kWh/MJ x 0.40) ÷ 7008

≈ **1.27 MW**

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[99] Assume at 80% plant capacity which is 7008 per year.

5.3.3.4 Heat and Power Co-generation Options

Gas Engine Co-generation

Gas engine co-generation plant is basically modified from gas engine plant by installing heat exchanger as waste heat recovery system. Heat is recovered from the hot exhaust gas. The power efficiency of gas engine cogen is assumed as 30% which is lower than gas engine plant that only generates power. However, the overall plant efficiency (including thermal efficiency) is 80%

The estimated power for gas engine

= (annual biogas heating energy x power efficiency) ÷ power plant operation hour per year[100]

= (8 x 10^7 MJ x 0.278 kWh/MJ x 0.30) ÷ 7008

≈ **950 kW**

Gas Turbine Co-generation

Gas turbine co-generation plant normally incorporates with gas compressor, pressure vessel, waste heat boiler, gas damper and miscellaneous. The waste heat boiler recovers heat while the rotation of turbine turns the generator to product electric. In this study, the overall cogen efficiency is assumed as 78% while the thermal efficiency and power efficiency at 54% and 24% respectively.

The estimated power for gas turbine

= (annual biogas heating energy x power efficiency) ÷ power plant operation hour per year[101]

= (8 x 10^7 MJ x 0.278 kWh/MJ x 0.24) ÷ 7008

≈ **760 kW**

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[100] Assume at 80% plant capacity which is 7008 per year.

[101] Assume at 80% plant capacity which is 7008 per year.

5.3.4 Financial Analysis

The price and cost used in this financial analysis are estimated cost derived from all source of information including other cases and studies, formula from other study, product catalogue and such.

5.3.4.1 Capital Cost

Cost for anaerobic digester

Construction cost for anaerobic digester increased with digester volume to power of 0.7 (Yeoh, 2004). Therefore the price for digester is estimate base on the digester price of Keck Seng Sdn Bhd. The recent digester quotation make by Novaviro Technology Sdn Bhd[102] based on Keck Seng plant is RM 2,166,000. This price is much higher than Keck Seng construction cost of RM 1,600,000 in year 1984. However, the quotation price is reasonable due to the inflation. Therefore the cost for generic base case biogas digester will be estimated according to RM 2,166,000 for 7,500 m^3.

Cost for anaerobic digester system = $2{,}166{,}000 \times (6{,}500/7{,}500)^{0.7}$

The anaerobic digester system (6,500 m^3) for generic base case will cost RM 1,960,000.

Cost for Biogas Storage System

In a study done by Yeoh (2004), estimation for the cost of biogas storage system to the biogas yield (m^3/yr) is formulated. A linear regression base on the cost in year 1985 adjusted with inflation rate of 5% yearly is the basic to estimate cost for biogas storage system according to size and year of construction. To get a better estimation for the generic case, modification had been done. The formula below is used to estimate the cost for a biogas storage system in year 2004 (RM):

$$\text{Cost for biogas storage system} = \frac{V}{2.12x10^{6}} x0.22x10^{6} x(1.05)^{19}$$

Where, V = Biogas volume capacity, m^3/yr

Therefore the cost biogas storage system for base case is RM 881,000.

Cost for Boilers

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[102] CDM potential from biogas recovery in the Palm Oil Industry. A working paper of Soeren/Bjoern

The cost for boilers construction for this base case is roughly estimated by adjusting with 5% inflation rate per year to the boilers construction cost of Keck Seng Sdn Bhd at 1984, which handles about the same amount of biogas as fuel. Hence the cost for boilers is estimated at RM 1,587,000.

Cost for Gas Treatment Facility

The gas treatment facility to scrub annual biogas production of 4,018,560 m^3 quoted by Novaviro Technology Sdn Bhd[103] is RM 304,000. Base on the assumption that the cost of facility is linear to the volume of gas treated and the cost of gas treatment facility is estimated according to the ratio of production. Therefore price of gas treatment facility for generic base case is RM 254,000.

Cost for Gas Engine Plant

Various sources of gas engine prices had been studied. Yeoh (2004) estimated USD 250,000 for a unit of 250 kW gas engine generator. Jenbacher gas engine (1065 kW) is claimed as USD 608,000 in the report "CDM Market Study for Malaysia". However, the price quoted by a local supplier is roughly RM 6 mil/ MW for gas engine plant (This is a rough estimation including transportation, taxation and current exchange, etc. which at a higher side). The first two sources are rather low as only the selling prices of gas engine are estimated.

The investment cost for the base case is deriveed according to the price for gas engine plant and power output graph (Figure 11) on Jenbacher's catalogue. This investment cost for a gas engine cogeneration plant accounts in cogeneration modules, electrical equipment, adaptation of the heating system, cooling, ventilation, system control, building, foundation, fuel, and initial operation. However, shipping and transportation as well as taxes and inflation are not considered in the previous estimation. By the assumption of tax exemption for the renewable energy project, and the other costs mentioned above will contribute roughly 20% to the investment cost, the estimated investment cost for the base case will be 1.2 times to the investment cost found from the graph.

---

[103] CDM potential from biogas recovery in the Palm Oil Industry. A working paper of Soeren/Bjoern.

Due to insufficient information, the investment cost of gas engine plant that only generates electric will be assumed as 80% of the cost for gas engine cogen system[104] (where the facilities for heat recovery are unnecessary).

For only electric generation option, the capacity of gas engine required is about 1.27 MW therefore two unit of 625 kW gas engine, as a total of 1.25 MW are to be installed. From the graph, the investment cost for cogen system is USD 1,200 / kW for that capacity range. When account into the 20% reduction for electric generation alone will lead to an installation cost of RM 4,560,000 [105]. By adding surplus of 20% for shipping, transportation and inflation, a total installation cost of RM 5,472,000 is estimated for 2 unit 625 kW gas engine power plant.

By assuming same capacity of gas engines are to be used in the gas engine cogen plant, by adding heat recovery equipment on top of the gas engine power plant, an estimated cost of RM 6,840,000 is to be spent on the gas engine cogen plant.

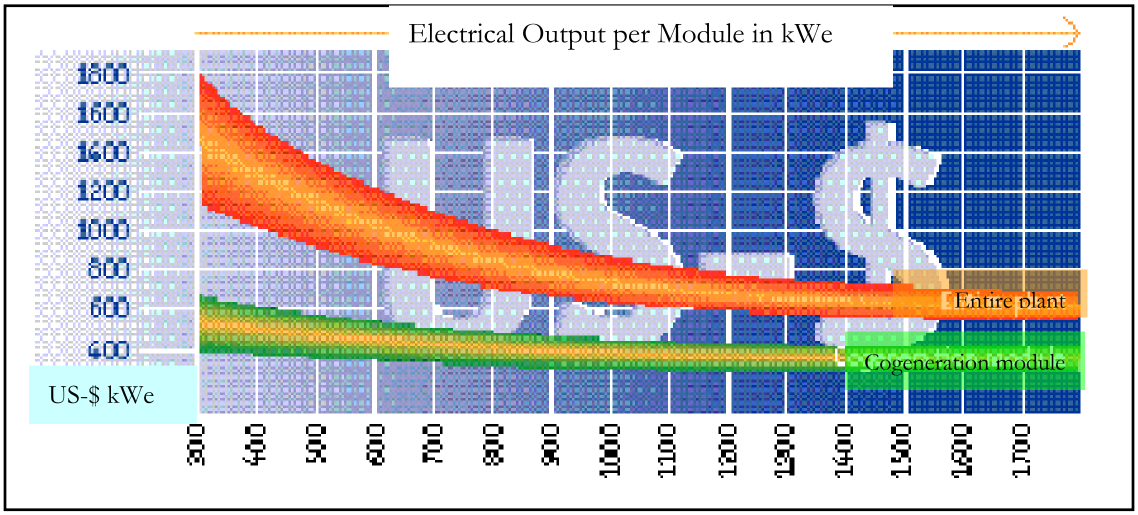

Figure 11 Price for Gas Engine Plant to Power Output

(Source: GE Jenbacher's catalogue, 2001)

Cost for Gas Turbine Cogen Plant

Gas turbine proposed for base case is at power capacity of 1 MW although the power output is only 700 kW as calculated above. This is due to the constraint where the size

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[104] A very rough estimation using the price ratio of 1 unit 1065 kW Jenbacher engine's price (USD 608,000) to the price of the cogen plant with same capacity (USD 852,000).

[105] USD/RM exchange rate is 3.8.

of gas turbine is generally 1 MW and above, therefore bigger size is selected. According to the price provide by PTM (2000), the price for 1 MW gas turbine plant including all other facilities (gas compressor, pressure vessel, waste heat boiler, gas damper and miscellaneous) is RM 7.2 Million in year 1999. As the price is a local price, it is assumed that the shipping and transportation costs is minimized and counted in. By adjusting this price with 5% inflation rate per year, we get a rough estimate of RM 9 million for the installation of gas turbine cogeneration plant.

5.3.4.2 Maintenance and Operational Cost

The maintenance and operational costs are roughly estimated according to Yeoh (2004), CDM Potential Working Paper of Soeren/Bjoern and the cost analysis of Keck Seng and Tennamaram SDP plants. The maintenance and operation cost for anaerobic digester, biogas storage system, boilers and power plants (including gas engine plants and gas turbine plant) are assumed as 3%. Where else the cost to maintain and operate gas treatment facility is assumed as 5%.

If grid connection is to be installed, the connection cost is estimated as RM 1.5 million[106]. The maintanence cost for grid connection is basically nil as the management of grid will be maintained by TNB.

The costing of the options suggested in this study is summarised in table below.

The assumptions for financial analysis are as below:

Table 50 Assumption for Financial Analysis

Description	Assumption
Electricity Sales Tariff	RM0.167 / kW-hr
Cost for grid connection	RM1.5 million
Fuel substitution cost[107] (if the electric is for self consumption)	RM0.163 / kW-hr

---

[106] The cost for grid connection is depending on the distance. It is assumed as within 2 km for this study (Adopted from Kamarulazizi Ibrahim, Lalchand, C., Mohamad Adan Yusof & Iskandar Majidi, M. (2002). *Renewable energy a private sector initiative a fruitful business for a bright future.* Centre for Education and Training in Renewable Energy and Energy Efficiency).

[107] These costs are including capital investment cost, fuel and maintenance cost. By assuming 80% of biomass power (RM 0.126/kWh) and 20% of diesel power (RM 0.311/kWh). Adopt from Kamarulazizi Ibrahim, Lalchand, C., Mohamad Adan Yusof & Iskandar Majidi, M. (2002).

Project life	21 years
Interest on debt	7%
CER price	USD 5.00 / tonne
CDM Transaction Costs	15% of CDM revenue

The financial analysis for different technology options are done using excel spreadsheets. The results are attached in Appendix P,

Appendix Q, Appendix R and Appendix S which are summarised in Table 51 and Table 52 below:

Table 51 Summary of Financial Analysis (Off-grid)

Technology Option	**Capital cost (RM)**	**O & M cost (RM)**	**IRR without CDM (%)**	**IRR with CDM (%)**	**IRR Improvement with CDM (%)**	**ROE without CDM (%)**	**ROE with CDM (%)**	**ROE Improvement with CDM (%)**
Power and Heat Generation (Gas Turbine)	11,841,000	355,230/yr	7.0	12.6	5.6	6.6	16.5	9.9
Power and Heat Generation (Gas Engine)	9,935,000	303,130/yr	**13.2**	**18.7**	5.5	17.3	29.1	11.8
Power Generation (Gas	8,567,000	262,090/yr	**9.2**	**16.0**	6.8	10.3	23.8	13.5

Renewable energy a private sector initiative a fruitful business for a bright future. Centre for Education and Training in Renewable Energy and Energy Efficiency.

Engine)								
Heat Generation (Steam Boilers)	4,428,000	132,840/yr	20.4	30.9	10.5	34.3	61.2	26.9

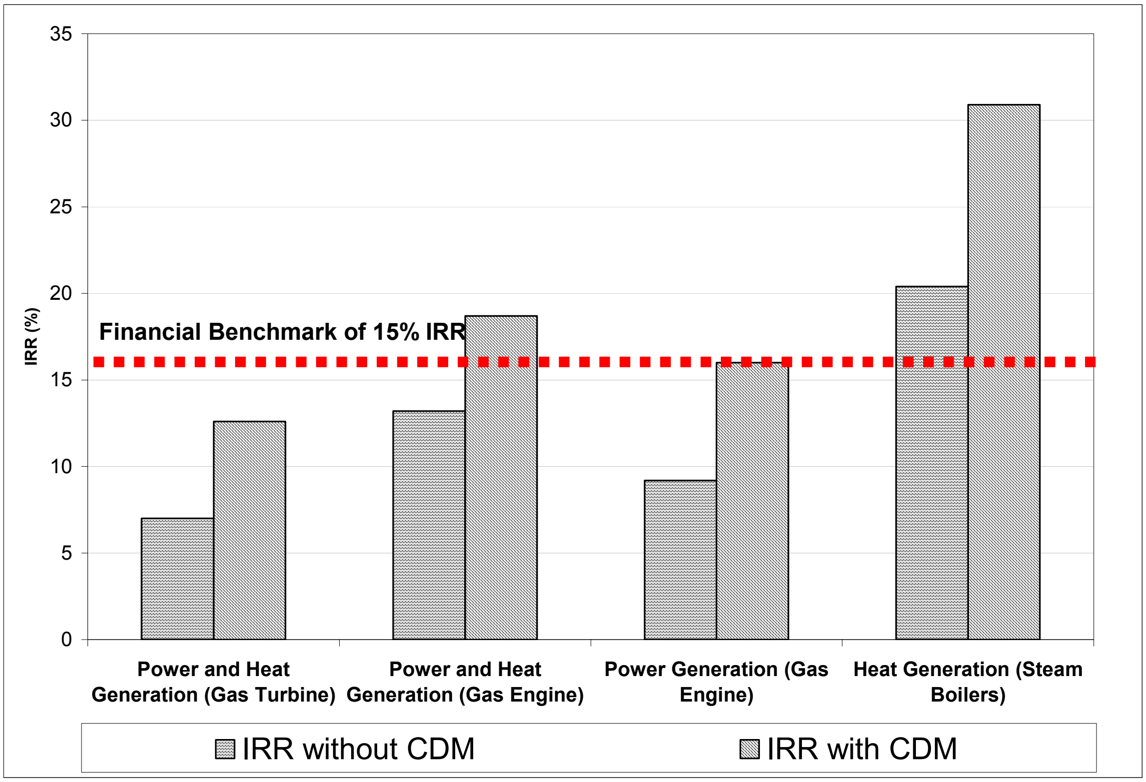

Figure 12 Financial Options for Off-Grid Case

Table 52 Summary of Financial Analysis (Grid-Connected)

Technology Option	Capital cost (RM)	O & M cost (RM)	IRR without CDM (%)	IRR with CDM (%)	IRR Improvement with CDM (%)	ROE without CDM (%)	ROE with CDM (%)	ROE Improvement with CDM (%)
Power and Heat Generation (Gas	13,341,000	355,230/yr	5.8	11.0	5.2	4.7	13.5	8.8

Turbine)								
Power and Heat Generation (Gas Engine)	11,435,000	303,130/yr	9.6	15.0	5.4	10.9	21.5	10.6
Power Generation (Gas Engine)	10,067,000	262,090/yr	7.6	13.7	6.1	7.5	18.8	11.3

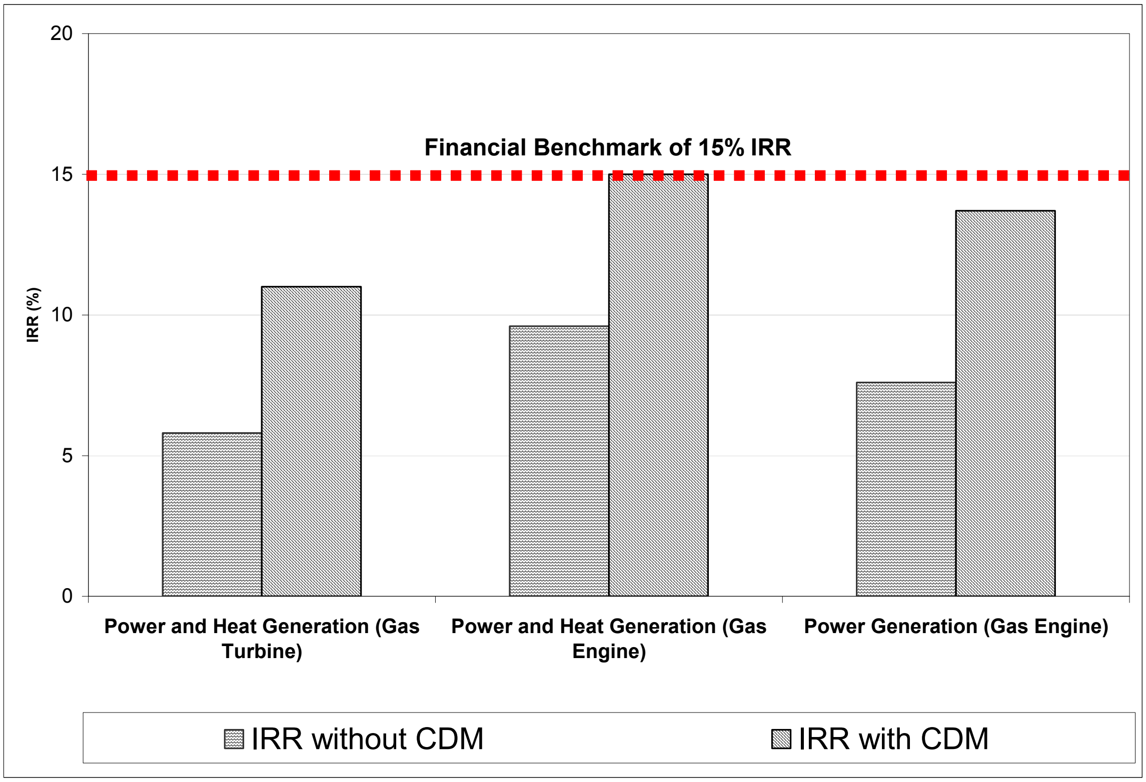

Figure 13 Financial Options for Grid-Connected Case

<u>Off-grid case</u>

The financial analysis indicates that CDM financing has significant impacts[108] for the gas engine options in both power generation alone and cogeneration of heat and power. For the gas turbine cogeneration option, the improvement is attractive for the ROE but not project IRR. In the case of heat generation using steam boilers, the analysis indicates both project IRR and ROE are already financially attractive without CDM financing.

In general, the improvement of project IRR ranges from 5 – 10% while the ROE improves between 10 – 27% for the off-grid cases.

Grid-connected case

For grid connection case, the financial analysis indicates that the CDM financing has an impact on gas engine for both co-gen and power options. In contrast, CDM has only marginal impact on feasibility for the gas turbine cogeneration option. This is probably due to the additional grid connection investment required which is not exceeding the power replacement savings.

The improvement of project IRR ranges between 5-6% while the improvement of ROE ranges from 9-11%.

In order to test the sensitivity of the results obtained, sensitivity analysis by varying the sizes of mills are carried out and presented in section 5.3.5.

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[108] improves both project IRR and ROE from unattractive to attractive based on the benchmark of 15%

5.3.5 Sensitivity Analysis : Palm Oil Milling Sizes

Three mills capacity were chosen for sensitivity analysis, namely small mill (≤ 20 mT FFB/hr), average mill (≈ 40 mT FFB/hr) and large mill (≥ 60 mT FFB/hr). The basic assumption for the sensitivity analysis is the mills' operation; biogas production and the quality of biogas yielded; and the technologies options adopted for each mill are similar, where:

- All mills operate 4700 hours yearly
- The ratio of POME generated to FFB is 60%
- Density of POME is 1 ton/m^3
- Average biogas production is 28 m^3 per m^3 of POME
- Heating Value of biogas[109] = 23.9 MJ/m^3
- Biogas produced contains 60% of methane
- Density of methane is 0.72 kg/m^3
- The efficiencies of the technology options are the same for all the cases
- The power plants capacity are 80% (operate at 7008 hours yearly)

Basically all the three cases are the same except for input capacity of FFB.

Table 53 Information on the Production for Different Cases for Sensitivity Analysis

Production	Case 1 (Small Mill)	Case 2 (Average Mill/base case)	Case 3 (Large Mill)
FFB input (mT/hr)	20	43	60
Annual capacity (ton FFB/yr)	94,000	200,000	282,000
Average POME generation (mT/hr)	12	25.5	36

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[109] Generated from Methane's heating value of 55.4 GJ/ ton and methane density at 0.72 kg/m3.

