CLEAN DEVELOPMENT MECHANISM
PROJECT DESIGN DOCUMENT FORM (CDM-PDD)
Version 03 - in effect as of: 28 July 2006

CONTENTS

Annexes

SECTION A. General description of project activity

A.1 Title of the project activity:

Ekurhuleni Landfill Gas Recovery Project – South Africa
Document version: 8
Document date: 27/06/2007

A.2. Description of the project activity:

The Ekurhuleni Metropolitan Municipality (the EMM) is proposing a Clean Development Mechanism (CDM) project activity at four landfills owned by the EMM in Gauteng province, South Africa. Greenhouse gas emission reductions will be achieved by the combustion of recovered methane contained in landfill gas that would be otherwise emitted to the atmosphere. It is estimated that the project activity will generate a minimum of 1.664 million CERs between the start of operations and end-2013.

The landfill facilities to be included in this CDM project activity are Weltevreden, Rooikraal, Rietfontein, and Simmer & Jack.

EMM proposes to recover landfill gas using both vertical gas extraction wells and horizontal gas collection systems. The collected landfill gas will be flared. It is the intention of the EMM to develop landfill gas utilization projects at all four sites after the initial gas collection infrastructure is in place and gas quantity and quality are well-defined. In particular, on-site generation of electricity is likely to be an attractive future option. However, landfill gas utilization will not be part of this CDM project for two reasons:

(1) Given the short window of opportunity for CDM during the first Kyoto commitment period, a simpler project structure is favoured to rapidly initiate project development; and
(2) it is a fiscally and technically responsible strategy for EMM to determine whole well-field gas quantity and quality through an initial "flaring only" CDM project before expensive capital decisions are made regarding gas utilization hardware.

Contributions to sustainable development:
This project will make substantial contributions to sustainable development. First, the project will result in direct foreign investment through the sale of CERs while encouraging new markets within South Africa for domestically-supplied goods and services. Second, the project will generate jobs which would not exist in the absence of the project. Third, the eventual use of the gas will generate additional jobs while utilizing a renewable energy resource for heat or electrical generation. Fourth, the project will improve the local environment—it will result in reduced air pollution, reduced odour nuisances, improved health & safety conditions for landfill workers and nearby residents, and reduction of the risk of fire and explosion at the four landfill sites. Fifth this project will be developed in accordance with South African environmental regulations and in accordance with the sustainable development criteria of the South African Designated National Authority.

Environmental benefits

The EMM has a stated commitment to establish, develop and operate regional waste disposal facilities which comply with the Minimum Requirements for Waste Disposal by Landfill (1998) set by the Department of Water Affairs and Forestry (DWAF). In consequence, all of the EMM sites are in possession of, and in compliance with, operating permits issued by the Gauteng Regional Office of the Department of Water Affairs and Forestry. The EMM CDM project will provide substantial environmental benefits by reducing the amount of landfill gas released to atmosphere. The benefits include reduction in emissions of methane, a potent greenhouse gas, as well as benefits from reduced emissions of toxic trace components and odorous constituents. The proposed project will support continued sound environmental management of the four landfill sites under consideration.

Local employment

The project will result in the creation of approximately 10 new jobs for the installation, operation, and maintenance of the landfill gas extraction facilities.

Technology transfer

Landfill gas recovery is not common practice in South Africa. This project activity thus presents opportunities for technology transfer and will support bringing landfill gas recovery into widespread practice in South Africa.

A.3. Project participants:

Name of Party involved ((host) indicates host Party)	Private and/or public entity project participants	Indication if party involved wishes to be considered as a project participant
South Africa (host)	Ekurhuleni Metropolitan Municipality	No
Spain	Endesa Generación S.A.	No

A.4. Technical description of the project activity:

A.4.1. Location of the project activity:

A.4.1.1. Host Party(ies):

South Africa

A.4.1.2. Region/State/Province etc.:

Gauteng province

A.4.1.3. City/Town/Community etc:

Ekurhuleni Metropolitan Municipality

A.4.1.4. Detail of physical location, including information allowing the unique identification of this project activity (maximum one page):

The Ekurhuleni Metropolitan Municipality is located in the province of Gauteng, Republic of South Africa (RSA). The EMM is immediately adjacent to the Johannesburg metropolitan area and has a population of approximately 3.5 million. Some of the larger population centres within the EMM are Germiston, Kempton Park, Benoni, Boksburg, and Springs. The EMM owns engineered landfill sites that operate in accordance with South African regulatory requirements. All of the sites are classified GLB-, which means they accept general waste (not hazardous waste), are large sites, and are not expected to generate leachate. Current waste collection totals approximately 1.25 million tonnes/yr under an annual operating budget of about 370 million Rand (ZAR) which is equivalent to approximately 52 million $US at current exchange rates. With five large operational landfill sites and one proposed site, the EMM has sufficient landfill capacity for the next 60-80 years. All of the landfill sites are privately operated under publicly-tendered management contractswith the EMM.