Daily POME generation (mT/d)	165	400	490
Total POME generation (mT/yr)	56,400	120,000	170,000
Average Biogas Yield (m^3/yr)	1,579,000	3,360,000	4,760,000
Annual biogas heating energy (MJ/yr)	3.8×10^7	8.0×10^7	1.1×10^8
CH_4 generation			
(m^3/yr)	947,400	2,000,000	2,856,000
(mT/yr)	682	1,440	2,056
CO_2 equivalent reduction (mT/yr)	14,300	30,200	43,200

5.3.5.1 Capacity and cost of equipment

The basic assumptions for facilities' capacity and financial costing are similar to generic base case (which represents the Average Mill in sensitivity analysis) as discussed in Section 5.3.3 and 5.3.4.

<u>Anaerobic Digester for Small Mill</u>

The designation size for digester is 3200 m^3 in order to handle the amount of POME produced for 18 days of retention.

Cost for anaerobic digester system = RM 2,166,000 x $(3,200/7,500)^{0.7}$

The anaerobic digester system (3,200 m^3) for small mill will cost RM 1,193,000

<u>Biogas Storage System for Small Mill</u>

Cost for biogas storage system for small mill = $\frac{1,579,000}{2.12x10^6} x0.22x10^6 x(1.05)^{19}$

= RM 414,000

Steam Boilers (Heat Generation) for Small Mill

The total boilers' capacity estimated

= (annual biogas heating energy x Thermal efficiency) ÷ Mill operating hour per year

= (3.8×10^7 MJ x 0.278 kWh/MJ x 0.85) ÷ 4700

= 1.91 MW

The boilers with total capacity of 2 MW will be selected.

By the assumption that the cost of boilers increase linearly to the capacity:

Cost of boilers (2 MW) = 2/4 x RM 1,587,000[110]

= RM 794,000

Gas Treatment Facility for Small Mill

The cost for gas treatment facility is assumed as linear to the volume treated:

Cost of gas treatment facility = (1,579,000/3,360,000) x RM 254,000

= RM 120,000

Gas Engine Power Plant for Small Mill

The estimated power for gas engine power plant

= (annual biogas heating energy x power efficiency) ÷ power plant operation hour per year[111]

= (3.8×10^7 MJ x 0.278 kWh/MJ x 0.40) ÷ 7008 hr

= 603 kW

A gas engine plant of 625 kW is selected for the power plant.

The cost for 625 kW cogen system is USD 1,200 / kW. The total installation price for a 625 kW gas engine power plant is RM 2,736,000, after account in all the surcharge and markdown as assumed in section 5.3.4

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[110] Price for 4 MW boilers estimated for average size mill.

[111] Assume at 80% plant capacity which is 7008 per year.

Gas Engine Cogen Plant for Small Mill

The estimated power for gas engine cogen plant

= (3.8 x 10^7 MJ x 0.278 kWh/MJ x 0.30) ÷ 7008 hr

= 450 kW

However, a 625 kW cogen system is to be installed to be consistent with the power generation only gas engine plant. Hence the installation cost is estimated at RM 3,420,000.

Gas Turbine Cogen Plant for Small Mill

The estimated power for gas turbine cogen plant

= (3.8 x 10^7 MJ x 0.278 kWh/MJ x 0.24) ÷ 7008 hr

= 360 kW

The gas turbine cogen plant is not feasible for small mill as the size of gas turbine is normally 1 MW and above.

Anaerobic Digester for Large Mill

The designation size for digester is 9,000 m^3 in order to handle the amount of POME (490 m3/d) produced for 18 days of retention.

Cost for anaerobic digester system = RM 2,166,000 x $(9,000/7,500)^{0.7}$

The anaerobic digester system with 9,000 m^3 capacity for a large mill will cost RM 2,461,000.

Biogas Storage System for Large Mill

Cost for biogas storage system for large mill = $\frac{4,760,000}{2.12x10^6}x0.22x10^6x(1.05)^{19}$

= RM 1,248,000

Steam Boilers (Heat Generation) for Large Mill

The total boilers' capacity estimated

= (annual biogas heating energy x Thermal efficiency) ÷ Mill operating hour per year

= (1.14 x 10^8 MJ x 0.278 kWh/MJ x 0.85) ÷ 4700

= 5.7 MW

The boilers with total capacity of 6 MW should be able to perform well.

By the assumption that the cost of boilers increase linearly to the capacity:

Cost of boilers (6 MW) = 6/4 x RM 1,587,000[112]

= RM 2,381,000

Gas Treatment Facility for Large Mill

The cost for gas treatment facility is assumed as linear to the volume treated:

Cost of gas treatment facility = (4,760,000/3,360,000) x RM 254,000

= RM 360,000

Gas Engine Power Plant for Large Mill

The power estimation for gas engine power plant

= (1.14 x 10^8 MJ x 0.278 kWh/MJ x 0.40) ÷ 7008 hr

= 1.8 MW

A gas engine plant consists of 2 units 1065 kW gas engines is necessary for the power plant.

The cost for 1065 kW cogen system is USD 900 / kW. The total commissioning price for 2 units 1065 kW gas engine power generation plant is RM 6,993,000 after considering all the assumption made in section 5.3.4

Gas Engine Cogen Plant for Large Mill

The power estimation for gas engine cogen plant

= (1.14x 10^8 MJ x 0.278 kWh/MJ x 0.30) ÷ 7008 hr

= 1.36 MW

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[112] Price for 4 MW boilers estimated for average size mill.

The cogen plant should also consist of 2 units 1065 kW gas engines, which costs about USD 900/kW. The turnkey cost for the cogen gas engine plant will be RM 8,741,000 with surcharge of 20% (shipping, transportation, etc).

Gas Turbine Cogen Plant for Large Mill

The estimated power for gas turbine cogen plant

$= (1.14 \times 10^8 \text{ MJ} \times 0.278 \text{ kWh/MJ} \times 0.24) \div 7008 \text{ hr}$

$= 1{,}085 \text{ kW}$

Gas turbine cogen plant of 1 MW is sufficient for the plant. Since the capacity for the plant constructed is the same as the average mill, the investment cost should be the same, which is RM 9,000,000.

Maintenance and Operational Costs

The maintenance and operational costs for the facilities are estimated at 3-5% which is of the same magnitude to the base case (that represents the average mill in this sensitivity analysis).

The costs for biogas utilization by small mill and large mill are summarised in

Appendix **T** and Appendix U respectively.

Summaries of Sensitivity Analysis

The sensitivity results are summarized in tables below:

Table 54 Summaries of Sensitivity Analysis (Off-grid)

Palm Oil Mill Size			**Small Scale (≤ 20 mT FFB/hr)**	**Average Scale (≈ 40 mT FFB/hr)**	**Large Scale (≥ 60 mT FFB/hr)**
Technological Option	Power and Heat Generation (Gas Turbine)	IRR without CDM (%)	Not feasible	7.0	10.3
		IRR with CDM (%)	Not feasible	12.6	*16.8
		IRR Improvement with CDM (%)	Not feasible	5.6	6.5
		ROE without CDM (%)	Not feasible	6.6	12.2

Palm Oil Mill Size			**Small Scale (≤ 20 mT FFB/hr)**	**Average Scale (≈ 40 mT FFB/hr)**	**Large Scale (≥ 60 mT FFB/hr)**
		ROE with CDM (%)	Not feasible	*16.5	*25.6
		ROE Improvement with CDM (%)	Not feasible	9.9	*13.4
	Power and Heat Generation (Gas Engine)	IRR without CDM (%)	9.7	13.2	13.4
		IRR with CDM (%)	*15.4	*18.7	*20.3
		IRR Improvement with CDM (%)	5.7	5.5	6.9
		ROE without CDM (%)	11.1	17.3	18.2
		ROE with CDM (%)	*22.3	29.1	33.9
		ROE Improvement with CDM (%)	11.2	11.8	15.6
	Power Generation (Gas Engine)	IRR without CDM (%)	7.6	9.2	11.1
		IRR with CDM (%)	14.2	*16.0	*18.3
		IRR Improvement with CDM (%)	6.6	6.8	7.2
		ROE without CDM (%)	7.6	10.3	13.6
		ROE with CDM (%)	*19.7	*23.8	*29.0
		ROE Improvement with CDM (%)	12.1	13.5	15.4
	Heat Generation (Steam Boilers)	IRR without CDM (%)	17.2	20.4	20.9
		IRR with CDM (%)	26.8	30.9	31.7
		IRR Improvement with CDM (%)	9.6	10.5	10.8
		ROE without CDM (%)	26.5	34.3	35.4
		ROE with CDM (%)	50.6	61.2	63.2

Palm Oil Mill Size			Small Scale (≤ 20 mT FFB/hr)	Average Scale (≈ 40 mT FFB/hr)	Large Scale (≥ 60 mT FFB/hr)
		ROE Improvement with CDM (%)	24.1	26.9	27.8

* Options where CDM improve IRR to the benchmark of 15%.

Table 55 Summaries of Sensitivity Analysis (Grid-connected)

Palm Oil Mill Size			Small Scale (≤ 20 mT FFB/hr)	Average Scale (≈ 40 mT FFB/hr)	Large Scale (≥ 60 mT FFB/hr)
Technological Option	Power and Heat Generation (Gas Turbine)	IRR without CDM (%)	Not feasible	5.8	9.0
		IRR with CDM (%)	Not feasible	11.0	*15.1
		IRR Improvement with CDM (%)	Not feasible	5.2	6.1
		ROE without CDM (%)	Not feasible	4.7	9.9
		ROE with CDM (%)	Not feasible	13.5	*21.8
		ROE Improvement with CDM (%)	Not feasible	8.8	11.9
	Power and Heat Generation (Gas Engine)	IRR without CDM (%)	6.8	9.6	11.7
		IRR with CDM (%)	11.6	*15.0	*17.5
		IRR Improvement with CDM (%)	4.8	5.4	5.8
		ROE without CDM (%)	6.2	10.9	14.8
		ROE with CDM (%)	14.6	*21.5	*27.2
		ROE Improvement with CDM (%)	8.4	10.6	12.4
	Power Generation (Gas Engine)	IRR without CDM (%)	4.7	7.6	9.8
		IRR with CDM (%)	10.2	13.7	*16.3
		IRR Improvement with CDM (%)	5.5	6.1	6.5
		ROE without CDM (%)	3.0	7.5	11.2

Palm Oil Mill Size			Small Scale (≤ 20 mT FFB/hr)	Average Scale (≈ 40 mT FFB/hr)	Large Scale (≥ 60 mT FFB/hr)
		ROE with CDM (%)	12.0	*18.8	*24.5
		ROE Improvement with CDM (%)	9.0	11.3	13.3

* Options where CDM improve IRR to the benchmark of 15%.

Discussions

Off-grid Case

The sensitivity analysis reveals that the gas turbine cogen option is feasible for large scale mills with CDM where the the IRR improves to 16.8%. The gas engine for power generation only and for power and heat generation are feasible for all mills when the CDM is considered. On the other hand, the investments on heat recovery alone are too attractive that no CDM is necessary for all small and large mills.

Grid-connected Case

Grid-connected power recovery for large mill is viable with CDM for all the options studied. The IRR increases from 9 – 12 % to 15 – 18 % with CDM addition. All the power recovery options are not feasible for small mills even though the CDM revenue is accounted. For the average mills, power recovery is feasible by using gas engine options.

5.3.6 Assessment of Additionality

The same approach as for landfill gas projects for additionality assessment was carried out:

Step 0 – Project starting date

In the case of POME biogas projects, as discussed earlier, POME biogas recovery and utilisation is a very rare practice so it can be safe to assume all projects are not started. Thus, the assessment can continue to the next step.

Step 1 a – Identification of alternatives

Apart from implementing biogas recovery for power and heat production, the following alternatives are assessed to be realistic:

- Status quo – no project activity, business as usual, methane emissions from anaerobic treatment;
- Flaring – capturing of methane generated from anaerobic ponds but flaring instead of utilising it for power and heat.

Step 1 b - Enforment of laws and regulations

Currently, specific regulations basically define the overall allowable final effluent discharge standards but there are no government regulations requiring palm oil mills to prevent the release of methane to the atmosphere. The regulations also do not specify how waste should be treated. Thus, it is no legal mandate under the existing legislation to capture and utilize methane from POME treatment[113], thus projects such as methane capturing from POME is eligible for CDM projects since the reduction is additional.

Step 2 – Investment Analysis

This assessment determines whether the proposed project is economically less attractive compared to the alternatives without the revenue from sale of CERs. For this study, both analysis options i.e. simple cost analysis and investment comparison analysis were carried out. For financial analysis, both project and equity IRR was elaborated in this study.

Based on the financial assessment, most POME biogas project options (except heat recovery case) are likely to be economically less attractive if compared to the no project and capturing for flaring alternatives. The methane capturing for flaring would require much less investment while still may qualify for CDM. However, as this study focussed on energy projects, the flaring option was not assessed in detail.

In contrast to landfill projects, the economical feasibility of biogas recovery and utilization projects is reported to be feasible. This is especially the case for projects involving the production of heat from biogas for the use in palm oil mill processes.

Technically, technologies such as digesters for POME, steam boilers for heat recovery are available locally and the market is definitely increasing. Only foreign technologies that might be applicable are gas engines used for power generation. Due to the import of technologies, the cost for projects with both power and heat recovery is higher and

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[113] UNDP/GEF. (2002). Project Document: Biomass-based Power Generation and Cogeneration in the Palm Oil Industry (Phase 1).

feasibility may before marginal. Thus, when it comes to assessing investment and technical barriers, the role of CDM financing is interesting to enhance the "bankability" of especially POME biogas projects with and without power (electricity) production.

Step 4 - Common Practices

As indicated in Section 3, the baseline scenario for existing POME treatment is open anaerobic lagoon system where methane is emitted to the atmosphere.

POME biogas (methane) recovery and utilization is definitely not common as indicated in Section 3.5.4 above. In total, it is safe to conclude that there are not more than 5 palm oil mills (out of 370 in Malaysia) that currently recover POME biogas for power or heat.

Thus, CDM projects on biogas (methane) recovery can be considered additional under the common practice assessment.

5.3.6.1 Other Assessments

Replicability

When it comes to replicability, it is believed that a typical project involving the recovery of biogas from POME can be replicated across the country especially for those above average size palm oil mills.

Data availability

Due to the heavy research in this field and the strong interest of government in encouraging waste reuse in palm oil industries, data availability for further assessment is foreseen not to be a problem.

Sustainable Development Policies

Similar to the case for landfill gas, POME methane recovery is consistent with the Malaysian Government's sustainable development policy as stated under the landfill gas section earlier (4.3.2).

6. Assessment of Total CDM Potential in Waste Sector

Based on the results derived above, the potential of developing renewable energy projects within the waste sectors is promising. This section summarises the estimates of the total potential CERs that can be generated from the waste sectors.

6.1 Total Potential of CERs in Waste Sectors

Based on the results derived from above sections, the potential of CERs within the various waste sectors are elaborated below:

6.1.1 Landfill gas

The total potential GHG reduction from landfill gas emissions estimated in this study is approximately 3,694,194 mT per year. These potential CERs constitutes approximately 26% of the total estimated baseline emissions as reported in Table 9, Section 3.2.5. The relatively lower potential of CERs can be explained with the following factors:

- the assumption of only 50% collection efficiency made for every case;
- landfills not recorded in the database were not project candidates;
- landfills below the 25 mT/d MSW threshold were considered non-recoverable; and,
- closed landfills where gas production is assumed to have passed the stage of viable recovery were not examined in this study.

The limitations of the study could be addressed in acquisition of better data and assessment of recoverable emissions could also be increased by:

1. Developing collection technology to increase collection efficiency to 85% for example that would result in CERs increasing to 170% of the study estimate;
2. Bundling or inclusion of small landfills by development of more economical gas collection and carrying out multiple projects simultaneously;
3. Flaring of gas in excess of power generation module capacities, ignored by this study;
4. Developing a program that extends over multiple landfills that permits transfer of modular power generation equipment to optimize landfill gas consumption at landfills in different stages of development;
5. Addressing the substantial mass of MSW in closed landfills that could be evaluated as significant for flaring projects.

6.1.1.1 CERs Pricing to Achieve Desired Financial Return

Table 56 CERs Price to Reach 15% ROE with CDM

Project (mT/d MSW to landfill)	Output	CDM Price to Achieve IRR = 15%, (USD)
25	Flare	5.69
50	Flare	4.2
100	Flare	3.05
150	1 MW	4.35
300	2 MW	2.75
400	3 MW	2.23

6.1.2 POME Biogas

In the case of CERs from POME biogas projects, the estimated potential is based on information related to the distribution of palm oil mill size and their relative CDM potentials as elaborated from earlier sections (Table 39).

The estimation is tabulated below:

Table 57 Total Potential CERs from POME Biogas

Palm Oil Mill Size	Total No. of Mills[a]	No. of Mills qualified[b]	Average Size Used (mT FFB/hr)	Average Emission red.(mT CO_2/yr)	Total Potential (mT CO_2/yr)
Large (> 50 FFB/hr)	148	74	55	39,000	2,886,000
Medium (30-50 FFB/hr)	148	74	40	30,000	2,220,000
Small (< 30 FFB/hr)	74	Bundling potential	20	15,000	Bundling potential[c]
Total	**370**				**5,106,000** **(49% of total emissions)**

[a] Elaborated for 2003 based on distribution ratio of 20:40:40 for total mills in operation in 2004, not including mills under construction or planned (around 30-40 mills as reported by MPOB, 2004).

[b] Assuming only 50% of the mills will qualify for the total potential, also to take account of the actual emission that could be lower than theoretical.

[c] Bundling potential not further assessed in this study.

It is noted that the total % potential CER for POME biogas projects are far higher (49%) than landfill gas (26%) for example. This is due to the fact that the recovery rate of methane using closed tank biogas digester systems as proposed is very high (reported to be more than 80-90% of emissions potential). In addition, the size distribution that meets the minimum threshold is also higher as compared to landfills.

It should also be noted that the chances of bundling smaller scale projects is relatively higher as compared to landfills for example since many palm oil mills are owned by the same large holding companies such as Guthrie, Golden Hope, Felda, Sime Darby, TSH etc. However, bundling potential was not assessed in detail in this study.

6.1.2.1 CER distribution & Power Generation Capacity from POME

The distribution of CERs potential and power generation potential from POME for the 3 regions are tabulated below:

Table 58 Distribution of CER Potential & Power Generating Capacity from POME

	Contribution to CER potential	CER potential (mT/yr)	Total Power Generation[a] (kWh/yr)	Installed Capacity[b] (MW)
Peninsula M.	62%	3,125,760	6.9×10^8	98
Sabah	30%	1,531,800	3.4×10^8	49
Sarawak	8%	408,480	0.9×10^8	13
Total	**100 %**	**5,106,000**	**1.58×10^9**	**160**

a. For POME, gas engine cogen which produces power and heat is the technology based. The power efficiency of gas engine cogen is assumed at 30%.

b. Total installed capacity is derived based on the power plant operation of 80% capacity factor i.e. 7008 hours per year.

6.1.2.2 CERs Pricing to Achieve Desired Financial Return

Table 59 CERs Price to Reach 15% ROE with CDM (Off-Grid)

Technology Option	CER price to reach 15% Equity IRR with CDM (USD)		
	Small mill	Average mill	Large mill
Power and Heat Generation (Gas Turbine)	**-**	**4.25**	**1.07**
Power and Heat Generation (Gas Engine)	**1.74**	**-1.04**	**-1.08**
Power Generation (Gas Engine)	**3.07**	**1.77**	**0.45**

Heat Generation (Steam Boilers)	**-2.49**	**-3.56**	**-3.63**

For off-grid cases, the average CER price required to achieve the project IRR of 15% is all below the commonly known average of USD 5 per CER. In general, large mills require lowest CER prices while the heat generation only option is feasible without CDM.

Table 60 CERs Price to Reach 15% ROE with CDM (Grid-connected)

Technology Option	**CER price to reach 15% Equity IRR with CDM (USD)**		
	Small mill	**Average mill**	**Large mill**
Power and Heat Generation (Gas Turbine)	-	5.84	**2.17**
Power and Heat Generation (Gas Engine)	5.18	**1.97**	**0.08**
Power Generation (Gas Engine)	6.62	**3.32**	**1.45**

For grid-connected case, it can be noted that CER prices of more than USD 5 per CER is required for small mills and also the gas turbine option for average mills. Similar case for off-grid projects, larger mills requires lower CER prices.

In summary, waste to energy projects for POME seems to be potentially attractive CDM projects especially for large palm oil mills.

6.1.3 Other Sources

As other sources are considered less significance in terms of size of total CERs potential, the estimation of potential CERs is therefore based on less detail analysis.

For swine farming, it is assumed that 50% of the total potential can be potentially eligible for CERs. This is based on the fact that the Government of Malaysia is in process of strengthening the control of swine farming and there are several plans to establish confined designated areas for pig farming (see Section 3.4). With the high intensity of swine manure within the same area, the use of biogas technologies become a very appropriate waste treatment alternatives as shown in many other countries. With the high potential of biogas application, the potential of CERs is therefore considered relatively high. Swine manure management is also one of the areas where CDM projects are currently being developed in many other countries.

For industrial wastewater, the CER potential due to methane is estimated around 20%. This lower estimate is due to the fact that the most common wastewater treatment systems are in placed and commonly aerobic based (less baseline emissions) and there are only limited numbers of open anaerobic systems. Bundling is also less probable for this case.

Similarly, for domestic sewage, the well established wastewater systems are mostly aerobic based systems. Septic tanks are also gradually replaced by centralized systems and potential of decentralized systems that could lead to CERs remains low unless there is a major change in policy and approach of wastewater treatment. In this study, the potential CERs for sewage is considered negligible as compared to other waste sources.

6.1.4 Summary of CERs Potential within Waste Sectors

The estimated potential of CERs that could be developed can be summarized below:

Table 61 Summary of Potential CERs from Waste Sectors in Malaysia

Waste Sectors (mT/yr)	Total Methane Potential (mT/yr)	Total CO_2 eq (mT/yr)	Potential of CERs /yr	% Sectoral Potential	% Potential CERs
MSW Landfill	685,843	14,402,700	3,694,194	26%	38%
Palm Oil Processing (POME)	500,000	10,500,000	5,106,000	49%	52%
Swine farming	71,000	1,491,100	745,550	50%	8%
Other Industries	40,000	924,000	184,800	20%	<2%
Sewage	4,000	84,000	negligible	negligible	-
Total	**1,300,843**	**27,401,800**	**9,730,544** **(30% total)**		

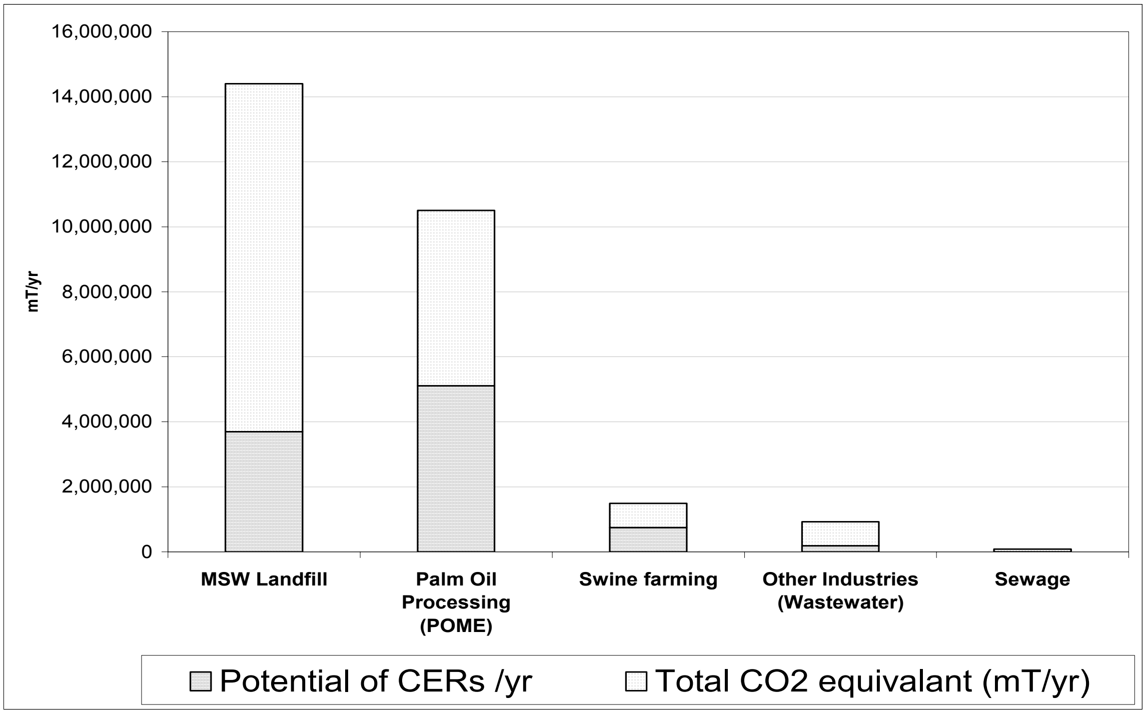

Figure 14 Total CO_2 Equivalent Emission and Potential of CERs for Waste Sectors Studied in Malaysia

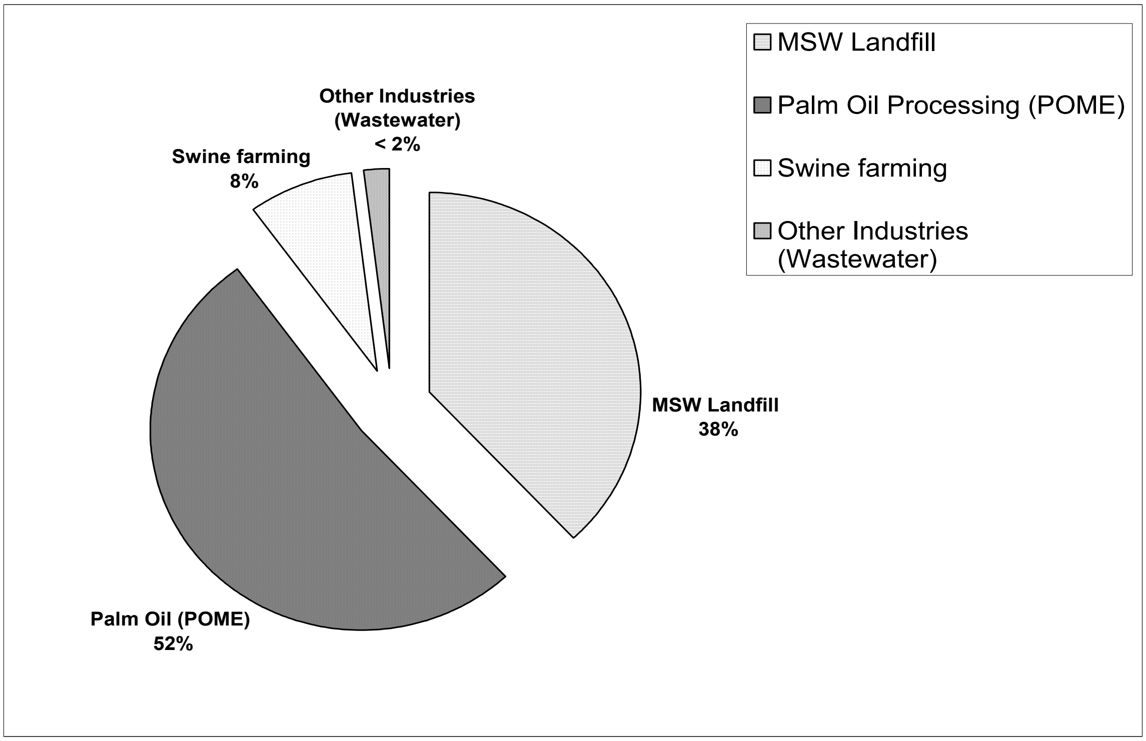

Figure 15 Distribution of CERs Potential from Waste Sectors in Malaysia

In summary, the total potential CERs that can be derived within the waste sectors are estimated to be within the range of 9 -10 million.

6.1.5 Summary of Renewable Energy Potential from CDM Projects

In the context of energy potential that could be derived from the CDM projects, the following assumptions were made:

- Methane recovery rate according to Table 61;
- All the power/ heat calculation based on efficiency of gas engines;
- Power generation efficiency of gas engine of 35% was used;
- Heat generation efficiency of 50% was used;
- Heat generation for landfills is not applicable but calculation for all the other sources;
- Energy generation hours of 7008 hours per year (80% capacity factor).

A summary of results is presented below:

Table 62 Power and Heat Potential from CDM Projects

Waste Sectors (mT/yr)	Methane Recovery Potential (mT/yr)	Total[c] Power (kWh/yr)	Total[d] Installed Capacity (MW)	Total Heat (kWh/yr)	Total Installed Capacity (MW)
MSW Landfill	176,000	3.9×10^8	45	Not Applicable	Not Applicable
Palm Oil Processing (POME)[a]	340,000	1.58×10^9	160	2.6×10^9	267
Swine farming[b]	35,500	1.6×10^8	23	2.7×10^8	39
Other Industries[b] (Wastewater)	8,000	4.9×10^7	7	8.4×10^7	12

Sewage	negligible	negligible	negligible	negligible	Not Applicable
Total (Approx.)	**559,500**	**2.18×10^9**	**235**	**3×10^9**	**318**

a. For POME, gas engine cogen which produces power and heat is the technology based. The power efficiency of gas engine cogen is assumed at 30% where else thermal efficiency at 50%
b. When heat is not necessary, power generation only by gas engine is base where the power efficiency is 40%.
c. Power/heat generation is calculated base on the heating value of methane (55.4 GJ/ton). Where, Methane potential x heating value x power/thermal efficiency x MJ-kWh conversion factor (0.278)
d. Total installed capacity is derived based on the power plant operation of 80% capacity factor i.e. 7008 hours per year.

The approximate total installed power generation capacity is estimated to be 235 MW and heat generation capacity of approximately 320 MW. The power generation potential from waste sectors is only around 1.4% of the national total Installed capacity of 16,800 MW in Malaysia[114].

6.2 Barriers and Policy Options

6.2.1 Potential Barriers: Waste to Renewable Energy

Despite the great potential of recovery energy from waste as renewable energy, there are various potential constraints that could impede the successful development. Although often referred to market failures, there are however different dimensions of these barriers. These barriers encompass inter-related issues involving a multitude of factors that affect different levels of stakeholders[115]. Some examples of these potential constraints are tabulated in Table 63 below:

Table 63 Barriers Impeding the Implementation of Waste to Energy Projects

Barrier types	Specific types	Examples

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[114] Malaysian Energy Commission. (2004). Statistics of Electricity Supply Industry in Malaysia.

[115] Wilkins, Gill. (2002). Technology Transfer for Renewable Energy: Overcoming Barriers in Developing Countries. The Royal Institute of International Affairs. Earthscan Publications, London, UK.

Political, legal and Institutional	Weak and incoherent policy	Policy not clearly defined and lack of follow up strategy and implementation plans. For example, there were no specific policy framework and strategies, and implementation plans formulated to meet the 5% renewable energy target by 2005 in Malaysia.
	Legal Insitutional	No specific dedicated legal/institutional framework established. Many uncertainties and broad policies with too many actors
	Lengthy procedures and time frame	Applications for CDM, renewable energy incentives such as tax allowances, reinvestment allowance have to go through a lengthy application and approval process which will discourage the take up.
Economic, financing and sustainability	Capital intensive / economic of scale	Renewable projects are high risk and financially not attractive in general. This is due to economies of scale, lack of local available technologies etc.
	Subsidies on fossil fuel	High subsidies on fossil fuel and lack of comparable incentives for renewable energy development.
	Lack of support on grid connection	Additional cost to the already high investment needed.
Socio-Environment	Resistance to change	Possessing traditional business operating culture, “can’t be bothered” attitude. In some case, lack of awareness and knowledge.
	Environmental cost	Externalities such as environmental cost is not usually accounted for in assessment of economic feasibility.

Technological transfer and local capacity	Technology availability and transfer	Lack of local suppliers and technical support for technologies. Conditions for technological transfer not established.
	Adaptation of technology	High reliance on imported technologies. High cost especially due to economies of scale. Lack of adaptation of technologies to suit local conditions and needs.

6.2.2 Policy Options and Measures

In order to address the various potential barriers described in the above section, there is a need to develop various policy options to encourage the implementation and penetration of renewable energy from waste.

The Malaysian Government is concerned to reduce the reliance on fossil fuel as primary energy source. Thus, the national energy policy stresses increasing use of renewable energy resources. There are several initiatives to encourage the development of renewable energy. In 2001, the Small Renewable Energy Power Program (SREP), an initiative of the Special Committee on Renewable Energy, was initiated to support the Government's strategy to intensify the development of renewable energy. SREP applies to all types of renewable sources of energy, including waste derived fuel such as biomass and biogas. Licences to energy producers will be provided for a period of 21 years, to be effective from the date of commissioning of the plant. The maximum capacity of renewable energy power plant is set at 10 MW. It was reported around 70 projects have been proposed under the SREP but less than 10 has been approved[116].

In addition to SREP, there are many other options to create better conditions for waste to energy projects. Some examples of these are tabulated in

Table 64 below. The list is definitely not exhaustive and can be elaborated further.

Table 64 Examples of Policy Measures and Instruments

Barrier	Policy measures	Examples of Policy Instruments

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[116] Reported at the National Seminar on Green and Renewable Bio-fuel, 6-7 December 2004, Kuala Lumpur, Malaysia.

Political, legal and Institutional	Clear legal and institutional framework	Define clear mandates and distribution of roles among related authorities, backed with legal support.
	Institutional strengthening	Establish designated governmental authority to spreahead, coordinate the renewable planning and development. Creating a "champion" for renewable energy.
Economic, financing and sustainability	Economic instruments	Accessible to capital: soft-loans, credit guarantee scheme for long loan period.
	Economic instruments	Special tariffs for renewable energy, Introduction of "green tax" for non-renewable, removal of subsidies for fossil fuel.
	Economic instruments	Special economic incentives e.g. tax relieve for waste companies engaging in renewable energy development.
Socio-Environment	Internalise Externalities	Incorporate externalities into the overall evaluation of energy planning and evaluation. This is especially the case for waste to energy since it can bring many subsequent environmental benefits while improving waste management.
Technology Transfer	Economic instruments	Allocation of funding for feasibility study, research and development into adaptation and localization of technologies
	Capacity building	Training of key personnel involved in planning and execution of energy planning. Integrated planning with close cooperation with various related ministries and departments.

6.3 Non-Financial Return Considerations

Implementation of renewable energy projects from waste resources are not only interesting from CDM and energy perspective, they are usually associated with many other non-financial returns, also known as environmental cost or externalities. Externalities can include aspects such as environmental impacts, social impacts etc. However, externalities are usually not included in traditional economic evaluation due to the challenges in costing externalities.

In the case of waste to energy projects, positive environmental impacts are well referenced. These environmental impacts, apart from global issues such as climate change, can include the reduction of local pollution, conservation of natural resources etc.

For example, for the case of landfill gas recovery and utilization, the following positivie environmental benefits are commonly cited:

- Reduced exploitation of fossil fuel and reliance on import;
- Reduction of odour nuisance to surrounding areas;
- Reduction of gas migration, which leads to less explosion & fire risks, vegetative damages etc;
- Improve the degradation process within the landfill;
- Etc.

For the case of POME biogas recovery and utilisation, the subsequent non-financial benefits include:

- Reduction of odour nuisance;
- Improvement in overall treatment efficiency under a controlled digestion situation;
- Digestates : return of nutrients, substitute chemical fertilisers;
- Etc.

7 Conclusions and recommendations

This study has indicated that there exist high potential in developing CDM projects within the waste sectors, particularly on the MSW landfills and POME anaerobic treatment systems. These two sectors were analysed in greater detail on their financial impacts due to CDM and additionality assessment.

In general, the presence of CDM financing improves the financial performance of the projects analysed. A financial internal rate of return (IRR) benchmark of 15% was set to determine the attractiveness of a project.

For the generic landfill gas recovery for energy project, the results indicated that the improvement of IRR due to CDM financing for projects above the minimum CDM threshold size is more than 15% for all but one case analyzed in each category of energy generation and, flaring. Sensitivity analysis based on different size range of landfills carried out indicated an improvement of IRR between the ranges of 2-6 % without to17-24% with CDM financing. Similar trends exist for the Return of Equity (ROE).

For generic POME biogas recovery for energy project, several technical options were analysed. When off-grid is to be considered, the results indicated that the improvement of IRR range from 7.0 - 13.2 % (without CDM) to 12.6 to 18.7% (with CDM financing) while the return of equity (ROE) also improves with CDM financing especially for the gas engine cogeneration and gas engine power generation options. For gas turbine option, only large scale mills seem to be able to be viable with CDM (IRR improves from 10.3% (without CDM) to 16.8% (with CDM)). However, if the project is to be grid-connected for SREP, the additional grid connection cost will reduce the attractiveness. Generally, the project IRR and equity IRR are lower. The power recovery of smaller mill is not attractive at all even though with CDM financing.

In terms of additionality, the detail assessment for both project types indicates that the two selected project types in general fulfil the additionality assessment. In general, the barriers identified such as financing barriers (as seen in the financial analysis) and technological barriers seems to be removed with the implementation as CDM projects.

The final evaluation concludes that the total potential certified emission reduction units (CERs) within the waste sectors analysed is between the range of 12-13 million CERs per year. Among these potential CERs, POME biogas projects emerge as the most promising sector (52%) where landfill gas is second (38%). This is interesting since the baseline emissions from landfills are higher than POME but the recovery potential for CERs is proven to be less as compared to POME biogas.

There are however various potential barriers that impedes the successful implementation of renewable energy projects including waste to energy projects in this study. Appropriate policy measures are required to remove these barriers that could encompass aspects such as political, legal, institutional, financial, technological issues. The results from this study indicate that CDM seems to be an obvious policy measures that could improve the viability of waste to energy projects.

The potential of CDM within the waste sectors is especially high within the palm oil mills and municipal landfills in Malaysia. It is recommended further detail studies and efforts on CDM to be focussed in these 2 areas.

7.1 Limitation of This Study

Essentially, this study only provides a quick review of CDM potential within selected waste sectors in Malaysia. As reliable and comprehensive data is in general not available, the quality of the findings could be improved with acquisition of more updated and reliable data. It should also be noted that the overall potential assessment was based on elaboration from generic cases whereby in reality, the conditions will be very much case specific.

7.2 Recommendations for Further Researches

This study focuses on methane emissions where waste to energy projects could be interesting for CDM. In some cases, the project design might not necessary be restricted to one single types of waste. Further investigations into the feasibility of combining the management of various types of waste resources within an integrated waste management scheme would be interesting. An example of such opportunities exists within the palm oil industrial sector. Apart from POME, the integration of treating the Empty Fruit Bunch (EFB) via for example composting could further reduce GHG emissions in addition to the POME reduction.

Similarly for landfill, a combination of landfill gas recovery with biogas utilisation from anaerobic digestion of leachate collected could also increase the significance of GHG emission reduction. Another potentially viable area would be to extract industrial grade CO_2 or, to incorporate greenhouses at landfill sites to utilize CO_2, either of which would also reduce GHG emissions

When it comes to cost benefit analysis of the waste sector CDM projects, non-financial returns were not included in the assessment of financial feasibility. For many of these projects, there are many subsequent positive environment and social impacts which are difficult to value. It is proposed that externalities such as environmental benefits be studied in greater detail and internalised into the overall assessment.