Some information regarding the four sites is given below:

- *Weltevreden*: the landfill has been operating since 1994 and is anticipated to close in 2037. The landfill has more than 2.1 million tonnes of waste in place. The site received about 223,000 m^3/yr of waste during the EMM fiscal year ending in end-June 2004.
- *Rooikraal*: the landfill has been operating since 1988, and is anticipated to close in 2039. The landfill contains more than 4.9 million tons of waste in place (through 2004). The site received about 289,000 m^3/yr of waste during the EMM fiscal year ending in end-June 2004.
- *Rietfontein*: in addition to domestic waste, Rietfontein accepts de-listed sludges and liquids. It has been operating since 1997 and is anticipated to close in 2037. The site had more than 1.1 million tonnes of waste in place (through 2004) and received about 137,000 m^3/yr of waste during the EMM fiscal year ending in end-June 2004.
- *Simmer & Jack*: has been operating since 1983. With the inclusion of adjacent land that has been purchased, this site will operate until approximately 2019. The landfill contained more than 2.5 million tonnes of waste in place (through 2004). The site received about 407,000 m^3/yr of waste in the EMM fiscal year ending in end-June 2004.

The sites are located as follows:

- *Simmer and Jack*: Corner of Johan Rissik and Main Reef Roads in Germiston, East of the N3 Highway. The site occupies Portion 2 of the farm Elandsfontein 901R. Access to the site is via Johan Rissik Road.
- *Weltevreden*: Next to Main Reef Road, north-east of Apex Road and the railway line on the Benoni/Brakpan border. The site is situated on the remainder of farm Weltevreden 77 IR, Benoni, District Brakpan.
- *Rietfontein*: South of the N17 Toll Road, west of Tonk Meter Road (R63) with Kwa Thema residential area bordering the site on the eastern and western sides. The site is situated on Portion 81 of farm Rietfontein 128-JR. Access to the site is via Tonk Meter Road.
- *Rooikraal*: South of the T-Junction of the R21 and Barry Marais Road (R43) and east of Villa Liza. The site is situated on 117 ha of Portion 17 of the farm Rooikraal 156 IR and Portion 17 of the farm Witpoortjie 117 IR. Access to the site is via Barry Marais Road.

A.4.2. Category(ies) of project activity:

Waste handling and disposal (landfill gas recovery)

A.4.3. Technology to be employed by the project activity:

The technology to be employed by the project activity is the installation of vertical wells and horizontal collectors to extract the landfill gas, which will then be flared.

Starting in March 2005 a gas yield investigation was carried out at the four sites in preparation for the CDM project. The specific and sole purpose of these pilot wells was to provide an initial assessment of gas quantity and quality for the purposes of the CDM project. The investigation comprised two to four gas wells and a 300 Nm^3/h flare at each site. The wells were pumped for gas and the yields monitored over a six month trial period. The maintenance and management of the wells and flares was undertaken by a third party contract which ended in December 2006. The full-scale project described below will replace the pilot wells as the project wells will be developed at a larger and more efficient scale.

Vertical landfill gas extraction wells will be installed in cells which have reached final grade and have final cover in place. Horizontal collectors will be installed in active cells during the period of waste placement. The installation of horizontal collectors will be fully integrated with site operations. The gas will be extracted under vacuum to one or more headers at each site and conveyed to an enclosed flare.

The captured landfill gas will be destroyed by combustion in a high-temperature enclosed flare. The components of the flare systems at each site will include:

- blower
- condensate knock-out
- flow control mechanism
- flame arrestor
- burner
- back-up generator

The technology to extract and utilise landfill gas has been fully commercial for more than 30 years and operates in an environmentally safe manner at more than a thousand sites worldwide. Via this project and other landfill gas CDM projects in South Africa, this technology and operational experience will be transferred to South Africa.

As discussed above, the commercial utilization of the landfill gas will be fully investigated after the available gas quantity and quality are better defined. Some possible uses of the gas include onsite generation of electricity or sale to nearby industrial or commercial customers. Because the CDM project activity will be limited to flaring, emission reductions as a result of fossil fuel displacement are not included in the project activity.

A.4.4 Estimated amount of emission reductions over the chosen crediting period:

Year	Annual estimation of emission reductions in tonnes of CO_2 equivalent
2007	10 852
2008	187 278
2009	252 524
2010	278 597
2011	306 152
2012	316 156
2013	312 098
Total estimated reductions (tonnes of CO_2 equivalent)	1 663 656
Total number of crediting years	7 (renewable twice)
Annual average over the crediting period of estimated reductions (tonnes of CO_2 equivalent)	237 665

A.4.5. Public funding of the project activity:

No public funding from Parties included in Annex I is involved in this project activity.