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Appendices

Appendix A - Reported MSW Amount Managed and Estimated Total MSW Generated in Malaysia

State	Adjusted Population ('000)	Amount of Waste Generated (Tonnes/day)^c	Amount of Waste Generated (Tonnes/Year)
Labuan	80	80	29,200
Perlis	230	230	83,950
Melaka	630	630	229,950
Negeri Sembilan	927	927	338,355
Terengganu	1,081	1,081	394,565
Pahang	1,171	1,171	427,415
Kelantan	1,266	1,266	462,090
Pulau Penang	1,331	1,331	485,815
Kuala Lumpur	1,456	1,456	531,440
Kedah	1,620	1,620	591,300
Perak	1,867	1,867	681,455
Sarawak	2,072	2,072	756,280
Sabah	2,600	2,600	949,000
Johor	2,740	2,740	1,000,100
Selangor	4,190	4,190	1,529,350
Total	**23,263**	**23,263**	**8,490,995**

(Source: Federal Ministry of Housing and Local Government (2003), Natural Resources and Environment Board Sarawak (2003), Environmental Protection Department Sabah (2001), DANIDA (2004))

Appendix B - Landfill Database for Malaysia

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
1	Selangor	MP PJ	Kelana Jaya / Air Hitam	407	1	5.0		9.0	8.1
2	Selangor	MP Klang	Telok Kapas	551	1	3.0		1.0	32.4
3	Selangor	MP Kajang	Sg Kembong	432	0	12.0	8.0		16.2
4	Selangor	MP Selayang	Kundang	418	1	9.0	8.0		32.4
5	Selangor	MD Kuala Langat	Tapak Plupusan Sampah		0	10.0	7.0		6.1
6	Selangor	MD Kuala Langat	Tapak Pelupusan Tanjung Sepat		0	10.0		9.0	1
7	Selangor	MD Kuala Langat	Tapak Pelupusan Banting	110	0	13.0		6.0	3
8	Selangor	MB Shah Alam	MPSA	300	0	10.0		8.0	12
9	Selangor	MP Subang Jaya	Worldwide Landfills Sdn. Bhd.	592	4	20.0	9.0		43
10	Selangor	MD Kuala Selangor	Kubang Badak B. Berjuntai	60	0	10.0	20.0		20
11	Selangor	MD Sabak Bernam	Jalan Panchang Bedena	100	3	22.0	20.0		4
12	Selangor		Ampang Jaya	494	1	17.0		7.0	10
13	Selangor	MD Hulu Selangor	Hulu Yam Bahru	350	1	20.0			
14	Selangor	MD Hulu Selangor	Kerling	120	1	20.0			
15	Selangor	MD Hulu Selangor	Bukit Beruntung	250	1	20.0			
16	Selangor	MD Sepang	Ampar Tenang	60					
	SUB-TOTAL	**4244**							
17	DBKL	DB KL	Taman Beringin	1415	2	8.0	8.0	0.0	12
18	DBKL	DB Kuala Lumpur	Jinjang Utara		2	27.0	25.0		10
19	DBKL	DB Kuala Lumpur	Sri Petaling		1	12.0		13.0	21
20	DBKL	DB Kuala Lumpur	Sungai Bersi		2	6.0		9.0	14
21	DBKL	DB Kuala Lumpur	Paka 2		2	5.0		10.0	6.5
22	DBKL	DB Kuala Lumpur	Paka 1		1	5.0		10.0	6.5

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
23	DBKL	DB Kuala Lumpur	Kampung Semarak (Brickfield)		0				
	SUB-TOTAL	**1415**							
24	N.Sembilan	MP Nilai	Pajam	80	3	22.0	8.0		27.9
25	N.Sembilan	MP Nilai	Kuala Sawah		3	5.0		1.0	10.1
26	N.Sembilan	MP Seremban	Sikamat	223	3	15.0		1.0	5.3
27	N.Sembilan	MP Port Dickson	Quarters MPPD		0	10.0		44.0	0.4
28	N.Sembilan	MP Port Dickson	Bukit Palung	53	0	38.0	29.0		25
29	N.Sembilan	MP Port Dickson	Penkalan Kempas		0	12.0		2.0	1.2
30	N.Sembilan	MP Port Dickson	Sua Betong		0	10.0	6.0		3.2
31	N.Sembilan	MP Port Dickson	Bt 2, Jln Seremban						2
32	N.Sembilan	MD Jelebu	Pertang	30	0	5.0		2.0	2.4
33	N.Sembilan	MD Jelebu	Sg. Muntuh	54	0	30.0	2.0		6.1
34	N.Sembilan	MD Jempol	MD Jempol (Rompin)	45	0	11.0	11.0	0.0	5
35	N.Sembilan	MD Jempol	MD Jempol (Bahau)		0	12.0		11.0	1.2
36	N.Sembilan	Kuala Pilah	Ulu Maasop	27					8
37	N.Sembilan	Tampin	Gemas	25					2
38	N.Sembilan	MD Rembau	Chembong	26	0	28.0	22.0		4
	SUB-TOTAL	**563**							
39	Melaka	MD Alor Gajah	Air Molek	100	0	43.0	34.0		2.4
40	Melaka	MD Alor Gajah	Pulau Sebang		0	42.0		2.0	0.8
41	Melaka	MB Melaka	Krubong	750	2	11.0	10.0		27.7
42	Melaka	MB Melaka	Krubong A		0	20.0		10.0	
43	Melaka	MB Melaka	Kota Laksamana		0	23.0		31.0	
44	Melaka	MD Jasin	Lipat Kajang		1	33.0		4.0	3.2
45	Melaka	MD Jasin	Batang Melaka	58	0	31.0		3.0	1.5
46	Melaka	MD Jasin	Kasang Pajak	65	0	1.0		2.0	9.2
	SUB-TOTAL	**973**							
47	Johor	MD Tangkak	Cachong	9	0	30.0		4.0	1
48	Johor	Johor Bahru	Larkin	704					20
49	Johor	Batu Pahat Timur	Air Itam	22					2
50	Johor	MP Muar	Bakri	300	1	12.0	11.0		14.6
51	Johor	MP JB	Ulu Tiram	90	2	6.0		1.0	17.4

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
		Tengah							
52	Johor	MP JB Tengah	Lima Kedai		0	5.0		7.0	2.5
53	Johor	MP JB Tengah	Kempas		0	9.0		7.0	0.9
54	Johor	MP JB Tengah	Taman Mega Ria		0	9.0		7.0	6.5
55	Johor	Kluang Selatan	Machap	21					4
56	Johor	Kluang Utara	Chamek	150					0.2
57	Johor	MD Kota Tinggi	Batu Empat	57	0	16.0	16.0	0.0	6
58	Johor	MD Kota Tinggi	Sg Rengil		0	10.0	6.0		
59	Johor	MD Kota Tinggi	Bandar Kota Tinggi		0	16.0		16.0	1.6
60	Johor	MD Mersing	Jemaluang	5	0	20.0	11.0		4
61	Johor	MD Mersing	Endau	18	0	20.0	11.0		4.9
62	Johor	MD Mersing	Sri Pantai	28	0	20.0	11.0		4
63	Johor	MD Labis	Pusat Membuang Sampah Jalan Temayar	30	0				2.4
64	Johor	MD Labis	Pusat Membuang Sampah Jalan Maskil		0	10.0	1.0		
65	Johor	Pbt Pasir Gudang	Kg Chennai	210					12
66	Johor	MD Pontian	Tapak Pelupusan Jalan Sawah, Pekan Nenas	30	0	10.0	6.0		12
67	Johor	MD Pontian	Tapak Pelupusan Rimba Terjun, Pontian	80	0	23.0		1.0	12
68	Johor	MD Pontian	Tapak Pelupusan Sanglang, Ayer Baloi	12	0	20.0	18.0		1.2
69	Johor	MD Segamat	Segamat Baru	22					3.3
70	Johor	MD Segamat	Jementah	97		53.0	34.0		2
71	Johor	MD Segamat	Lebuh Raya Segamat / Kuantan	90					90
72	Johor	MD Tangkak	Simpang Bekoh	10	0	23.0	4.0		3
73	Johor	MD Tangkak	Batu 16 Sengkang, Bukit Gambir	32	0	34.0	34.0	0.0	7

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
74	Johor	MD Simpang Renggam	Simpang Renggam (Ladang cep 1)	15	0	16.0	8.0		6
75	Johor	MD Simpang Renggam	Machap		0	10.0		8.0	3
76	Johor	MD Simpang Renggam	Renggam		0	4.0		30.0	2
77	Johor	MD Simpang Renggam	Simpang Renggam (Jln Kulai Cina)			5.0		9.0	0.5
78	Johor	MD Yong Peng	MDYP	10	1				0.4
	SUB-TOTAL	**2042**							
79	Pahang	MD Rompin	Kg. Feri	15	1	37.0	21.0		5
80	Pahang	MD Pekan	Pekan Nenasi	30	2	35.0	16.0		22.7
81	Pahang	MP Kuantan	Taman Bandar		0	3.0	21.0		2
82	Pahang	MP Kuantan	Gambang		0	36.0		3.0	2
83	Pahang	MP Kuantan	Indera Mahkota		1	8.0		11.0	50
84	Pahang	MP Kuantan	Jabor Jerangau	400	2	25.0	11.0		55
85	Pahang	MP Kuantan	Alabara		0	1.0		19.0	20
86	Pahang	MD Bentong	Sg. Semabut		1				2
87	Pahang	MD Bentong	Chamang	80	0	11.0	9.0		3
88	Pahang	MP Temerloh	Ulu Tualang	142	3	8.0	6.0		7.3
89	Pahang	MD Cameron Highlands	Tapak Plupusan Sisa Pepejal MDCH (Simpang Pulai)	29	0	7.0	3.0		0.4
90	Pahang	MD Cameron Highlands	Tapak Plupusan Sisa Pepejal MDCH (Cameron Highlands)	33	0	11.0		3.0	0.4
91	Pahang	MD Jerantut	Kg. Mat Lilau	25	2	8.0	7.0		4.4
92	Pahang	MD Jerantut	Batu 57		0	12.0		8.0	2
93	Pahang	MD Maran	Tapak Sampah Maran	18	2	25.0	16.0		4
94	Pahang	MD Maran	Tapak Sampah Jenka 10	9	1	33.0	7.0		8
95	Pahang	MD Raub	Sg. Ruan	2	3	7.0	7.0		3.4

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
96	Pahang	MD Raub	Cheroh	46	3	17.0	13.0		4.9
	SUB-TOTAL	**829**							
97	Terengganu	MP Kemaman	Fikri		0	9.0		19.0	2
98	Terengganu	MP Kemaman	Gelugor		0	11.0		12.0	1.2
99	Terengganu	MP Kemaman	Gelugor		0	13.0	11.0		10
100	Terengganu	MP Kemaman	Mak Cili Paya	400	0	21.0	19.0		5
101	Terengganu	Dugun	Dugun	26					
102	Terengganu	MP K. Terengganu	Tok Jembal		0	9.0		10.0	8.1
103	Terengganu	MP K. Terengganu	Wakaf Tok Keh		0	10.0		19.0	4
104	Terengganu	MP K. Terengganu	Kubank Ikan	80	0	6.0		0.0	13.3
105	Terengganu	MD Besut	Landfield (Sistem Tambus)	58	0	17.0	11.0		4.6
106	Terengganu	MD Hulu Terengganu	Tapak Pelupusan MDHT	25	0	31.0	22.0		9.5
107	Terengganu	Kuala Terengganu	KT	146					
108	Terengganu	MD Marang	MDM	18	0	18.0		0.0	2.5
	SUB-TOTAL	**753**							
109	Kelantan	MP Kota Baru	Panji		0	26.0		17.0	4
110	Kelantan	MP Kota Baru	Tebing Tinggi	200	0	16.0		1.0	19
111	Kelantan	MD K. Krai Selatan	Sg Sam	5	0	16.0		4.0	0.3
112	Kelantan	MD K. Krai Selatan	Bukit Tembeling	6	0	13.0	4.0		4
113	Kelantan	MP K. Krai Selatan	Dabong	2	0	10.0	8.0		0.2
114	Kelantan	MD Jeli	MD Jeli (Bato"O")	4	0	10.0		4.0	0.4
115	Kelantan	MD Jeli	MD Jeli (Kg. Sg. Mengkong)	10	0	15.0	4.0		2.4
116	Kelantan	MD Machang	Air Bertaga	35	0	8.0	2.0		4
117	Kelantan	MD Pasiir Puteh	Tapak Pelupusan Bukit	32	0	38.0	22.0		2

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
			Gedombak						
118	Kelantan	MD Tumpat	Kok Bedollah	45	1	22.0	16.0		20
119	Kelantan	MD Tanah Merah	Kg Cat Rimau	16	1	18.0		5.0	
120	Kelantan	MD Bachok	Kg. Sungai Gali, Telong	10	0	14.0	9.0		10
121	Kelantan	MD Bachok	Kg. Hujung Repek, Repek	12	0	10.0		9.0	2.5
	SUB-TOTAL	**377**							
122	Perak	MD Kinta Selatan	Sg. Siput Selatan	58	2	38.0	14.0		26.7
123	Perak	MD Kinta Selatan	Kg. Batu Putih (Kg. Tersusun)		0	24.0	24.0		2
124	Perak	MD Kinta Selatan	Staman Sri Kampar		0	10.0		34.0	4
125	Perak	MD Kinta Berat	Tj Tualang	28					1
126	Perak	MB Ipoh	Bercham	500	1	21.0	18.0		50
127	Perak	MB Ipoh	Buntong		0	16.0		18.0	20
128	Perak	MB Taiping	Jebong		0	8.0	4.0		20
129	Perak	MB Taiping	Tekkah Jaya	180	0	19.0		5.0	40
130	Perak	MD Tapah	Pekan Getah	40	1	19.0		0.0	21.5
131	Perak	MD Tapah	Bidor		1	33.0	24.0		2.1
132	Perak	MD Hilir Perak	MDHP (Teluk Intan)	67	0	15.0	11.0		20.3
133	Perak	MD Hilir Perak	Tapak Sampah MDHP (Kaw. Pekan Jenderata)		0	27.0	25.0		0.4
134	Perak	MD Hilir Perak	Tapak Sampah MDHP (Kaw. Bagan Datoh)	5	0	27.0	25.0		1.2
135	Perak	MD Kuala Kangsar	MDKK		0	20.0	18.0		13.4
136	Perak	MD Kuala Kangsar	Sg Siput Utara, Salak Utara	70					24
137	Perak	MD Kuala Kangsar	Manong	1					1
138	Perak	MD Kuala Kangsar	Liman Kati	3					1
139	Perak	MD Kuala Kangsar	Sauk	1					1
140	Perak	MD Lenggong	Air Kala	5	0	19.0	15.0		1.5
141	Perak	MD Lenggong	Kuak	2	0	20.0		5.0	1.2
142	Perak	MD	Tapak	7	0	16.0	11.0		8.4

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
		Penkalan Hulu	Pelupusan Sisa Pepejal						
143	Perak	MD Selama	Tapak Pelupusan MDS	12	0	17.0	13.0		4
144	Perak	MD Tanjong Malim	Panderas	25	0	30.0	24.0		2.5
145	Perak	MD Kerian	Jalan Dinnistown Parit Buntar	17	0	24.0		1.0	0.8
146	Perak	MD Kerian	Pematang Pasir Alor Pongsu (Beriah) Bagan Serai	32	0	22.0	21.0		2.4
147	Perak	MD Gerik	MD Gerik (1)	10	0	21.0		7.0	1.8
148	Perak	MD Gerik	MD Gerik (2)		0	35.0	7.0		2
149	Perak	MP Manjung	Sungai Wangi	90	1	23.0		1.0	10.1
150	Perak	MP Manjung	Tapak Pelupusan Teluk Cempedak	9	0	15.0	14.0		2
151	Perak	MP Manjung	Pantai Remis	9	0	34.0	34.0		1.2
152	Perak	MP Manjung	Beruas	5	0	34.0	34.0		.8
	SUB-TOTAL	**1176**							
153	Penang	MP Pulau Pinang	Jeli Jelutong	600	1	21.0		3.0	20
154	Penang	MP Sebarang Prai	Ampang Jajar	500	3	23.0		1.0	17
155	Penang	MP Sebarang Prai	Pulau Burong	150	3	29.0	24.0		64
156	Penang	MP Sebarang Prai	Kelebang	50					
	SUB-TOTAL	**1300**							
157	Kedah	MP Kulim Kecah	Padang Cina		0	27.0	8.0		56
158	Kedah	Kulim/KHTP	Jalan Batu Putih	110					8
159	Kedah	Bandar Bahru		18					0.4
160	Kedah	MD Baling	Pulai		3	17.0	3.0		6.8
161	Kedah	MD Baling	Keual Pegang		0	13.0		2.0	11
162	Kedah	MD Baling	Kg Chennai	24					9.6
163	Kedah	MP Sungai	Semeling	300	1	24.0	15.0		51

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
		Petani							
164	Kedah	MP Sungai Petani	Jeniang	3	0	16.0		3.0	1.5
165	Kedah	MP Kota Setar	Bukit Tok Bertandok		2	26.0	21.0		9.7
166	Kedah	MP Kota Setar	Jabi	260					16.3
167	Kedah	MP Kota Setar	Bkt Pinang Jaya	5					1
168	Kedah	MD Kubang Pasu	Paya Kemunting	50	2	31.0	30.0		5
169	Kedah	MD Langkawi	Tapak Pelupusan Sisa-Sisa Pepejal Majlis	60	0	25.0	16.0		30
170	Kedah	MD Padang Terap	MDPT	25	0	16.0	16.0		2
	SUB-TOTAL	**855**							
171	Perlis	MP Kangar	Kuala Perlis	42	0	20.0			8
	SUB-TOTAL	**42**							
172	Sarawak	DB Kuching Utara	Batu 8 1/2, Jalan Matang (Closed)	100	1	20.0			7.9
173	Sarawak	MD Kuching Selatan	Mambong (New)	450	3	20.0			20
174	Sarawak	MD Lawas	KM7, Jln Kuala Lawas	6.9		15.0			0.1
175	Sarawak	MD Marandong dan Julau	Lot 182, Meradong Land District, KM9, Jln Klupu, Bintagor	18		8.0			1.2
176	Sarawak	MD Marandong dan Julau	Lot 72, Blok 6, Jikang LD Julau	8		60.0			0.8
177	Sarawak	MD Marandong dan Julau	KM3, Pakan Wuak Rd. Pakan Subdistrict	4		60.0			0
178	Sarawak	MD Samarahan	Kg. Plaie, 94300 Kota Semarahan	15		20.0			2.3
179	Sarawak	MD Marudi	Jln Limbang, Marudi	20		25.0			1
180	Sarawak	MD Limbang	Lot 1129, Blok 12,	30		10.0			4.3

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
			Pandamaran Land District, Limbang						
181	Sarawak	MD Sibu	Batu 26, Jln KJD, Sibu						0.6
182	Sarawak	MP Miri	Tudan, 17 Km Miri-Kuala Baram Rd. Miri	120					11.1
183	Sarawak	MP Miri	Sibuti, 50 km from Miri	130		100.0			100
184	Sarawak	MD Saratok	Perabun, Seratok	22.5		20.0			2
185	Sarawak	MD Saratok	Panjang, Roban	9		10.0			0.8
186	Sarawak	MD Sarikei	Km 4, Jln Kerubong, Selalang	15		20.0			4
187	Sarawak	MD Sarikei	Kg Jerjih, Belawai	3		20.0			4
188	Sarawak	MD Simunjan	Km 8, Jln Simunjan						0.8
189	Sarawak	MD Serian	Bt 8, Jln Serian/Sri Aman, Serian	25		30.0			5.3
190	Sarawak	MB Kuching Selatan	Bt 8, Jln Matang, Kuching	350		20.0			7.9
191	Sarawak	MP Sibu	Jln Kemuyang, Sibu	200		12.5			13.6
192	Sarawak	MD Bau	Lot 227, Blok 9, Senggi poak	27.5		10.0			2.3
193	Sarawak	MD Betong	Betong	10					0.4
194	Sarawak	MD Betong	Pusa	4		6.0			1.7
195	Sarawak	MD Betong	Spaoh	4		4.0			0.9
196	Sarawak	MD Betong	Debak	4		6.0			1.4
197	Sarawak	MP Padawan	nil						
198	Sarawak	MD Dalat dan Mukah	KM 6, Jln Mukah / Dalat	16		7.0			2
199	Sarawak	MD Dalat dan Mukah	Pekan Selangau	5		15.0			2
200	Sarawak	MD Dalat dan Mukah	Jln Bahong Balingian	2		20.0			2.4
201	Sarawak	MD Dalat dan Mukah	Km 3, Jln Mukiah/Dalat	8		10.0			4
202	Sarawak	MD Dalat dan Mukah	Stapang	2		25.0			3.8