SECTION B. Application of a baseline and monitoring methodology

B.1. Title and reference of theapproved baseline and monitoring methodology applied to the project activity:

Methodology AM00011/Version 03: "Landfill gas recovery with electricity generation and no capture or destruction of methane in the baseline scenario"

B.2 Justification of the choice of the methodology and why it is applicable to the project activity:

Methodology AM00011 is applicable to landfill gas capture and electricity generation projects where:

- *The baseline is atmospheric release of the landfill gas:* This is the baseline for this project activity, as described in Section B4 below.
- *There are no regulations and/or contractual requirements requiring active landfill gas extraction and flaring to reduce landfill gas emissions.* The South African Minimum Requirements for Waste Disposal to Landfill, published in 1998 and revised in 2005, do not require active extraction and recovery of landfill gas. These requirements indicate that landfill gas monitoring with passive control measures should be implemented where appropriate. The four EMM sites are in compliance with South African regulations with regard to gas monitoring and control measures, and no further control measures are required by law. There are thus no regulations requiring the active extraction and recovery of landfill gas from these sites. In addition, the EMM sites are operated by private companies under contract to EMM, and there are no current contractual requirements to extract and flare landfill gas.
- *The captured gas can be used to evaporate leachate, generate electricity, and/or is flared:* The CDM project activity proposed for the EMM sites is flaring of the recovered landfill gas. Once the landfill gas quantity and quality are well-defined as a result of the CDM project, it is the intention of the EMM to develop gas utilization projects. However, landfill gas utilization is not part of this project activity.
- *Emission reductions associated with generation of the displaced electricity do not generate credits:* The proposed CDM project activity does not involve the generation of electricity—thus this condition is not applicable to this project activity.

As stated above, the baseline is the continuation of the current practice of atmospheric release of the landfill gas (LFG). Neither the South African environmental guidelines for landfill management (*Minimum Requirements for Waste Disposal by Landfill, 1998*), which are implemented through landfill permits, nor any local regulations mandate capture of the landfill gas. The EMM project proposes to flare the captured landfill gas and will not claim emission reductions associated with potential other uses such as the generation of electricity.

Therefore the EMM project complies with the applicability criteria of the approved methodology and the use of AM00011 is justified.

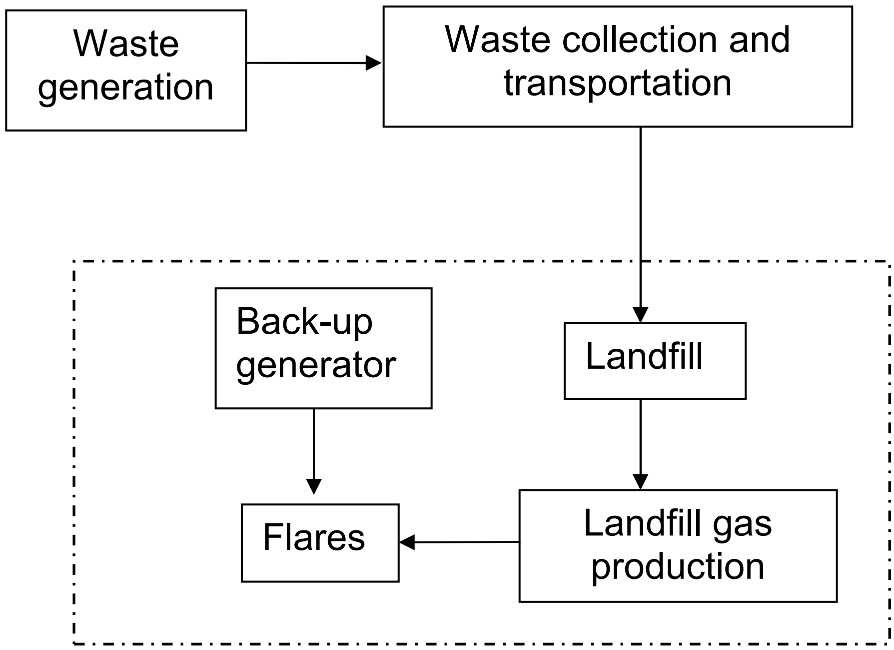
B.3. Description of the sources and gases included in the project boundary

The project boundary of the CDM project activity is the Weltevreden, Rooikraal, Rietfontein, and Simmer & Jack landfill sites, where landfill gas will be captured and destroyed. It consists of the existing four landfill sites, as well as the proposed gas extraction systems. These systems will include vertical extraction wells, horizontal gas collectors, gas collection headers and blowers/flares for efficient gas collection and combustion. In due course, after further definition of gas quantity and quality gas utilisation project are envisioned.

The following emissions sources are considered within the project boundaries:

	Source	**Gas**	**Included?**	**Justification**
Baseline	Landfill (waste body)	CO_2	No	Part of the natural carbon cycle
		CH_4	Yes	Main component of landfill gas
		N_2O	No	Not applicable
Project activity	Landfill gas capturing and flaring	CO_2	No	Part of the natural carbon cycle
		CH_4	Yes	Main component of landfill gas
		N_2O	No	Not applicable
	Emissions of the back-up generator	CO_2	Yes	Main component of generator emissions.
		CH_4	No	Not applicable
		N_2O	No	Insignificant

The project boundary is indicated in the diagram below.