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
203	Sarawak	MD Luar Bandar Sibu	Batu 26, Jln KJD						0.6
204	Sarawak	MD Kapit	5 km, Jln Bkt Goram	10		18.0			4
205	Sarawak	MD Lundu	nil						
206	Sarawak	MD Kanowit	Km 7, Jln Kanowit-Durin, Kanowit	16		12.0			3.2
207	Sarawak	MD Lubuk Antu	Jln Empelam, Engkilili	0.5		20.0			1.2
208	Sarawak	MD Lubuk Antu	Lot 132, Jln Batu Kaya	0.5		20.0			0.9
209	Sarawak	MD Sri Aman	Km 12, Sri Aman/Serian Rd	35					1.2
210	Sarawak	MD Sri Aman	Lingga	20		15.0			1.6
211	Sarawak	MD Sri Aman	Pantu	4		10.0			0.6
212	Sarawak	MD Subis	nil						
213	Sarawak	MD Sarikei	Jln Merudu, 4 km			5.0		17.0	2.4
214	Sarawak	MD Sarikei	Jln Sare, 12 km			9.0		8.0	4.8
215	Sarawak	MP Sibu	Jln Seng Ling off Jln Oya (bulky waste only)	120					8.1
216	Sarawak	MD Betong	Km 1 1/2			20.0		3.0	0.44
217	Sarawak	MD Dalat dan Mukah	Belingin, 2 km			12.0		5.0	20
	SUB-TOTAL	**1814.9**							
216	Sabah	MD Papar	Batu 6, Kg Lankawit, Jln Bk Manggis	10		10.0			10
217	Sabah	MD Lahad Datu	Tg Bakaruan, Km 31, Tawau Hghwy	36		20.0			50
218	Sabah	MD Kota Belud		24		9.0			2
219	Sabah	DB Kota Kinabalu	Kg Kayu Madang, Telopok	300		12.5			114.6
220	Sabah	MD Tambunan	Km 14, Magkatai, Tambunan	4		12.0			15
221	Sabah	MD Ranau	Tanah Merah (Simpang Jln	50		20.0			15

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
			Air Panas Poring-Sandakan)						
222	Sabah	Lem. Bandaran Kudat	Batu 7.5, Jln Sikuati Kudat	70		10.0			10
223	Sabah	MP Tawau	Bukit Gemuk Tawau			10.0			15
224	Sabah	MD Penampang	Kayu Madang. Talipok Bandaraya						
225	Sabah	MD Siitang	Jln Pantai, Merintaman	10		20.0			0.8
226	Sabah	MD Turaran	Kg Tajau	0.5		5.0			1.6
227	Sabah	MD Kinbatangan	Pekan Kota Kinabataingan	1		10.0			2
228	Sabah	MP Sandakan	Jln Fook Dim, Batu 8, Jln Labuk Sandakan	300		20.0			101.2
229	Sabah	MD Beaufort	Jln Lama Beaufort-Kota Kinabaru Baru	64		15.0			5
230	Sabah	MD Kuala Penyu	Kepayan Skim	16		5.0			0.4
231	Sabah	MD Kota Marudu/Pitas	Pekan Lama, Jln Timbun	5		5.0			0.8
232	Sabah	MD Keningau	Jln Ulu Liawan Kenenggau	106		20.0			10.1
233	Sabah	M\D Tenom	Kg Amboi	120		15.0			3.8
234	Sabah	MD Beluran	Pekan Beluran	8		30.0			20.2
235	Sabah		Pekan Telupid	6		25.0			6.1
236	Sabah	MD Kunak	Kg Pankalan Madai	3		5.0			6.1
237	Sabah	MD Nabawan	nil						
238	Sabah	MD Semporna	nil						
239	Sabah	MD Papar	Kg Kelananhan			4.0		19.0	1
240	Sabah	MD Penampang	Kg Gumbahon Duvanson			13.0		8.0	62.4
241	Sabah	MD Kinbatangan	Kota Kinbatangan sewerage site			11.0		3.0	4.27
242	Sabah	MD Keningau	Jln Meningit, Keingau			21.0		13.0	0.8
243	Sabah	MD Tenom	Jln Binaie, Tenom			16.0		17.0	4.52
	SUB-	**1133.5**							

	State	LA	Site Name / Address	Generation Rate, mt/d	CLASS	Life Span, (Yrs)	Open, (Yrs)	Closed, (Yrs)	Area, (ha)
	TOTAL								
	GRAND TOTAL			**17517.4**					

Appendix C - Distribution of Swine Population According to States (2002)

State	**SPP according to farm size**							**Total**	**%**
	<=100	**101-500**	**501-1,000**	**1,001-2,000**	**2,001-5,000**	**5,001-10,000**	**>10,000**		
Kedah	1,700	3,900	0	0	0	0	0	5,600	0.4
Perlis	0	0	0	1,300	0	0	0	1,300	0.1
Penang	1,537	16,055	53,364	94,338	95,979	24,551	12,850	298,674	21.3
Perak	755	7,676	15,963	34,745	149,320	158,400	75,000	441,859	31.6
Selangor	0	2,733	31,260	81,600	76,045	28,730	12,000	232,368	16.6
N.Sembilan	0	0	0	1,500	0	0	0	1,500	0.1
Malacca	160	3,549	20,013	42,800	38,300	28,760	0	133,582	9.5
Johore	0	1,900	7,010	8,600	66,400	78,300	114,600	276,810	19.8
Pahang	0	0	0	1,026	0	6,000	0	7,026	0.5
Trengganu	0	0	0	0	0	0	0	0	0.0
Kelantan	1,216							1,216	0.1
Total Peninsula	5,368	35,813	127,610	265,909	426,044	324,741	214,450	1,399,935	100
Sarawak									
Sabah									
Total Malaysia									

Appendix D - Total Fresh Fruit Bunches Processed by Mills in Malaysia (2003)

State	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Johor	921,564	823,074	1,053,169	1,211,534	1,261,644	1,305,508	1,370,140	1,289,599	1,301,622	1,173,355	1,019,749	1,217,
Kedah	31,384	45,421	62,489	64,126	63,892	59,614	58,154	45,818	44,764	37,037	30,660	34,8
Kelantan	70,451	54,158	79,739	105,978	115,164	116,551	115,578	110,270	113,788	109,164	83,603	95,8
Melaka	17,179	17,142	22,899	21,151	19,832	17,864	18,662	18,412	17,613	16,151	12,804	14,1
N.Sembilan	137,927	154,617	203,564	213,468	219,493	218,877	245,653	230,494	208,728	173,427	137,084	151,7
Pahang	590,629	563,985	800,574	943,469	976,306	1,036,058	1,097,748	1,043,205	1,029,369	880,640	746,309	862,8
Penang	20,094	22,047	27,388	30,022	31,028	28,607	29,053	25,327	22,238	18,702	15,772	19,4
Perak	557,778	519,594	628,964	636,316	684,733	718,657	828,840	777,183	699,398	611,247	502,897	651,0
Selangor	213,934	222,180	287,174	300,890	315,536	305,594	326,065	301,657	278,101	252,519	215,268	256,0
Terengganu	144,124	115,557	148,343	170,112	185,516	192,553	208,218	202,429	221,446	206,714	157,388	182,8
P.Malaysia	2,705,064	2,537,775	3,314,303	3,697,066	3,873,144	3,999,883	4,298,111	4,044,394	3,937,067	3,478,956	2,921,534	3,486,
Sabah	1,420,534	1,132,749	1,422,027	1,601,796	1,817,266	1,856,033	1,953,188	1,975,173	2,050,310	2,056,445	1,950,974	1,915,
Sarawak	300,779	242,281	281,823	277,767	284,819	332,710	396,107	428,450	440,020	408,105	363,665	408,3
Sabah/Sarawak	1,721,313	1,375,030	1,703,850	1,879,563	2,102,085	2,188,743	2,349,295	2,403,623	2,490,330	2,464,550	2,314,639	2,323,
MALAYSIA	4,426,377	3,912,805	5,018,153	5,576,629	5,975,229	6,188,626	6,647,406	6,448,017	6,427,397	5,943,506	5,236,173	5,809,

Appendix E - Estimated POME and GHG emissions in Malaysia (2003)

State	POME[117] (m^3/yr)	BIOGAS (cubic m/yr)	CH_4 (cubic m/yr)	CH_4 (mT/yr)	MT CO_2 equiv.
Johor	704,975	19,739,311	11,843,587	8,527	179,075
Kedah	128,276	3,591,739	2,155,044	1,552	32,584
Kelantan	1,401,431	39,240,079	23,544,048	16,952	355,986
Melaka	6,318,640	176,921,926	106,153,155	76,430	1,605,036
N.Sembilan	173,757	4,865,196	2,919,118	2,102	44,137
Pahang	4,690,199	131,325,583	78,795,350	56,733	1,191,386
Penang	1,963,874	54,988,483	32,993,090	23,755	498,856
Perak	1,275,919	35,725,721	21,435,432	15,434	324,104
Selangor	25,370,061	710,361,708	426,217,025	306,876	6,444,401
Terengganu	12,693,101	355,406,821	213,244,092	153,536	3,224,251
P.Malaysia	54,720,235	1,532,166,567	919,299,940	661,896	13,899,815
Sabah	15,192,564	425,391,790	255,235,074	183,769	3,859,154
Sarawak	40,562,625	1,135,753,498	681,452,099	490,646	10,303,556
Sabah/ Sarawak	55,755,189	1,561,145,288	936,687,173	674,415	14,162,710
MALAYSIA	**110,475,423**	**3,093,311,855**	**1,855,987,113**	**1,336,311**	**28,062,525**

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[117] Based on estimation of 0.65 m^3 per 1 mT of FFB processed.

Appendix F - Statistics Department Manufacturing Industries

1	Industry	**43**	API Fuel oil
2	Sweetened Condensed Milk	**44**	Gasoline
3	Milk Powder as infant feed	**45**	Pneumatic tires
4	Full cream powdered milk	**46**	Inner tubes
5	Milk drinks	**47**	Rubber RSS
6	Canned pineapple	**48**	SMR rubber
7	Canned fish	**49**	Processed latex
8	Frozen shrimps / prawns	**50**	Rubber gloves
9	Crude coconut oil	**51**	Catheters
10	Margerine	**52**	Rubber sheets
11	Blended cooking oil	**53**	Rubber compounds
12	Whole rice	**54**	Rubber bands
13	Broken rice	**55**	Rubber footwear
14	Wheat flour	**56**	PVC pipes
15	Biscuit	**57**	Earthen bricks
16	Refined Sugar	**58**	Ceramic tiles
17	Mixed poultry feed	**59**	Cement
18	Sweet carbonated beverages	**60**	Cement roofing tiles
19	Sweet non-carbonated beverages	**61**	Asbestos cement flat sheets
20	Cigarettes	**62**	Asbestos roofing sheets
21	Cotton yarn	**63**	Ready mix concrete
22	Cotton cloth	**64**	Iron / Steel bars and rods
23	Male trouser	**65**	GI iron sheets
24	Male shirt	**66**	Welded iron/steel pipe/tube/fitting
25	Blouse	**67**	Tins
26	Dress	**68**	Iron / Steel drums
27	Veneer in sheets	**69**	GI iron/steel wire
28	Block board	**70**	Wire mesh / net
29	Plywood	**71**	Telephone / Telegraphic cable
30	Timber moldings	**72**	Insulated wire / cable
31	Dressed lumber	**73**	Household refrigerator
32	Herbicides as liquid	**74**	Room air conditioner
33	Herbicides non-liquid	**75**	Television set
34	Fertilizers	**76**	Radio
35	Emulsion paint	**77**	Semi-conductor
36	Gloss paint	**78**	Electronic transistor
37	Undercoat	**79**	Integrated circuit

38	Primer	**80**	Passenger car < 1600 cc
39	Toilet soap	**81**	Passenger car > 1600 cc
40	Detergent powder	**82**	Commercial vehicle
41	Kerosene	**83**	Motorcycle / Scooter
42	LPG		

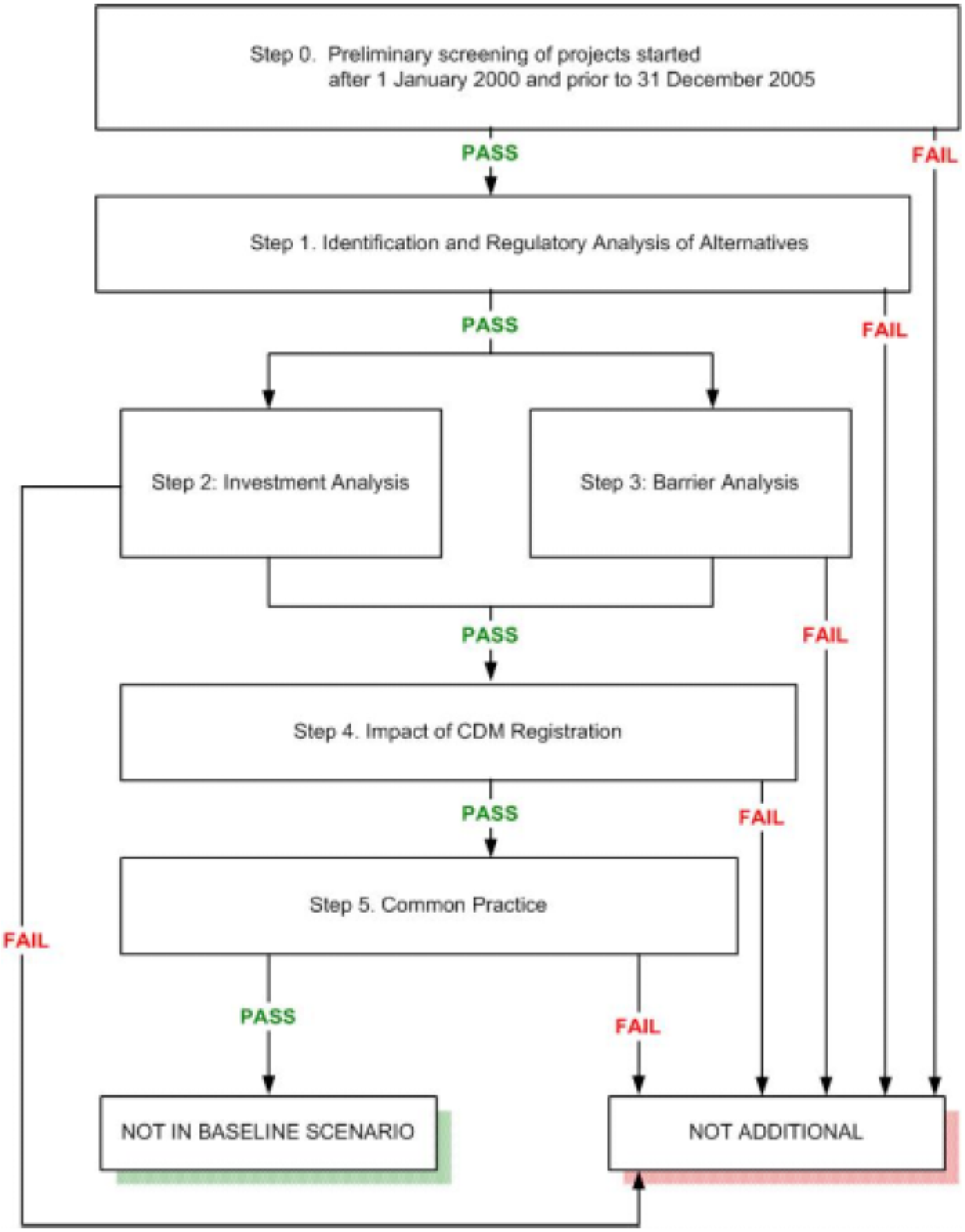
Appendix G - Reduced Categories, Facility Numbers and Production

INDUSTRY	Production			
	No. sites	Sales ex-factory, (RM '000)	Product, (mT)	Organic waste
Other Milk product	15	2256468	302535	Y
Canned pineapple	3	63616	18897	Y
All process aquatic	35	994734	47729	Y
fish landing			1320000	
aquaculture			197000	
Coconut oil	18	69724	18795	Y
Other fats	9	724432	80348	Y
oleochemical (palm refinery)	42		1700000	Y
Rice mill	42	615222	466549	Y
Flour Mill	11	952868	701044	Y
Biscuit	46	977574	124288	Y
Refined Sugar	5	1640093	1424086	Y
Cocoa, chocolate, confectionery	34	1431607		Y
Other food	31	1269604		Y
fruits			1349000	Y
vegetables			813000	Y
meat (red + poultry)			110000	Y
Animal feed	42	2368246	2381565	Y
Beverages	10	608397	524748	Y
Natural fibre weave / spin	15	618938	236960	Y
Dye, bleach, print, finish	12	805300		Y
Synthetic textile	9	2554364		Y
Tannery / Leather	7	51778		Y
Pulp, paper, paperboard	12	1465891		Y
Boxes / Containers of paper	81	2011285		Y
Other paper / paperboard items	35	1025876		Y
Printing, publish	124	3909000		Y
Fertilizer / Pesticide	20	1144899	1503981	Y
Paint / varnish / lacquer	33	1399340	139668	Y
Pharmaceutical	43	557001		Y
Soap and cleaning chemical	18	987871	106876	Y
Other Chemical	61	2840916		Y
Crude Oil Refinery	5	27980544	20298669	Y
Misc. Petroleum / Coal product	26	632358		Y
Rubber remill / Latex product	55	4001186	1135637	Y
Other rubber product	190	5860453		Y
latex products (glove, catheter, thread)	138		342000	Y

Appendix H - GHG Generation by Selected Industries

	Production						Wastewater				Contaminant level, COD					CH4 conversion		Wastewater Treatment		
INDUSTRY	**No. sites**	**note**	**Product, (mT)**	**other**	**unit**	**Ave Product, (mT)**	**WW ratio**	**unit**	**Est'd WW output**	**unit**	**COD**	**unit**	**COD**	**unit**	**COD mass, mT/yr**	**(0.3m^3/kg COD; 0.6 kg/m^3; 1000kg/mT) mT/year**	**CO_2: CH_4 = 21**	**likelihood of full WWTP**	**likelihood of anaerobic treatment**	**flaring?**
case: fish processing						1364	46	m^3/mT	62730	m^3/yr	5000	mg/L	5	kg/m^3	3.14E+02	56	1186	low	low to none	NA
case: oleochemical (palm refinery)	42		1700000			40476	9.3	m^3/hr	81468	m^3/yr	5000	mg/L	5	kg/m^3	4.07E+02	73	1540	high	some	yes
case: animal rendering		animal est.	2000				1.25E+00	m^3/mT animal	2500	m^3/yr	10000	mg/L	10	kg/m^3	2.50E+01	5	95	medium	low	NA
case: fruit			10000				14	m^3/mT	1.35E+05	m^3/yr	1400	mg/L	1.4	kg/m^3	1.89E+02	34	714	low	low to none	NA
case: red meat slaughterhouse		mT/day	600				7.40E+00	m^3/mT	1.62E+06	m^3/yr	21800	mg/L	21.8	kg/m^3	3.53E+04	6359	133544	medium	low to none	NA
case: process & packinghouse		mT/day	350				1.25E+01	m^3/mT	1.60E+06	m^3/yr	32000	mg/L	32	kg/m^3	5.11E+04	9198	193158	medium	low to none	NA
case: poultry		bird/day	73000	1.74	kg/bird	46362	3.44E+01	m^3/1000	9.17E+05	m^3/yr	9890	mg/L	9.89	kg/m^3	9.07E+03	1632	34266	high	low	NA
case: brewery	2*				L/year	1.00E+07	12	m^3/m^3	1.20E+05	m^3/yr	2250	mg/L	2.25	kg/m^3	2.70E+02	49	1021	high	high	yes
case: ethanol distillery (cane molasses)	3*				L/year	7.00E+06	11	m^3/m^3	7.70E+04	m^3/yr	31000	mg/L	31	kg/m^3	2.39E+03	430	9023	high	high	yes
case: soft drink									1.83E+06	m^3/yr	1400	mg/L	1.4	kg/m^3	2.56E+03	460	9658	high	low	NA
case: synthetic Rayon		est.	20000				60	m^3/mT	1.20E+06	m^3/yr	2800	mg/L	2.8	kg/m^3	3.36E+03	605	12701	medium	low	NA
case: Tannery							188	m^3/day	68438	m^3/yr	5000	mg/L	5	kg/m^3	3.42E+02	62	1293	medium	low	NA
case: waste paper mill			182500						5000	m^3/d	2500	mg/L	2.5	kg/m^3	4562.5	821	17246	high	low to none	NA
case: latex products (glove, catheter, thread)	138		342000			2478	600	m^3/day	219000	m^3/yr	1500	mg/L	1.5	kg/m^3	3.29E+02	59	1242	high	some	yes
case: Natural rubber	100*		850000			8500	1300	m^3/day	474500	m^3/yr	3500	mg/L	3.5	kg/m^3	1.66E+03	299	6278	medium	medium	yes