Project boundary -·-·-·-·-·

The emissions from the transport of waste to the landfill site are not taken into account. These emissions are not affected by the project activity and are thus the same as the transport emissions under the baseline scenario.

B.4. Description of how the baseline scenario is identified and description of the identified baseline scenario:

Methodology AM00011 defines the baseline as atmospheric release of the landfill gas.

At the four landfill sites considered in this CDM project activity, the baseline is a continuation of the current practice of releasing landfill gas to the atmosphere.

Key elements used to determine the baseline are shown in the table in Annex 3 to this document.

B.5. Description of how the anthropogenic emissions of GHG by sources are reduced below those that would have occurred in the absence of the registered CDM project activity (assessment and demonstration of additionality):

According to methodology AM0011, additionality is determined by a four step process.

Step 1: Assessment of legal requirements
As discussed previously in this document, the South African Minimum Requirements for Waste Disposal by Landfill (1998) do not require landfill operators to actively collect and flare landfill gas. Landfill gas monitoring and passive control measures (venting of gas to the atmosphere) are approved by the local regulatory authority as part of the landfill permit process. The four EMM sites included in this project

activity do not currently extract and flare landfill gas but are compliant with their operating permits. The extraction and flaring of landfill gas is not common practice in South Africa, and it is unlikely that legislation requiring the collection and flaring of landfill gas will be passed during the term of this project. There are thus no legal requirements in South Africa regarding landfill gas recovery that would affect the selection of a baseline scenario.

Step 2: Assessment of economically attractive scenarios
This step is intended to determine whether there is an alternative, economically attractive, scenario that might be implemented by the EMM in the absence of the proposed CDM project activity.

Several scenarios were evaluated, as outlined below:

No	Scenario	Notes/comments	Assessment
1	No landfill gas (LFG) capture (current scenario without recovery)	Zero costs.	Likely.
2	Modified amount of LFG is extracted	Significantly *less* LFG recovery would decrease project viability due to cost. There is no technical basis for assuming significantly*more* LFG.	Unlikely
3	Air or O_2 injection in the landfill	This option was not considered as this can result in internal landfill fires, severe site management difficulties, and high levels of air pollution from the off-gases of uncontrolled subsurface combustion. In addition, injecting pure O_2 into a landfill site would be prohibitively expensive.	Unlikely
4	Changed or changing waste composition	All four sites included in the proposed CDM project activity are licensed to receive general waste until their anticipated closure dates. They cannot therefore accept hazardous waste or other types of waste.	Unlikely and prohibited by current regulations and permit conditions
5	Another on-site LFG use	No realistic potential on-site gas use is known at this time.	Unlikely
6.	Another off-site LFG use	Potential off-site gas use not realistic due to current lack of gas infrastructure and interest by potential gas users in vicinity of site. Off-site gas use is also not financially viable.	Unlikely
7.	Project is deferred for five years	Emission reductions have no current value post-2012 and there is therefore no rationale for delaying the project.	Unlikely

No	Scenario	Notes/comments	Assessment
8.	Combinations of the above.	Since all individual scenarios are unlikely, then the combinations thereof are also unlikely.	Unlikely.
9	*LFG capture and utilisation:*		
9a	Supply to off-site buyer for use as fuel gas	Limited gas infrastructure in South Africa and potential buyers limited. Not financially viable without CDM support.	Unlikely.
9b	Electricity generation and supply to national grid	Low electricity prices in South Africa and not financially viable without CDM support.	Unlikely.
10	LFG capture and flaring (project scenario)	Estimated capital costs ZAR 39.5 million (US$ 5.5 million) and not financially viable without CDM support.	Unlikely.

Internal rate of return (IRR) and net present value (NPV) financial models were generated for the following scenarios:

- Scenario 9b: LFG capture with electricity generation and supply to national grid, excluding income from the sale of CERs and the same scenario including CER income;
- Scenario 10: LFG capture and flaring with the income from the sale of CERs and the same scenario without the income from the sale of CERs

The models were developed for the project period – from project commissioning to the end of 2012. The discount rate for the NPV calculations was taken as a real discount rate of 5% (equivalent to a nominal rate of approximately 11%). The current exchange rate was used.

The results of the models are as follows:

Scenario	IRR	NPV
Scenario 9b: LFG capture with electricity generation and supply to national grid, **without** income from the sale of CERs	Significantly negative	-135.5 million ZAR (-18.9 million US$)
Scenario 9b: LFG capture with electricity generation and supply to national grid, **with** income from the sale of CERs	-9%	-53.8 million ZAR (-7.5 million US$)
Scenario 10: LFG capture and flaring **with** the income from the sale of CERs	19%	.1.6 million ZAR (0.2 million US$)
Scenario 10: LFG capture and flaring **without** the income from the sale of CERs	Significantly negative	-71 million ZAR (-9.9 million US$)

These results show that scenario 9b is not financially viable without the sale of CERs. Similarly, scenario 10, capture and flaring of landfill gas, is only financially viable with the income from the sale of CERs.