Appendix I - Additionality Assessment Scheme by CDM Methology Panel



Appendix J - Analysis of Landfill Records by Size Class

Summary of Landfills with Generation Rate Records							
State	**>400**	**300-400**	**200-300**	**150-200**	**1-150**	**Total No.**	**Total Generation, (mt/day)**
Selangor	6	2	1	2	1	12	4244
DBKL	1					1	1415
N. Sembilan			1		8	9	563
Melaka	1			1	2	4	973
Johor	1	1	1	2	18	23	2042
Pahang	1			1	10	12	829
Terengganu	1			1	5	7	753
Kelantan			1		11	12	377
Perak	1			2	20	23	1176
Penang	2			2	0	4	1300
Kedah		1	1	1	7	10	855
Perlis					1	1	42
Sarawak	1	1		2	30	33	995
Sabah		2			15	17	851
Grand Totals	**15**	**7**	**5**	**14**	**128**	**168**	**16415**
of which **Closed**, Approximate	7	1	2	2	59	71	
Total Reported Landfills							243
Landfills with unknown Status							45
Landfills with Recorded Lifespan estimate							198
Recorded Closure estimate							71
Average Lifespan, years			17	Ave. Lifespan Deviation, yrs			9-25
Ave. Period Operating for Open LF, years			14	Ave. Open Period Deviation, yrs			7-21
Average Dormancy post-closure, years			8	Ave. Closure Deviation, yrs			2-14

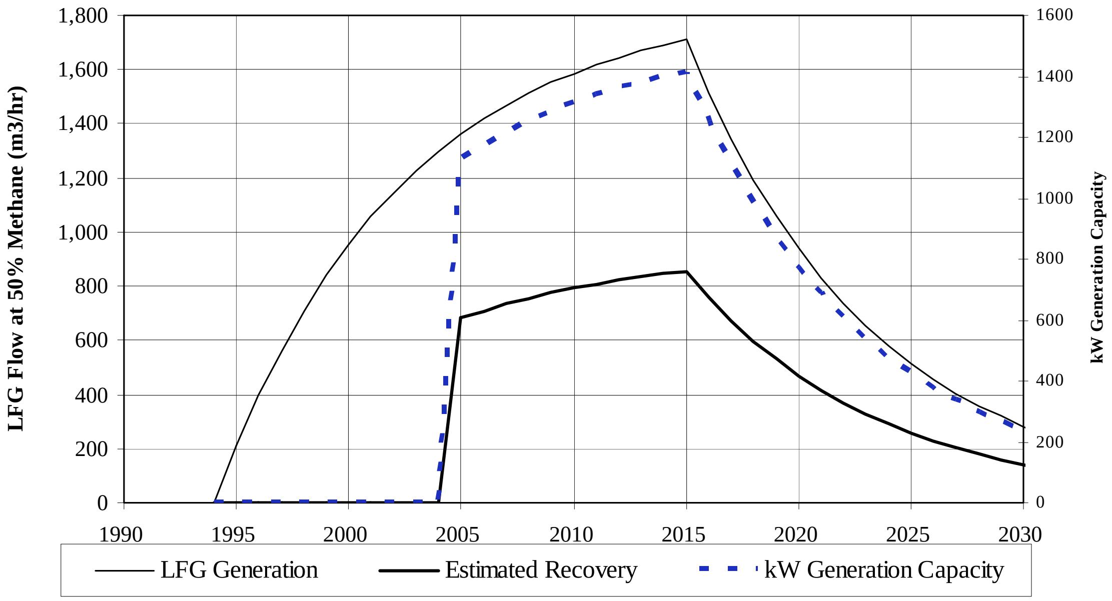
Appendix K - Summary of First Order Decay Model for LFG Generation and Power Generation

Incremental 1 MW Capacity and Years Sustainable					
k	**Lo**	**MW**	**400 mt/yr Yrs**	**300 mt/yr Yrs**	**150 mt/yr Yrs**
0.4	**250**	**8**	11	-	-
		7	-	-	-
		6	-	11	-
		5	1	-	-
		4	-	1	-
		3	1	-	11
		2	1	1	1
		1	2	2	1
0.08	**250**	**5**	8	-	-
		4	7	5	-
		3	4	10	-
		2	5	5	5
		1	9	9	15
0.12	**140**	**3**	12	-	-
		2	4	13	-
		1	6	6	13
0.4	**84**	**2**	11	11	-
		1	2	1	11
0.08	**84**	**1**	19	15	-

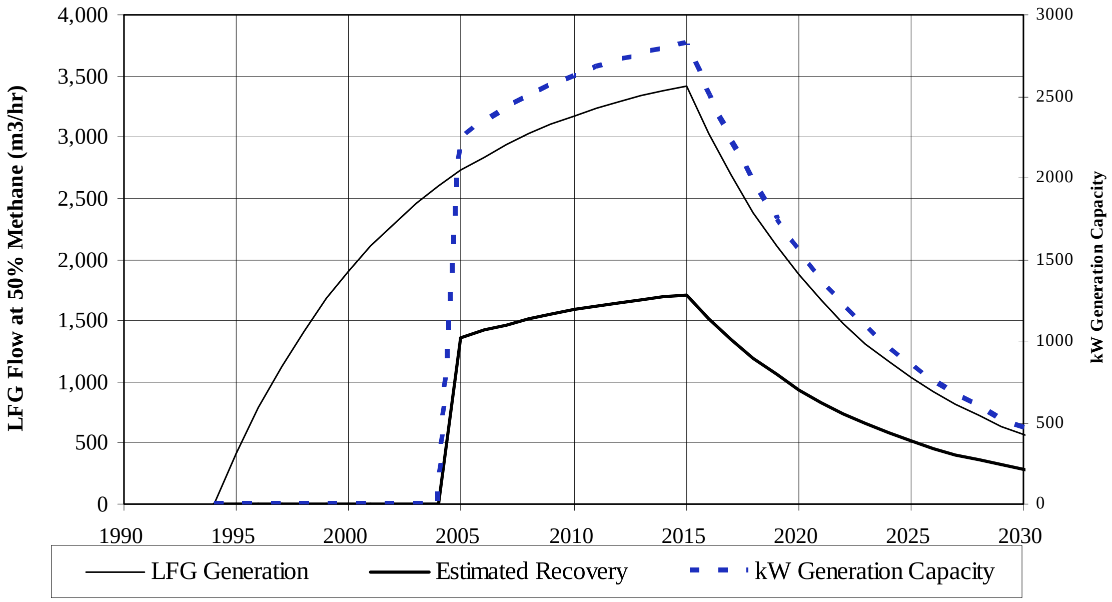
Note: 8 MW & 11 years represents 8 MW operating for 11 continuous years, etc..

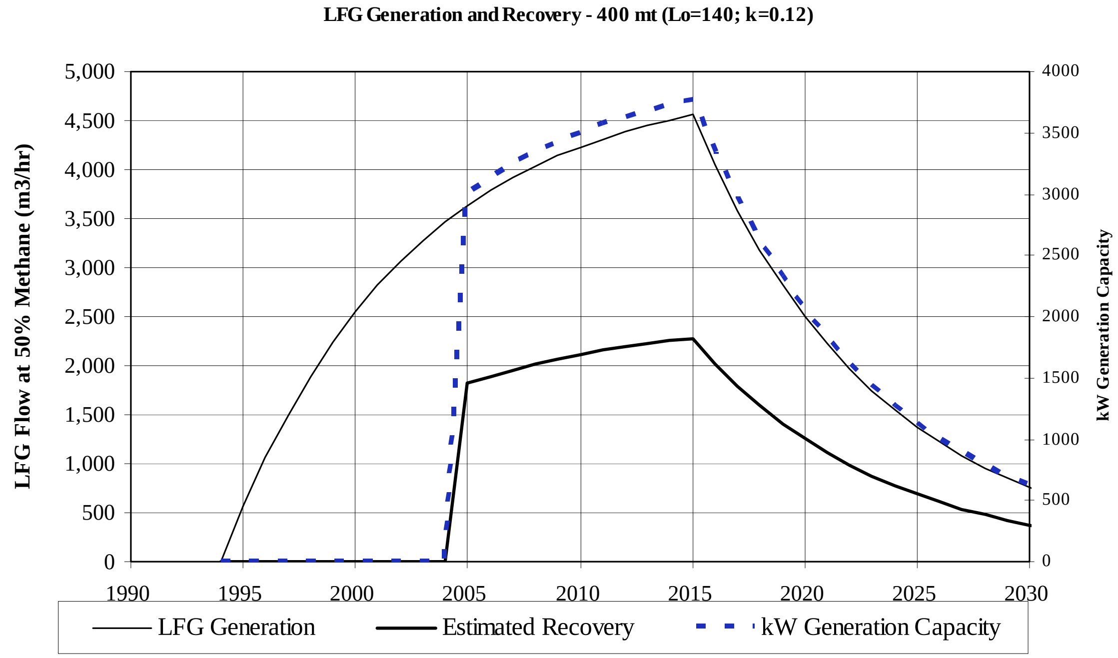
Appendix L - Graphical Results of First Order Decay Model for LFG Generation for Estimation of Power Generation Capacity (150, 300 & 400 mT/day Landfills)

LFG Generation and Recovery - 150 mt (Lo=140; k=0.12)

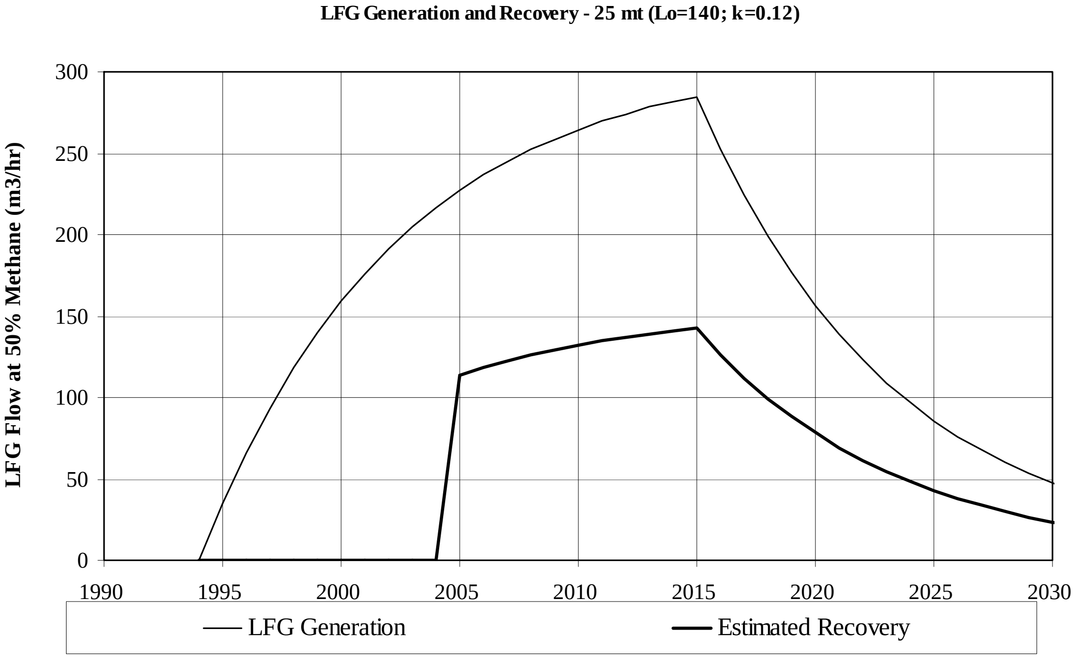


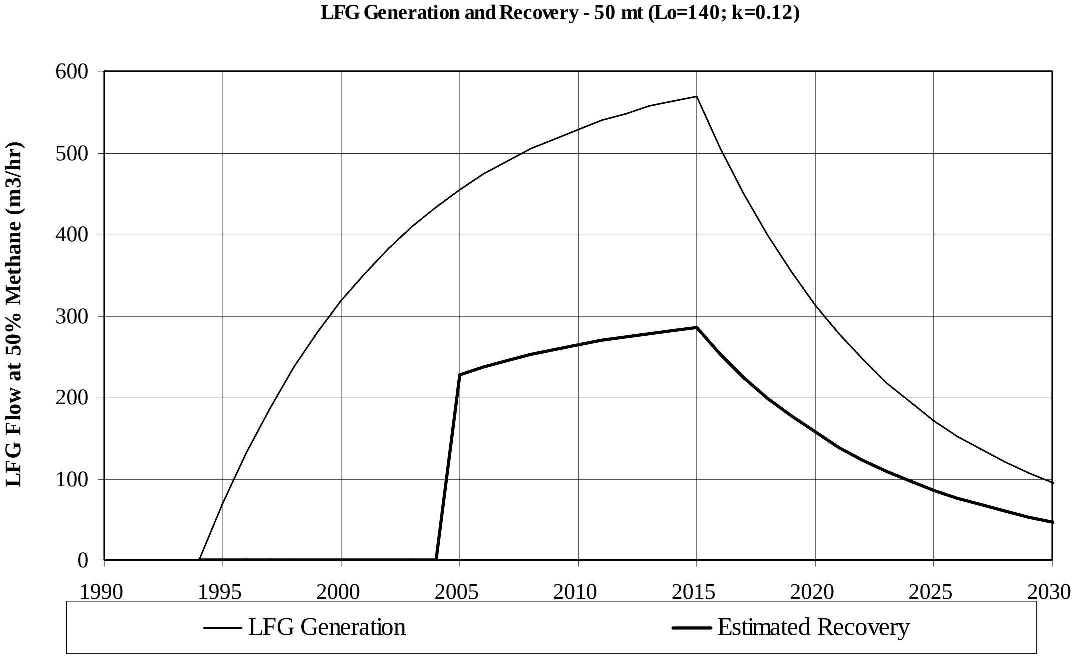
LFG Generation and Recovery - 300 mt (Lo=140; k=0.12)



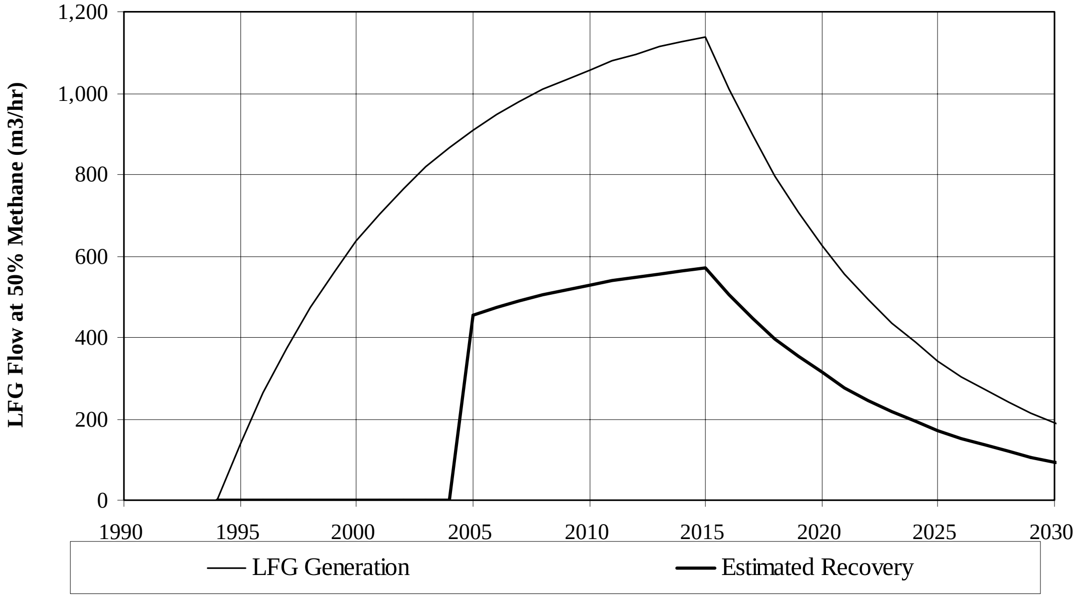

LFG Generation and Recovery - 400 mt (Lo=140; k=0.12)
LFG Flow at 50% Methane (m3/hr)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
kW Generation Capacity
4000
3500
3000
2500
2000
1500
1000
500
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
LFG Generation
Estimated Recovery
kW Generation Capacity

Appendix M - Graphical Results of FOD Model for LFG Generation for Flaring (25, 50 and 100 mT/day Landfills)





LFG Generation and Recovery - 100 mt (Lo=140; k=0.12)



Appendix N - Financial Models for Landfill Gas Utilization

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

Project Analyzed: **25 mT MSW Landfill**

Key Assumptions (Cells of input values in green)

Financial:				**Notes/Source**
Exchange Rate, RM/USD			**3.8**	
Uses of funds, Ringgit				
	Planning and gas collection		**627,000**	**M10**
	Electricity production incl gridconnection		**0**	
	Enginering and contingencies		**62,700**	
	Total Capital Expenditure		**689,700**	
Sources of funds, Ringgit				
	Equity	**30%**	**206,910**	
	Debt	**70%**	**482,790**	
	Total sources	**100%**	**689,700**	
Operating Expenditure per year (opex), Ringgit				
	Maintenance		**62,700**	**M11**
	Manpower		**54,000**	**M11**
	Others		**11,670**	**M11**
Revenue per year, Ringgit				
	Electricity sales tariff, RM sen/kWh		**N/A**	
	Sales Units, kWh		**N/A**	
	Sales income		**0**	
CDM-related Parameters				
	Methane to CO2		**21**	
	Price of CERs in USD/ton CO2		**5.0**	
NO Flaring of Excess	**Collected & flared methane per year, mt**		**716**	**M12**
	CDM Revenues, Ringgit		**285,684**	
	CDM Transaction Costs, % of revenue		**15%**	**M5**
Assumptions on Debt Financing				
	Interest Rate		**7%**	
	Loan Tenure		**10**	**years**
Other Assumptions:				

Operational:			**Notes/Source**
Assumptions on Facility			
	Gross Facility Capacity, MW	**0**	**CASE**
	Auxiliary consumption	**0%**	
	Net Capacity (MW)	**0.0**	
	Capacity Factor	**N/A**	
	Units Generated per year, kWh	**N/A**	
	Plant life (years)	**10**	
	Plant efficiency		
	or, Heat Rate, KJ/kWh	**11,383**	
Assumptions on Fuel			
	Fuel Type	**Landfill gas**	
	Lower Heating value, kJ/kg LFG	26,163	
	Fuel Price, RM/ton	**0**	
	Methane content, %	**50%**	**M9**

RESULTS

A. PROJECT IRR	**N/A**
B. PROJECT IRR (with CDM)	**9.4%**
D. EQUITY IRR	**N/A**
E. EQUITY IRR (with CDM)	**12.3%**

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

Project Analyzed: 50 mT MSW Landfill

Key Assumptions (Cells of input values in green)

Financial:				Notes/Source
Exchange Rate, RM/USD			3.8	
Uses of funds, Ringgit				
	Planning and gas collection		912,000	M10
	Electricity production incl gridconnection		0	
	Enginering and contingencies		91,200	
	Total Capital Expenditure		1,003,200	
Sources of funds, Ringgit				
	Equity	30%	300,960	
	Debt	70%	702,240	
	Total sources	100%	1,003,200	
Operating Expenditure per year (opex), Ringgit				
	Maintenance		91,200	M11
	Manpower		84,000	M11
	Others		17,520	M11
Revenue per year, Ringgit				
	Electricity sales tariff, RM sen/kWh		N/A	
	Sales Units, kWh		N/A	
	Sales income		0	
CDM-related Parameters				
	Methane to CO2		21	
	Price of CERs in USD/ton CO2		5.0	
NO Flaring of Excess	Collected & flared methane per year, mt		1432	M12
	CDM Revenues, Ringgit		571,368	
	CDM Transaction Costs, % of revenue		15%	M5
Assumptions on Debt Financing				
	Interest Rate		7%	
	Loan Tenure		10	years
Other Assumptions:				

Operational:			Notes/Source
Assumptions on Facility			
	Gross Facility Capacity, MW	0	CASE
	Auxiliary consumption	0%	
	Net Capacity (MW)	0.0	
	Capacity Factor	N/A	
	Units Generated per year, kWh	N/A	
	Plant life (years)	10	
	Plant efficiency		
	or, Heat Rate, KJ/kWh	11,383	
Assumptions on Fuel			
	Fuel Type	Landfill gas	
	Lower Heating value, kJ/kg LFG	26,163	
	Fuel Price, RM/ton	0	
	Methane content, %	50%	M9

RESULTS

A. PROJECT IRR	N/A
B. PROJECT IRR (with CDM)	22.9%
D. EQUITY IRR	N/A
E. EQUITY IRR (with CDM)	46.2%

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

Project Analyzed: 100 mT MSW Landfill

Key Assumptions (Cells of input values in green)