All other scenarios are not financially viable. It is therefore clear that the continuation of the current practice is the economically most attractive course of action if the project could not benefit from the CDM. The project activity therefore passes step 2 of the additionality test.

The EMM is exploring the possibility of later using the recovered gas for electricity generation as this scenario looks marginally viable and could potentially be developed as a suitable project if the gas quality and quantity are satisfactory.

Step 3: Assessment of barriers and common practice
This step is applicable only if the proposed project activity has a higher internal rate of return or a lower cost than the baseline scenario. This is not the case in this situation, and so this step is not applicable here.

Step 4: Check on the credibility of the baseline
Methodology AM00011 suggests several reasons why the most economically-attractive scenario may not be a credible baseline. These are addressed below:

- *The most economically attractive scenario may not be realistic from a financing perspective*. For the EMM sites, the most economically-attractive scenario is the *status quo*: no capture of landfill gas. This is the scenario that is currently in place at the landfill sites included in the project activity. The EMM has budgeted for continuing operations on the basis of the current scenario, and this scenario is thus financially realistic.
- *There may not be sufficient local support for the most economically attractive scenario*: The venting of landfill gas to the atmosphere is currently best practice in South Africa. As noted in the Minimum Requirements for Waste Disposal by Landfill, "although landfill gas has been recognised as a source of odour and as a potential explosion hazard, few gas management systems have been constructed in South Africa to date" (DWAF, 1998, p.8-11). The EMM sites included in this project have been operating without recovery of landfill gas since commissioning, and it is thus unlikely that lack of local support would be a barrier to continued operation on this basis. All sites have local monitoring committees which have not raised any objections to current landfill gas management practices.
- *Other physical obstructions may impede the most economically attractive scenario from being realised:* Because the EMM sites have been operating without recovery of landfill gas since commissioning, there is no indication that physical obstructions would impede continued operation on this basis.
- *Legislation or other obligations may influence the most economically attractive scenario:* As outlined in Step 1 above, current legislation regarding the disposal of waste by landfill does not require the recovery of landfill gas, and it is unlikely that such legislation will be forthcoming during the term of the project.

The application of the AM00011 methodology (which presumes no recovery of landfill gas in the baseline) thus finds that a scenario with no recovery of landfill gas represents a credible baseline for this project activity. This scenario is the most economically attractive, and there are no other barriers. Therefore this project is fully in line with a baseline of no landfill gas recovery.

B.6. Emission reductions:

B.6.1. Explanation of methodological choices:

In accordance with methodology AM00011, the greenhouse gas emission reductions achieved by the project in a given year (ER_y) are equal to the amount of methane actually destroyed during the year ($MDproject_y$) multiplied by the approved Global Warming Potential value for methane (GWP_CH_4):

$ER_y = MDproject_y \times GWP\_CH_4 – PE_{flare,y}$
where

- ER_y is measured in tonnes of CO_2 equivalents (tCO_2e).
- $MDproject_y$ is measured in tonnes of methane (tCH_4).
- the approved Global Warming Potential value for methane (GWP_CH_4) for the first commitment period is 21 tCO_2e/ tCH_4.
- $PE_{flare,y}$ are the project emissions resulting from the flaring of the residual gas stream in year y, measured in tonnes of CO_2 equivalents (tCO_2e).

$PE_{flare,y}$ is calculated using the procedure described in the *"Tool to determine project emissions from flaring gases containing methane"*. The emissions of the back-up generator are included in $PE_{flare,y}$

The methane destroyed by the project activity ($MDproject_y$) during a year is equal to the methane flared.

$MDproject_y = [(CH_4flared_y + CH_4leachate_y + CH_4electricity_y)*D_{CH4}]$
where

- $CH_4flared_{y,}$ $CH_4leachate_y$ and $CH_4electricity_y$ are measured in cubic metres (m^3) and are determined by metering the volume of landfill gas flared and the methane concentration of the landfill gas.
- D_{CH4} is the methane density expressed in tonnes of methane per normal cubic meter of methane.

B.6.2. Data and parameters that are available at validation:

This section contains data and parameters that are determined only once and remain fixed throughout the crediting period, and that are available when validation is undertaken.