Financial:				**Notes/Source**
Exchange Rate, RM/USD			3.8	
Uses of funds, Ringgit				
	Planning and gas collection		1,254,000	M10
	Electricity production incl gridconnection		0	
	Enginering and contingencies		125,400	
	Total Capital Expenditure		1,379,400	
Sources of funds, Ringgit				
	Equity	30%	413,820	
	Debt	70%	965,580	
	Total sources	100%	1,379,400	
Operating Expenditure per year (opex), Ringgit				
	Maintenance		125,400	M11
	Manpower		144,000	M11
	Others		26,940	M11
Revenue per year, Ringgit				
	Electricity sales tariff, RM sen/kWh		N/A	
	Sales Units, kWh		N/A	
	Sales income		0	
CDM-related Parameters				
	Methane to CO2		21	
	Price of CERs in USD/ton CO2		5.0	
NO Flaring of Excess	**Collected & flared methane per year, mt**		2864	M12
	CDM Revenues, Ringgit		1,142,736	
	CDM Transaction Costs, % of revenue		15%	M5
Assumptions on Debt Financing				
	Interest Rate		7%	
	Loan Tenure		10	years
Other Assumptions:				

Operational:			**Notes/Source**
Assumptions on Facility			
	Gross Facility Capacity, MW	0	CASE
	Auxiliary consumption	0%	
	Net Capacity (MW)	0.0	
	Capacity Factor	N/A	
	Units Generated per year, kWh	N/A	
	Plant life (years)	10	
	Plant efficiency		
	or, Heat Rate, KJ/kWh	11,383	
Assumptions on Fuel			
	Fuel Type	Landfill gas	
	Lower Heating value, kJ/kg LFG	26,163	
	Fuel Price, RM/ton	0	
	Methane content, %	50%	M9

RESULTS

A. PROJECT IRR	N/A
B. PROJECT IRR (with CDM)	39.4%
D. EQUITY IRR	N/A
E. EQUITY IRR (with CDM)	85.7%

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

Project Analyzed: **150 mT MSW Landfill**

Key Assumptions (Cells of input values in green)

Financial:				**Notes/Source**	
Exchange Rate, RM/USD			**3.8**		
Uses of funds, Ringgit					
	Planning and gas collection		**1,254,000**	**M1**	
	Electricity production incl gridconnection		**3,593,000**	**M2**	
	Enginering and contingencies		**993,930**	**M1**	
	Total Capital Expenditure		**5,840,930**		**5,840,930 RM/MW**
Sources of funds, Ringgit					
	Equity	**30%**	**1,752,279**		
	Debt	**70%**	**4,088,651**		
	Total sources	**100%**	**5,840,930**		
Operating Expenditure per year (opex), Ringgit					
	Maintenance		**373,300**	**M3**	
	Manpower		**108,000**	**M3**	
	Others		**48,130**	**M3**	
Revenue per year, Ringgit					
	Electricity sales tariff, RM sen/kWh		**16.7**	**M4**	
	Sales Units, kWh		**7,008,000**		
	Sales income		**1,170,336**		
CDM-related Parameters					
	Methane to CO2		**21**		
	Price of CERs in USD/ton CO2		**5.0**		
NO Flaring of Excess	**Saved methane emissions per year, mt**		**1525**		
	CDM Revenues, Ringgit		**608,295**		
	CDM Transaction Costs, % of revenue		**15%**	**M5**	
Assumptions on Debt Financing					
	Interest Rate		**7%**		
	Loan Tenure		**10**	**years**	

Other Assumptions:

1. Effects of income tax are not considered.

2. 1 km connection distance to grid assumed for all cases

Operational:			**Notes/Source**
Assumptions on Facility			
	Gross Facility Capacity, MW	**1**	**CASE**
	Auxiliary consumption	**0%**	
	Net Capacity (MW)	**1.0**	**IRP**
	Capacity Factor	**80.0%**	**M6**
	Units Generated per year, kWh	**7,008,000**	
	Plant life (years)	**10**	
	Plant efficiency		
	or, Heat Rate, KJ/kWh	**11,383**	**M7**
Assumptions on Fuel			
	Fuel Type	**Landfill gas**	
	Lower Heating value, kJ/kg LFG	26,163	**M8**
	Fuel Price, RM/ton	**0**	
	Methane content, %	**50%**	**M9**

RESULTS

A. PROJECT IRR	**1.6%**
B. PROJECT IRR (with CDM)	**13.2%**
C. PROJECT IRR (with CDM, 50% Upfront)	**16.9%**
Increase due to CDM,sen per kWh	**8.680013378**
D. EQUITY IRR	**-13.2%**
E. EQUITY IRR (with CDM)	**22.4%**
F. EQUITY IRR (with CDM, 50% Upfront)	**88.8%**
Increase due to CDM,sen per kWh	**8.680013378**

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

Project Analyzed: 300 mT MSW Landfill

Key Assumptions (Cells of input values in green)

Financial:				**Notes/Source**	
Exchange Rate, RM/USD			3.8		
Uses of funds, Ringgit					
	Planning and gas collection		2,394,000	M1	
	Electricity production incl gridconnection		6,186,000	M2	
	Enginering and contingencies		1,777,860	M1	
	Total Capital Expenditure		10,357,860		5,178,930 RM/MW
Sources of funds, Ringgit					
	Equity	30%	3,107,358		
	Debt	70%	7,250,502		
	Total sources	100%	10,357,860		
Operating Expenditure per year (opex), Ringgit					
	Maintenance		746,600	M3	
	Manpower		147,000	M3	
	Others		89,360	M3	
Revenue per year, Ringgit					
	Electricity sales tariff, RM sen/kWh		16.7	M4	
	Sales Units, kWh		14,016,000		
	Sales income		2,340,672		
CDM-related Parameters					
	Methane to CO2		21		
	Price of CERs in USD/ton CO2		5.0		
NO Flaring of Excess	**Saved methane emissions per year, mt**		3049		
	CDM Revenues, Ringgit		1,216,591		
	CDM Transaction Costs, % of revenue		15%	M5	
Assumptions on Debt Financing					
	Interest Rate		7%		
	Loan Tenure		10	years	

Other Assumptions:

1. Effects of income tax are not considered.
2. 1 km connection distance to grid assumed for all cases

Operational:			**Notes/Source**
Assumptions on Facility			
	Gross Facility Capacity, MW	2	CASE
	Auxiliary consumption	0%	
	Net Capacity (MW)	2.0	IRP
	Capacity Factor	80.0%	M6
	Units Generated per year, kWh	14,016,000	
	Plant life (years)	10	
	Plant efficiency		
	or, Heat Rate, KJ/kWh	11,383	M7
Assumptions on Fuel			
	Fuel Type	Landfill gas	
	Lower Heating value, kJ/kg LFG	26,163	M8
	Fuel Price, RM/ton	0	
	Methane content, %	50%	M9

RESULTS

A. PROJECT IRR	4.8%
B. PROJECT IRR (with CDM)	16.8%
C. PROJECT IRR (with CDM, 50% Upfront)	22.3%
Increase due to CDM,sen per kWh	8.680013378
D. EQUITY IRR	-1.3%
E. EQUITY IRR (with CDM)	31.4%
F. EQUITY IRR (with CDM, 50% Upfront)	137.0%
Increase due to CDM,sen per kWh	8.680013378

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

Project Analyzed: 400 mT MSW Landfill

Key Assumptions (Cells of input values in green)

Financial:				Notes/Source	
Exchange Rate, RM/USD			3.8		
Uses of funds, Ringgit					
	Planning and gas collection		3,534,000	M1	
	Electricity production incl gridconnection		8,779,000	M2	
	Enginering and contingencies		2,561,790	M1	
	Total Capital Expenditure		14,874,790		4,958,263 RM/MW
Sources of funds, Ringgit					
	Equity	30%	4,462,437		
	Debt	70%	10,412,353		
	Total sources	100%	14,874,790		
Operating Expenditure per year (opex), Ringgit					
	Maintenance		1,119,900	M3	
	Manpower		192,000	M3	
	Others		131,190	M3	
Revenue per year, Ringgit					
	Electricity sales tariff, RM sen/kWh		16.7	M4	
	Sales Units, kWh		21,024,000		
	Sales income		3,511,008		
CDM-related Parameters					
	Methane to CO2		21		
	Price of CERs in USD/ton CO2		5.0		
NO Flaring of Excess	Saved methane emissions per year, mt		4574		
	CDM Revenues, Ringgit		1,824,886		
	CDM Transaction Costs, % of revenue		15%	M5	
Assumptions on Debt Financing					
	Interest Rate		7%		
	Loan Tenure		10	years	

Other Assumptions:

1. Effects of income tax are not considered.
2. 1 km connection distance to grid assumed for all cases

Operational:			Notes/Source
Assumptions on Facility			
	Gross Facility Capacity, MW	3	CASE
	Auxiliary consumption	0%	
	Net Capacity (MW)	3.0	IRP
	Capacity Factor	80.0%	M6
	Units Generated per year, kWh	21,024,000	
	Plant life (years)	10	
	Plant efficiency		
	or, Heat Rate, KJ/kWh	11,383	M7
Assumptions on Fuel			
	Fuel Type	Landfill gas	
	Lower Heating value, kJ/kg LFG	26,163	M8
	Fuel Price, RM/ton	0	
	Methane content, %	50%	M9

RESULTS

A. PROJECT IRR	5.9%
B. PROJECT IRR (with CDM)	18.1%
C. PROJECT IRR (with CDM, 50% Upfront)	24.4%
Increase due to CDM,sen per kWh	8.680013378
D. EQUITY IRR	2.2%
E. EQUITY IRR (with CDM)	34.6%
F. EQUITY IRR (with CDM, 50% Upfront)	154.5%
Increase due to CDM,sen per kWh	8.680013378

	Notes/Sources
M1	**SCS Engineers Inc.; Core Competencies Sdn. Bhd.**
M2	**1 KM distance to grid connection assumed**
M3	**OPEX described in report**
M4	**SREP from TNB**
M5	**Soeren/Bjoern's (PTM) CDM capacity building project (draft 2004)**
M6	**Capacity factor assumption for base case**
M7	**kJ/kW-hr, heat rate from SCS Engineers Inc.**
M8	**kJ/kg of landfill gas from SCS Engineers Inc.**
M9	**methane content assumed 50% described in report**
M12	**collected & flared methane as 50% of landfill generation average over 10 initial producing years**

Appendix O - Cost for Technology Options for Biogas Utilization

Project	**Cost (RM)**					**Life time of investment**	**efficiency**	**Expected Output (biogas is fully utilized)**
Cogen (Heat & Power) Using Gas Turbine **(1 MW_e)**	Component 1 (Digesters)	Component 2 (Biogas Storage System)	Component 3 (Gas Turbine and miscellaneous)	Component 4	**Total**	21 years	Overall = 78 % Thermal = 54 % Power = 24 %	Heat = 4.3x10^7MJ/yr Electric =1.9x10^7MJ/yr =5.3x10^6 kWh
	Capital							
	1,960,000	881,000	9,000,000		**11,841,000**			
	O & M							
	58,800/yr	26,430/yr	270,000/yr		**355,230**/yr			
Cogen (Heat & Power) Using Gas Engine **(1.25 MW_e)**	Component 1 (Digesters)	Component 2 (Biogas Storage System)	Component 3 (Gas Treatment)	Component 4 (Gas Engine plant)	**Total**	21 years	Power = 40 %	Electric =3.2x10^7MJ/yr =8.9x10^6 kWh
	Capital							
	1,960,000	881,000	254,000	6,840,000	**9,935,000**			
	O & M							
	58,800/yr	26,430/yr	12,700/yr	250,200/yr	**303,130/yr**			
Power generation Using Gas Engine **(1.25 MW_e)**	Component 1 (Digesters)	Component 2 (Biogas Storage System)	Component 3 (Gas Treatment)	Component 4 (Gas Engine plant)	**Total**	21 years	Overall = 80 % Thermal = 50 % Power = 30 %	Heat = 4.0x10^7MJ/yr Electric =2.4 x10^7MJ/yr =6.7x10^6 kWh
	Capital							
	1,960,000	881,000	254,000	5,472,000	**8,567,000**			
	O & M							
	58,800/yr	26,430/yr	12,700/yr	164,200/yr	**262,090/yr**			
Heat Generation (Steam) Using Steam Boiler **(4 MW)**	Component 1 (Digesters)	Component 2 (Biogas Storage System)	Component 3 (Boilers)	Component 4	**Total**	21 years	Thermal = 85 %	Heat = 6.8x10^7MJ/yr
	Capital							
	1,960,000	881,000	1,587,000		**4,428,000**			
	O & M							
	58,800/yr	26,430/yr	47,610/yr		**132,840**/yr			

Appendix P - POME Biogas Utilization (Average Mill): Power and Heat Generation Using Gas Turbine (Off-grid and Grid Connection)

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

PROJECT ANALYSED: **POME Biogas utilization (Average Mill) - Power and Heat generation using Gas Turbine (Off-grid)**

Key Assumptions (Cells of input values in green)

Financial:			**Notes/Source**	
Exchange Rate, RM/USD		3.8		
Uses of funds, Ringgit				
Cost of Facilities				
Anaerobic digester		1,960,000	P1	
Biogas storage system		881,000	P1	
Gas turbine and miscellaneous		9,000,000	P1	
Capital Costs		11,841,000	P1	
Working Capital (one month of opex)		0		
Development costs (approx., as % of EPC cost)		0		
Total Capital Expenditure		11,841,000		11,841,000 RM/MW
Sources of funds, Ringgit				
Equity	30%	3,552,300		
Debt	70%	8,288,700		
Total sources	100%	11,841,000		
Operating Expenditure per year (opex), Ringgit				
Fuel costs		0		
Fixed Costs/ O & M Costs		355,230	P1	
Anarobic Digester		58,800	P1	
Biogas storage system		26,430	P1	
Gas turbine		270,000	P1	
Variable Costs @RM/kWh	0.01	0		
Revenue (Saving) per year, Ringgit				
Fuel substitution cost for electricity generation, RM/kWh		0.163	P2	
Electric generated, kWh		4,633,690		
Saving on Electric, RM		755,291		
Diesel Price, RM/kWh		0.0612	P3	
Heat generation (diesel substitute), RM		733,401		
Total Saving		1,488,693		
CDM-related Parameters				
Price of CERs in USD/ton CO2		5.0		
Baseline for CERs generated for electricity, kg CO2/kWh		0.6	P4	
Baseline for CERs generated for fuel substitution, kg CO2/kWh		0.2664	P5	
Saved methane emission t CO2-eq per year		30,200	P6	
CDM Revenues, Ringgit/yr		695,174		
CDM Transaction Costs, % of revenue		15%		
Assumptions on Debt Financing				
Interest Rate		7%		
Loan Tenure		10	years	

Other Assumptions:
1. Effects of income tax are not considered.
2.Biomass power generation plant operates at 80% working capacity with RM0.126/kWh operation cost
3.Another 20% of power generation is generated by diesel genset with an operational cost of RM0.311/kWh

Operational:		**Notes/Source**
Assumptions on Facility		
Overall Efficiency of Plant	78.0%	P7
Power Efficiency	24.0%	P7
Thermal Efficiency	54.0%	P7
Power Generation		
Gross Facility Capacity, MW	1	P8
Auxiliary consumption	13%	P4
Net Capacity (MW)	0.9	
Effective capacity due to fuel supply	76.0%	P9
Capacity Factor	80.0%	P10
Units Generated per year, kWh	5,326,080	
Plant life (years)	21	
Heat Recovery		
Ratio of Heat to power generated	2.25	P11
Equivalent Heat recovered, kWh/yr	11,983,680	
Heat generated yearly, MJ	43,106,763	
Assumptions on Fuel		
Fuel Type	Biogas	
Heating value, MJ/m3	23.9	P12
Fuel Price, RM/ton	0	

RESULTS	
A. PROJECT IRR	7.0%
B. PROJECT IRR (with CDM)	12.6%
C. PROJECT IRR (with CDM, 33% Upfront)	14.7%
Increase due to CDM,sen per kWh	4.0
D. EQUITY IRR	6.6%
E. EQUITY IRR (with CDM)	16.5%
F. EQUITY IRR (with CDM, 33% Upfront)	29.1%
Increase due to CDM,sen per kWh	4.0

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

PROJECT ANALYSED: **POME Biogas utilization (Average Mill) - Power and Heat generation using Gas Turbine (With Grid Connection)**

Key Assumptions (Cells of input values in green)

Financial:				**Notes/Source**	
Exchange Rate, RM/USD			3.8		
Uses of funds, Ringgit					
	Cost of Facilities				
	Anaerobic digester		1,960,000	P1	
	Biogas storage system		881,000	P1	
	Gas turbine and miscellaneous		9,000,000	P1	
	Grid connection		1,500,000		
	Capital Costs		13,341,000	P1	
	Working Capital (one month of opex)		0		
	Development costs (approx., as % of EPC cost)		0		
	Total Capital Expenditure		13,341,000		13,341,000 RM/MW
Sources of funds, Ringgit					
	Equity	30%	4,002,300		
	Debt	70%	9,338,700		
	Total sources	100%	13,341,000		
Operating Expenditure per year (opex), Ringgit					
	Fuel costs		0		
	Fixed Costs/ O & M Costs		355,230	P1	
	Anarobic Digester		58,800	P1	
	Biogas storage system		26,430	P1	
	Gas turbine		270,000	P1	
	Variable Costs @RM/kWh	0.01	0		
Revenue (Saving) per year, Ringgit					
	Electricity sales tariff, RM/kWh		0.167	P13	
	Electric generated, kWh		4,633,690		
	Electric Saving		773,826		
	Diesel Price, RM/kWh		0.0612	P3	
	Heat generation (diesel substitute), RM		733,401		
	Total Saving and Sale, RM		1,507,227		
CDM-related Parameters					
	Price of CERs in USD/ton CO2		5.0		
	Baseline for CERs generated for electricity, kg CO2/kWh		0.6	P4	
	Baseline for CERs generated for fuel substitution, kg CO2/kWh		0.2664	P5	
	Saved methane emission t CO2-eq per year		30,200	P6	
	CDM Revenues, Ringgit/yr		695,174		
	CDM Transaction Costs, % of revenue		15%		
Assumptions on Debt Financing					
	Interest Rate		7%		
	Loan Tenure		10	years	

Other Assumptions:

1. Effects of income tax are not considered.

2. Grid connection investment cost is depending on distance of connection. It is assumed as RM 1.5 million in this study (which is roughly 2 km connection distance to grid)

Operational:			**Notes/Source**
Assumptions on Facility			
	Overall Efficiency of Plant	78.0%	P7
	Power Efficiency	24.0%	P7
	Thermal Efficiency	54.0%	P7
	Power Generation		
	Gross Facility Capacity, MW	1	P8
	Auxiliary consumption	13%	P4
	Net Capacity (MW)	0.9	
	Effective capacity due to fuel supply	76.0%	P9
	Capacity Factor	80.0%	P10
	Units Generated per year, kWh	5,326,080	
	Plant life (years)	21	
	Heat Recovery		
	Ratio of Heat to power generated	2.25	P11
	Equivalent Heat recovered, kWh/yr	11,983,680	
	Heat generated yearly, MJ	43,106,763	
Assumptions on Fuel			
	Fuel Type	Biogas	
	Heating value, MJ/m3	23.9	P12
	Fuel Price, RM/ton	0	
	Fuel supply (biogas) per year, m3	3,360,000.00	

RESULTS	
A. PROJECT IRR	5.8%
B. PROJECT IRR (with CDM)	11.0%
C. PROJECT IRR (with CDM, 33% Upfront)	12.6%
Increase due to CDM,sen per kWh	4.0
D. EQUITY IRR	4.7%
E. EQUITY IRR (with CDM)	13.5%
F. EQUITY IRR (with CDM, 33% Upfront)	19.4%
Increase due to CDM,sen per kWh	4.0

Appendix Q - POME Biogas Utilisation (Average Mill): Power and Heat Generation Using Gas Engine (Off-grid and Grid Connection)

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

PROJECT ANALYSED: **POME Biogas Utilisation (Average Mill) - Power and Heat Generation via Gas Engine (Off-grid)**

Key Assumptions (Cells of input values in green)