Data / Parameter:	**L_0**
Data unit:	Nm^3 landfill gas/kg organic C
Description:	Theoretical landfill gas generation potential based on the biodegradable organic carbon content of specific waste fractions.
Source of data used:	Van Zanten, B. and Scheepers, M. (1994) *Modelling of landfill gas potentials*, Report prepared for the International Energy Agency (IEA) Expert Working Group on Landfill Gas, published by Technical University of Lulea, Sweden
Value applied:	1.87
Justification of the choice of data or description of measurement methods	A comprehensive field validation study was performed in the Netherlands in the mid-1990s in which zero order, first order, first order multi-component and second order kinetic models for landfill gas generation were compared for 9 full scale Dutch landfills where extensive information on waste inputs and gas

and procedures actually applied :	recovery was available. The study concluded that a multi-component model based on the biodegradable organic carbon content of specific waste fractions yielded the smallest deviation from actual field generation and recovery data (approximately 18 to 22%).
Any comment:	Many widely available models for landfill gas generation that were developed for regulatory or national inventory purposes may not have been field validated, and are not appropriate for site-specific landfill gas generation modelling. Site-specific theoretical models were developed for each of the EMM sites.

Data / Parameter:	**k**
Data unit:	1/year
Description:	Kinetic constant
Source of data used:	Pipatti, R. and Vieira, S. (2006) *IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste*, EXCEL spreadsheet IPCC_Waste_Model_sb24
Value applied:	Either 0.07 for "rapidly" biodegradable putrescible fraction of landfilled waste, or 0.04 for "slowly" biodegradable paper fraction of waste
Justification of the choice of data or description of measurement methods and procedures actually applied :	The value of 0.07 is the minimum value for k for "dry tropical climate" for the rapidly degradable putrescible fraction consisting mainly of food waste, while 0.04 is the minimum value for k for "dry tropical climate" for the slowly degradable fraction. Using the minimum values adds conservatism to this calculation. See Annex 3 for additional information.
Any comment:	

Data / Parameter:	**$EI_{generator}$**
Data unit:	t CO_2/MWh
Description:	Emissions factor of the diesel back-up generator
Source of data used:	IPCC guideline for selected small-scale project activities SSCWG05_repan_03_AMS_I_D_grid_electricity
Value applied:	2.4
Justification of the choice of data or description of measurement methods and procedures actually applied :	This value is recommended for a diesel generator system of less than 15kW, with a load factor of 25%.
Any comment:	

B.6.3 Ex-ante calculation of emission reductions:

Ex ante emissions estimates are made by projecting the future landfill gas generation at the EMM landfills using a first order kinetic model. Emission reductions *ex post* will be determined by metering of the actual quantity of methane captured and flared, and so these *ex ante* estimates are for reference purposes only.

Baseline emissions

An estimation of the potential landfill gas production has been performed by Landfills +, Inc. using the methodology of Van Zanten and Scheepers (1994)[1]. This methodology is based on a multi-component first order kinetic model which has been validated at full-scale landfills. Rather than using the total waste mass, this modelling is based on the biodegradable organic carbon content of various waste fractions. Details regarding the assumptions underlying the baseline modelling, and the formulae used, are provided in Annex 3.

The results of the baseline calculations are presented in the table below:

Year	Landfill gas production (Nm^3/hr)	Landfill gas recovered (Nm^3/hr)	Landfill gas emitted to air (Nm^3/hr)	Landfill gas emitted to air (Nm^3/year)	Methane gas emitted to air (Nm^3/year)	CO_2e emitted to air (tonne/year)
2007	2 718	-	2 718	23 806 010	9 522 404	142 836
2008	16 923	-	16 923	148 246 149	59 298 460	889 477
2009	17 552	-	17 552	153 755 355	61 502 142	922 532
2010	18 193	-	18 193	159 370 417	63 748 167	956 223
2011	18 847	-	18 847	165 098 043	66 039 217	990 588
2012	19 524	-	19 524	171 033 165	68 413 266	1 026 199
2013	20 205	-	20 205	177 000 016	70 800 006	1 062 000
Total						**5 989 855**

Leakage

AM00011 supposes zero leakage from the project activity.

Predicted emission reductions

The predicted emission reductions are based on a conservative calculation of the expected mass of methane that can be recovered. The assumptions for this conservative calculation are described in Annex 3. *Ex ante* emissions estimates are made by projecting the future greenhouse gas emissions of the landfills using a first order kinetic model as described above.

The project activity emissions comprise emissions due to methane gas not captured, as well as the emissions of the diesel back-up generator.

The estimated emissions due to methane gas not captured are calculated as follows:

[1] Van Zanten, B., and Scheepers, M. (1994) *Modelling of landfill gas potentials*, Report prepared for International Energy Agency(IEA) Expert Working Group on Landfill Gas, published by Technical University of Lulea, Sweden.