Financial:				**Notes/Source**	
Exchange Rate, RM/USD			3.8		
Uses of funds, Ringgit					
	Cost of Facilities				
	Anaerobic digester		1,960,000	P1	
	Biogas storage system		881,000	P1	
	Gas treatment		254,000	P1	
	Gas engine plant		6,840,000	P1	
	Capital Costs		9,935,000	P1	
	Working Capital (one month of opex)		0		
	Development costs (approx., as % of EPC cost)		0		
	Total Capital Expenditure		9,935,000		7,948,000 RM/MW
Sources of funds, Ringgit					
	Equity	30%	2,980,500		
	Debt	70%	6,954,500		
	Total sources	100%	9,935,000		
Operating Expenditure per year (opex), Ringgit					
	Fuel costs		0		
	Fixed Costs/ O & M Costs		303,130	P1	
	Anarobic Digester		58,800	P1	
	Biogas storage system		26,430	P1	
	Gas treatment		12,700	P1	
	Gas engine plant		205,200	P1	
	Variable Costs @RM/kWh	0.01	0		
Revenue per year, Ringgit					
	Fuel substitution cost for electricity generation, RM/kWh		0.163	P2	
	Electric generated, kWh		5,792,112		
	Saving on electric, RM		944,114		
	Diesel Price, RM/kWh		0.0612	P3	
	Heat generation (diesel substitute), RM		679,075		
	Total Saving and Sale, RM		1,623,189		
CDM-related Parameters					
	Price of CERs in USD/ton CO2		5.0		
	Baseline for CERs generated for electricity, kg CO2/kWh		0.6	P4	
	Baseline for CERs generated for fuel substitution, kg CO2/kWh		0.2664	P5	
	Saved methane emission t CO2-eq per year		30200	P6	
	CDM Revenues, Ringgit/yr		705,860		
	CDM Transaction Costs, % of revenue		15%		
Assumptions on Debt Financing					
	Interest Rate		7%		
	Loan Tenure		10	years	

Other Assumptions:
1. Effects of income tax are not considered.
2.Biomass power generation plant operates at 80% working capacity with RM0.126/kWh operation cost
3.Another 20% of power generation is generated by diesel genset with an operational cost of RM0.311/kWh

Operational:			**Notes/Source**
Assumptions on Facility			
	Overall Efficiency of Plant	80.0%	P7
	Power Efficiency	30.0%	P7
	Thermal Efficiency	50.0%	P7
	Power Generation		
	Gross Facility Capacity, MW	1.25	P8
	Auxiliary consumption	13%	P4
	Effective capacity due to fuel supply	76%	P9
	Net Capacity (MW)	0.8	
	Capacity Factor	80.0%	P10
	Units Generated per year, kWh	6,657,600	
	Plant life (years)	21	
	Heat Recovery		
	Ratio of Heat to power generated	1.67	P11
	Equivalent Heat recovered, kWh/yr	11,096,000	
	Heat generated yearly, MJ	39,913,669	
Assumptions on Fuel			
	Fuel Type	Biogas	
	Heating value, MJ/m3	23.9	P12
	Fuel Price, RM/ton	0	
	Fuel supply (biogas) per year, m3	3,360,000	

RESULTS

A. PROJECT IRR	13.2%
B. PROJECT IRR (with CDM)	18.7%
C. PROJECT IRR (with CDM, 33% Upfront)	23.0%
Increase due to CDM,sen per kWh	3.98
D. EQUITY IRR	17.3%
E. EQUITY IRR (with CDM)	29.1%
F. EQUITY IRR (with CDM, 33% Upfront)	93.0%
Increase due to CDM,sen per kWh	3.98

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

PROJECT ANALYSED: **POME Biogas Utilisation (Average Mill) - Power and Heat Generation via Gas Engine (With Grid Connection)**

Key Assumptions (Cells of input values in green)

Financial:					Notes/Source	
Exchange Rate, RM/USD				3.8		
Uses of funds, Ringgit						
	Cost of Facilities					
	Anaerobic digester			1,960,000	P1	
	Biogas storage system			881,000	P1	
	Gas treatment			254,000	P1	
	Gas engine plant			6,840,000	P1	
	Grid connection			1,500,000		
	Capital Costs			11,435,000	P1	
	Working Capital (one month of opex)			0		
	Development costs (approx., as % of EPC cost)			0		
	Total Capital Expenditure			11,435,000		9,148,000 RM/MW
Sources of funds, Ringgit						
	Equity		30%	3,430,500		
	Debt		70%	8,004,500		
	Total sources		100%	11,435,000		
Operating Expenditure per year (opex), Ringgit						
	Fuel costs			0		
	Fixed Costs/ O & M Costs			303,130	P1	
		Anarobic Digester		58,800	P1	
		Biogas storage system		26,430	P1	
		Gas treatment		12,700	P1	
		Gas engine plant		205,200	P1	
	Variable Costs @RM/kWh	0.01		0		
Revenue per year, Ringgit						
	Electricity sales tariff, RM/kWh			0.167	P13	
	Sales Units, kWh			5,792,112		
	Electric Sales income			967,283		
	Diesel Price, RM/kWh			0.0612	P3	
	Heat generation (diesel substitute), RM			679,075		
	Total Saving and Sale, RM			1,646,358		
CDM-related Parameters						
	Price of CERs in USD/ton CO2			5.0		
	Baseline for CERs generated for electricity, kg CO2/kWh			0.6	P4	
	Baseline for CERs generated for fuel substitution, kg CO2/kWh			0.2664	P5	
	Saved methane emission t CO2-eq per year			30200	P6	
	CDM Revenues, Ringgit/yr			705,860		
	CDM Transaction Costs, % of revenue			15%	P3	
Assumptions on Debt Financing						
	Interest Rate			7%		
	Loan Tenure			10	years	

Other Assumptions:

1. Effects of income tax are not considered.
2. Grid connection investment cost is depending on distance of connection. It is assumed as RM 1.5 million in this study (which is roughly 2 km connection distance to grid)

Operational:			Notes/Source
Assumptions on Facility			
	Overall Efficiency of Plant	80.0%	P7
	Power Efficiency	30.0%	P7
	Thermal Efficiency	50.0%	P7
	Power Generation		
	Gross Facility Capacity, MW	1.25	P8
	Auxiliary consumption	13%	P4
	Effective capacity due to fuel supply	76%	P9
	Net Capacity (MW)	0.8	
	Capacity Factor	80.0%	P10
	Units Generated per year, kWh	6,657,600	
	Plant life (years)	21	
	Heat Recovery		
	Ratio of Heat to power generated	1.67	
	Equivalent Heat recovered, kWh/yr	11,096,000	
	Heat generated yearly, MJ	39,913,669	
Assumptions on Fuel			
	Fuel Type	Biogas	
	Heating value, MJ/m3	23.9	P12
	Fuel Price, RM/ton	0	
	Fuel supply (biogas) per year, m3	3,360,000	

RESULTS	
A. PROJECT IRR	9.6%
B. PROJECT IRR (with CDM)	15.0%
C. PROJECT IRR (with CDM, 33% Upfront)	17.8%
Increase due to CDM,sen per kWh	3.98
D. EQUITY IRR	10.9%
E. EQUITY IRR (with CDM)	21.5%
F. EQUITY IRR (with CDM, 33% Upfront)	50.6%
Increase due to CDM,sen per kWh	3.98

Appendix R - POME Biogas Utilisation (Average Mill): Power Generation Using Gas Engine (Off-grid and Grid Connection)

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

PROJECT ANALYSED: **POME Biogas Utilisation (Average Mill) - Power Generation via Gas Engine (Off-grid)**

Key Assumptions (Cells of input values in green)

Financial:				**Notes/Source**	
Exchange Rate, RM/USD			**3.8**		
Uses of funds, Ringgit					
	Cost of Facilities				
	Anaerobic digester		**1,960,000**	**P1**	
	Biogas storage system		**881,000**	**P1**	
	Gas treatment		**254,000**	**P1**	
	Gas engine plant		**5,472,000**	**P1**	
	Capital Costs		**8,567,000**	**P1**	
	Working Capital (one month of opex)		**0**		
	Development costs (approx., as % of EPC cost)		**0**		
	Total Capital Expenditure		**8,567,000**		**6,853,600 RM/MW**
Sources of funds, Ringgit					
	Equity	**30%**	**2,570,100**		
	Debt	**70%**	**5,996,900**		
	Total sources	**100%**	**8,567,000**		
Operating Expenditure per year (opex), Ringgit					
	Fuel costs		**0**		
	Fixed Costs/ O & M Costs		**262,090**	**P1**	
	Anarobic Digester		**58,800**	**P1**	
	Biogas storage system		**26,430**	**P1**	
	Gas treatment		**12,700**	**P1**	
	Gas engine plant		**164,160**	**P1**	
	Variable Costs @RM/kWh	**0.01**	**0**		
Revenue per year, Ringgit					
	Fuel substitution cost for electricity generation, RM/kWh		**0.163**	**P2**	
	Electric generated, kWh		**7,621,200**		
	Saving on electric, RM		**1,242,256**		
CDM-related Parameters					
	Price of CERs in USD/ton CO2		**5.0**		
	Baseline for CERs generated for electricity, kg CO2/kWh		**0.6**	**P4**	
	Saved methane emission t CO2-eq per year		**30200**	**P6**	
	CDM Revenues, Ringgit/yr		**673,664**		
	CDM Transaction Costs, % of revenue		**15%**		
Assumptions on Debt Financing					
	Interest Rate		**7%**		
	Loan Tenure		**10**	**years**	

Other Assumptions:
1. Effects of income tax are not considered.
2.Biomass power generation plant operates at 80% working capacity with RM0.126/kWh operation cost
3.Another 20% of power generation is generated by diesel genset with an operational cost of RM0.311/kWh

Operational:			**Notes/Source**
Assumptions on Facility			
	Gross Facility Capacity, MW	**1.25**	**P8**
	Auxiliary consumption	**13%**	**P4**
	Effective capacity due to fuel supply	**100%**	**P9**
	Net Capacity (MW)	**1.1**	
	Capacity Factor	**80.0%**	**P10**
	Units Generated per year, kWh	**8,760,000**	
	Plant life (years)	**21**	
	Plant efficiency	**40.0%**	**P4**
	or, Heat Rate, KJ/kWh		
Assumptions on Fuel			
	Fuel Type	**Biogas**	
	Heating value, MJ/m3	**23.9**	**P12**
	Fuel Price, RM/ton	**0**	
	Fuel supply (biogas) per year, m3	**3,360,000**	

RESULTS	
A. PROJECT IRR	**9.2%**
B. PROJECT IRR (with CDM)	**16.0%**
C. PROJECT IRR (with CDM, 33% Upfront)	**20.3%**
Increase due to CDM,sen per kWh	**7.69**
D. EQUITY IRR	**10.3%**
E. EQUITY IRR (with CDM)	**23.8%**
F. EQUITY IRR (with CDM, 33% Upfront)	**107.1%**
Increase due to CDM,sen per kWh	**7.69**

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

PROJECT ANALYSED: **POME Biogas Utilisation (Average Mill) - Power Generation via Gas Engine (With Grid Connection)**

Key Assumptions (Cells of input values in green)

Financial:					Notes/Source	
Exchange Rate, RM/USD				3.8		
Uses of funds, Ringgit						
	Cost of Facilities					
	Anaerobic digester			1,960,000	P1	
	Biogas storage system			881,000	P1	
	Gas treatment			254,000	P1	
	Gas engine plant			5,472,000	P1	
	Grid connection			1,500,000		
	Capital Costs			10,067,000	P1	
	Working Capital (one month of opex)			0		
	Development costs (approx., as % of EPC cost)			0		
	Total Capital Expenditure			10,067,000		8,053,600 RM/MW
Sources of funds, Ringgit						
	Equity		30%	3,020,100		
	Debt		70%	7,046,900		
	Total sources		100%	10,067,000		
Operating Expenditure per year (opex), Ringgit						
	Fuel costs			0		
	Fixed Costs/ O & M Costs			262,090	P1	
		Anarobic Digester		58,800	P1	
		Biogas storage system		26,430	P1	
		Gas treatment		12,700	P1	
		Gas engine plant		164,160	P1	
	Variable Costs @RM/kWh		0.01	0		
Revenue per year, Ringgit						
	Electricity sales tariff, RM/kWh			0.167	P13	
	Sales Units, kWh			7,621,200		
	Electric Sales income			1,272,740		
CDM-related Parameters						
	Price of CERs in USD/ton CO2			5.0		
	Baseline for CERs generated for electricity, kg CO2/kWh			0.6	P4	
	Saved methane emission t CO2-eq per year			30200	P6	
	CDM Revenues, Ringgit/yr			673,664		
	CDM Transaction Costs, % of revenue			15%		
Assumptions on Debt Financing						
	Interest Rate			7%		
	Loan Tenure			10	years	

Other Assumptions:

1. Effects of income tax are not considered.
2. Grid connection investment cost is depending on distance of connection. It is assumed as RM 1.5 million in this study (which is roughly 2 km connection distance to grid)

Operational:			Notes/Source
Assumptions on Facility			
	Gross Facility Capacity, MW	1.25	P8
	Auxiliary consumption	13%	P4
	Effective capacity due to fuel supply	100%	P9
	Net Capacity (MW)	1.1	
	Capacity Factor	80.0%	P10
	Units Generated per year, kWh	8,760,000	
	Plant life (years)	21	
	Plant efficiency	40.0%	P3
	or, Heat Rate, KJ/kWh		
Assumptions on Fuel			
	Fuel Type	Biogas	
	Heating value, MJ/m3	23.9	P12
	Fuel Price, RM/ton	0	
	Fuel supply (biogas) per year, m3	3,360,000	

<u>RESULTS</u>	
A. PROJECT IRR	7.6%
B. PROJECT IRR (with CDM)	13.7%
C. PROJECT IRR (with CDM, 33% Upfront)	16.6%
Increase due to CDM,sen per kWh	7.69
D. EQUITY IRR	7.5%
E. EQUITY IRR (with CDM)	18.8%
F. EQUITY IRR (with CDM, 33% Upfront)	49.4%
Increase due to CDM,sen per kWh	7.69

Appendix S - POME Biogas Utilization (Average Mill): Heat Generation Using Steam Boilers

FINANCIAL MODEL TO ASSESS PROJECT FEASIBILITY (IN REAL TERMS)

PROJECT ANALYSED: **POME Biogas utilization (Average Mill) - Heat generation using steam boilers**

Key Assumptions (Cells of input values in green)

Financial:				**Notes/Source**	
Exchange Rate, RM/USD			3.8		
Uses of funds, Ringgit					
	Cost of Facilities				
	Anaerobic digester		1,960,000	P1	
	Biogas storage system		881,000	P1	
	Biogas boilers		1,587,000	P1	
	Capital Costs		4,428,000		
	Working Capital (one month of opex)		0		
	Development costs (approx., as % of EPC cost)		0		
	Total Capital Expenditure		4,428,000		1,107,000 RM/MW
Sources of funds, Ringgit					
	Equity	30%	1,328,400		
	Debt	70%	3,099,600		
	Total sources	100%	4,428,000		
Operating Expenditure per year (opex), Ringgit					
	Fuel costs		0		
	Fixed Costs/ O & M Costs		132,840		
	Anarobic Digester		58,800	P1	
	Biogas storage system		26,430	P1	
	Biogas Boiler		47,610	P1	
	Variable Costs @RM/kWh	0	0		
Revenue per year, Ringgit					
	Diesel price, RM/kWh		0.0612	P2	
	Diesel substituted yearly, L		2,184,000	P3	
	Saving from diesel substitute, RM/yr		1,150,560		
CDM-related Parameters					
	Price of CERs in USD/ton CO2		5.0		
	Baseline for CERs generated, kg CO2/kWh		0.2664	P4	
	Saved methane emission t CO2-eq per year		30,200	P5	
	CDM Revenues, Ringgit/yr		668,958		
	CDM Transaction Costs, % of revenue		15%	P6	
Assumptions on Debt Financing					
	Interest Rate		7%		
	Loan Tenure		10	years	
Other Assumptions:					
1. Effects of income tax are not considered.					

Operational:			**Notes/Source**
Assumptions on Facility			
	Gross Boiler Capacity, MW	4	P7
	Effective capacity due to fuel supply	100.0%	
	Plant efficiency	85.0%	P8
	Annual operating hours	4,700	P5
	Plant life (years)	21	
	Power equivalent of boiler, kWh/yr	18,800,000	
	Heat Generated per year, MJ	67625899	
Assumptions on Fuel			
	Fuel Type	Biogas	
	Heating value, MJ/m3	23.9	P10
	Fuel Price, RM/ton	0	
	Fuel supply per year, m3	3,360,000	

RESULTS	
A. PROJECT IRR	20.4%
B. PROJECT IRR (with CDM)	30.9%
C. PROJECT IRR (with CDM, 33% Upfront)	59.2%
Increase due to CDM,sen per kWh	3.56
D. EQUITY IRR	34.3%
E. EQUITY IRR (with CDM)	61.2%
F. EQUITY IRR (with CDM, 33% Upfront)	415.9%
Increase due to CDM,sen per kWh	3.56

	Notes/Sources
P1	**Derived from combination of various sources. Details are stated in the report**
P2	**These costs are including capital investment cost, fuel and maintenance cost. By assuming 80% of biomass power (RM 0.126/kWh) and 20% of diesel power (RM 0.311/kWh). Adopt from Kamarulazizi Ibrahim, Lalchand, C., Mohamad Adan Yusof & Iskandar Majidi, M. (2002). *Renewable energy a private sector initiative a fruitful business for a bright future*. Centre for Education and Training in Renewable Energy and Energy Efficiency.**
P3	**IRP compeed fuel library**
P4	**Soeren/Bjoern's (PTM) CDM capacity building project (draft 2004)**
P5	**IRP (compeed) emission factor of fuel boiler**
P6	**Assumption for base case**
P7	**Mathias, A.J (2004). Overview of cogeneration technologies and applications. Presented in 2004 Cogeneration Week in the Philippines.**
P8	**Design capacity of the power plant**
P9	**The potential of the plant to operate at maximum capacity due to fuel (biogas) supply**
P10	**IRP assumption**
P11	**Derived from the power efficiency and thermal efficiency**
P12	**Generated from Methane's heating value of 55.4 GJ/ ton and methane density at 0.72 kg/m^3.**
P13	**SREP from TNB**

Appendix T - Cost for Different Biogas Utilization by a Small Palm Oil Mill

Project	**Cost (RM)**				
Cogen (Heat & Power) Using Gas Engine (625 kW_e)	Component 1 (Digesters)	Component 2 (Biogas Storage System)	Component 3 (Gas Treatment)	Component 4 (Gas Engine plant)	**Total**
	Capital				
	1,193,000	414,000	120,000	3,420,000	**5,147,000**
	O & M				
	35,790/yr	12,420/yr	6,000/yr	102,600/yr	**156,810/yr**
Power generation Using Gas Engine (625 kW_e)	Component 1 (Digesters)	Component 2 (Biogas Storage System)	Component 3 (Gas Treatment)	Component 4 (Gas Engine plant)	**Total**
	Capital				
	1,193,000	414,000	120,000	2,736,000	**4,463,000**
	O & M				
	35,790/yr	12,420/yr	6,000/yr	82,080/yr	**136,290/yr**
Heat Generation (Steam) Using Steam Boiler (2 MW)	Component 1 (Digesters)	Component 2 (Biogas Storage System)	Component 3 (Boilers)	Component 4	**Total**
	Capital				
	1,193,000	414,000	794,000		**2,401,000**
	O & M				
	35,790/yr	12,420/yr	23,820/yr		**72,030**/yr

Appendix U - Cost for Different Biogas Utilization by a Large Mill

Project	**Cost (RM)**				
Cogen (Heat & Power) Using Gas Turbine (1 MW$_e$)	Component 1 (Digesters)	Component 2 (Biogas Storage System)	Component 3 (Gas Turbine and miscellaneous)	Component 4	**Total**
	Capital				
	2,461,000	**1,248,000**	9,000,000		12,709,000
	O & M				
	73,830/yr	37,440/yr	270,000		381,270/yr
Cogen (Heat & Power) Using Gas Engine (2 x 1065 kW$_e$)	Component 1 (Digesters)	Component 2 (Biogas Storage System)	Component 3 (Gas Treatment)	Component 4 (Gas Engine plant)	**Total**
	Capital				
	2,461,000	**1,248,000**	360,000	**8,741,000**	12,810,000
	O & M				
	73,830/yr	**37,440/yr**	18,000/yr	**262,230/yr**	391,500/yr
Power generation Using Gas Engine (2 x 1065 kW$_e$)	Component 1 (Digesters)	Component 2 (Biogas Storage System)	Component 3 (Gas Treatment)	Component 4 (Gas Engine plant)	**Total**
	Capital				
	2,461,000	**1,248,000**	360,000	**6,993,000**	11,062,000
	O & M				
	73,830/yr	**37,440/yr**	18,000/yr	**209,790/yr**	339,060/yr
Heat Generation (Steam) Using Steam Boiler (6 MW)	Component 1 (Digesters)	Component 2 (Biogas Storage System)	Component 3 (Boilers)	Component 4	**Total**
	Capital				
	2,461,000	**1,248,000**	2,381,000		6,090,000
	O & M				
	73,830/yr	**37,440/yr**	71,430/yr		182,700/yr