Year	Landfill gas production (Nm^3/hr)	Landfill gas recovered (Nm^3/hr)	Landfill gas not captured (Nm^3/hr)	Landfill gas not captured (Nm^3/year)	Methane gas not captured (Nm^3/year)	CO_2e not captured (tonne/year)
2007	2 718	344	2 373	20 790 842	8 316 337	124 745
2008	16 923	5 940	10 983	96 212 768	38 485 107	577 277
2009	17 552	8 009	9 543	83 596 376	33 438 550	501 578
2010	18 193	8 836	9 357	81 968 935	32 787 574	491 814
2011	18 847	9 710	9 137	80 042 511	32 017 004	480 255
2012	19 524	10 027	9 498	83 198 750	33 279 500	499 193
2013	20 205	9 898	10 307	90 292 838	36 117 135	541 757
Total						**3 216 618**

The estimated emissions of the diesel back-up generator are calculated as follows:

Year	CO_2e emitted by diesel back-up generator (tonne/year)
2007	5
2008	71
2009	80
2010	80
2011	80
2012	80
2013	80
Total	**476**

The following information and assumptions are used to calculate the emissions of the diesel generator:

- Flares at the Rooikraal, Simmer and Jack and Weltevreden sites begin operation at the start of December 2007. The flare at Rietfontein begins operation at the beginning of July 2008.
- All of the flares have a power rating of 30 kW, with the exception of that at Weltevreden, which has a power rating of 37 kW.
- According to EMM, grid outages of about 5 days per annum are experienced. In the calculations, outages of 3% (about 11 days per annum) were assumed. This resulted in a conservative estimate of generator emissions.

The estimated project activity emissions are thus calculated as follows:

Year	CO_2e not captured (tonne/year)	CO_2e emitted by diesel back-up generator (tonne/year)	CO_2e emitted to air (tonne/year)
2007	124 745	5	124 750
2008	577 277	71	577 347

2009	501 578	80	501 658
2010	491 814	80	491 894
2011	480 255	80	480 335
2012	499 193	80	499 273
2013	541 757	80	541 837
Total	**3 216 618**	**476**	**3 217 094**

B.6.4 Summary of the ex-ante estimation of emission reductions:

Year	Estimation of project activity emissions (tonnes of CO_2e)	Estimation of baseline emissions (tonnes of CO_2e)	Estimation of leakages (tonnes of CO_2e)	Estimation of overall emissions reductions (tonnes of CO_2e)	Conservative estimation of overall emissions reductions (tonnes of CO_2e)
2007	124 750	142 836	0	18 086	10 852
2008	577 347	889 477	0	312 130	187 278
2009	501 658	922 532	0	420 874	252 524
2010	491 894	956 223	0	464 329	278 597
2011	480 335	990 588	0	510 253	306 152
2012	499 273	1 026 199	0	526 926	316 156
2013	541 837	1 062 000	0	520 163	312 098
Total (tonnes of CO_2e)	**3 217 094**	**5 989 855**	**0**	**2 772 761**	**1 663 656**

Note that in the table above, the conservative estimation of project activity emission reductions in the last column is 60% of the calculated potential emission reductions.

B.7 Application of the monitoring methodology and description of the monitoring plan:

B.7.1 Data and parameters monitored:

Data / Parameter:	**Q**
Data unit:	Nm^3/hr
Description:	Volume of landfill gas collected from project wells per unit time
Source of data to be used:	Measured value
Value of data applied for the purpose of calculating expected emission reductions in section B.5	For the purposes of calculating expected emission reductions, the theoretical amount of landfill gas generated by the full mass of general waste in place was calculated. Note that only general waste was assumed to be biodegradable. The fraction of waste in place in each site in a given year that could have landfill gas extraction (vertical wells or horizontal collectors) was considered, based on site development plans. It was assumed that 75% of the theoretical landfill gas generation from the general waste mass with gas extraction in place was

	recoverable. The recovered gas was assumed to contain 40% methane by volume. Finally, 60% of the potential methane recovered was used to provide a conservative estimate of CERs.
Description of measurement methods and procedures to be applied:	Continuous monitoring by flow meter. Data to be aggregated monthly and yearly.
QA/QC procedures to be applied:	Flow meters will be subject to regular maintenance and calibration to ensure accuracy.
Any comment:	The specific type and manufacturer of the flow meters and the calibration procedures to be used will be determined through a tender process yet to be completed. A typical accuracy of a thermal mass flow meter is 5% or better.

Data / Parameter:	$\mathbf{W_{CH4}}$
Data unit:	%
Description:	Methane fraction in landfill gas
Source of data to be used:	Measured value. The % - reading will be calculated to a g/m3 unit by using the molecular mass of methane and relevant temperature and pressure measurements.
Value of data applied for the purpose of calculating expected emission reductions in section B.5	40% by volume. Landfill gas that is undiluted by air typically contains 50 to 60% methane by volume. An assumption of 40% is thus conservative.
Description of measurement methods and procedures to be applied:	Measured by a continuous gas quality analyser.
QA/QC procedures to be applied:	Gas analyzer will be subject to regular maintenance and calibration to ensure accuracy.
Any comment:	The specific type and manufacturer of the gas analyser and the calibration procedures to be used will be determined through a tender process yet to be completed.

Data / Parameter:	$\mathbf{LFG_{leachate,v}}$
Data unit:	m^3
Description:	Volume of landfill gas used for leachate evaporation
Source of data to be used:	Measured value
Value of data applied for the purpose of calculating expected emission reductions in section B.5	N/A
Description of measurement methods	Measured by continuous flow meter. Data to be aggregated monthly and yearly.

and procedures to be applied:	
QA/QC procedures to be applied:	Flow meters will be subject to regular maintenance and calibration to ensure accuracy.
Any comment:	This parameter only becomes relevant if destruction methods other than flaring are implemented.

Data / Parameter:	**$LFG_{electricity,y}$**
Data unit:	m^3
Description:	Volume of landfill gas used for electricity generation
Source of data to be used:	Measured value
Value of data applied for the purpose of calculating expected emission reductions in section B.5	N/A
Description of measurement methods and procedures to be applied:	Measured by continuous flow meter. Data to be aggregated monthly and yearly.
QA/QC procedures to be applied:	Flow meters will be subject to regular maintenance and calibration to ensure accuracy.
Any comment:	This parameter only becomes relevant if destruction methods other than flaring are implemented.

Data / Parameter:	**$LFG_{flare,y}$**
Data unit:	m^3
Description:	Volume of landfill gas transported to the flare
Source of data to be used:	Measured value
Value of data applied for the purpose of calculating expected emission reductions in section B.5	75% of the landfill gas generated in the mass of waste that could have landfill gas extraction (75% recovery) and 60% of the remainder for conservative calculation.
Description of measurement methods and procedures to be applied:	Measured by continuous flow meter. Data to be aggregated monthly and yearly.
QA/QC procedures to be applied:	Flow meters will be subject to regular maintenance and calibration to ensure accuracy.
Any comment:	The specific type and manufacturer of the flow meters and the calibration procedures to be used will be determined through a tender process yet to be completed. A typical accuracy of a thermal mass flow meter is +-5% or better.

Data / Parameter:	**EL**
Data unit:	MWh
Description:	Amount of electricity generated
Source of data to be used:	Measured value
Value of data applied for the purpose of calculating expected emission reductions in section B.5	N/A
Description of measurement methods and procedures to be applied:	Measured continuously using a kWh meter. Data to be aggregated monthly and yearly.
QA/QC procedures to be applied:	Electricity meters will be subject to regular maintenance and calibration to ensure accuracy.
Any comment:	This parameter only becomes relevant if destruction methods other than flaring are implemented.

Data / Parameter:	**T_{flare}**
Data unit:	^oC
Description:	Temperature of the exhaust gas from the flare
Source of data to be used:	Measured
Value of data applied for the purpose of calculating expected emission reductions in section B.5	1000^oC
Description of measurement methods and procedures to be applied:	Continuous monitoring using a thermocouple or alternative temperature measuring device.
QA/QC procedures to be applied:	Thermocouples or alternative temperature measuring devices should be calibrated annually and replaced as needed.
Any comment:	A temperature above 500^oC indicates that the flare is operating

Data / Parameter:	**$fv_{i,h}$**
Data unit:	-
Description:	Volumetric fraction of component i in the residual gas in the hour, h, where i = CH_4, CO, CO_2, O_2, H_2, N_2
Source of data to be used:	Measured
Value of data applied for the purpose of	N/A

calculating expected emission reductions in section B.5	
Description of measurement methods and procedures to be applied:	Monitored using a gas analyser. Values to be averaged hourly.
QA/QC procedures to be applied:	Analysers to be calibrated periodically, according to manufacturer's recommendations.
Any comment:	The specific type and manufacturer of the gas analysers and the calibration procedures to be used will be determined through a tender process yet to be completed This parameter is used to calculate the flare efficiency for enclosed flares

Data / Parameter:	$\mathbf{FV_{RG,\,h}}$
Data unit:	m^3/h
Description:	Volumetric flow rate of the residual gas in dry basis at normal conditions in the hour, h
Source of data to be used:	Measured
Value of data applied for the purpose of calculating expected emission reductions in section B.5	N/A
Description of measurement methods and procedures to be applied:	Continuous measurement using a flow meter. Values to be averaged hourly or at a shorter time interval.
QA/QC procedures to be applied:	Flow meters to be calibrated periodically, according to manufacturer's recommendations.
Any comment:	The specific type and manufacturer of the flow meters and the calibration procedures to be used will be determined through a tender process yet to be completed. This parameter is used to calculate the flare efficiency for enclosed flares with continuous monitoring.

Data / Parameter:	$\mathbf{T_{O2,\,h}}$
Data unit:	-
Description:	Volumetric fraction of O_2 in the exhaust gas of the flare in the hour, h
Source of data to be used:	Measured
Value of data applied for the purpose of calculating expected emission reductions in	N/A

section B.5	
Description of measurement methods and procedures to be applied:	Continuous measurement using a gas analyser. Values to be averaged hourly or at a shorter time interval.
QA/QC procedures to be applied:	Analysers to be calibrated periodically, according to manufacturer's recommendations.
Any comment:	The specific type and manufacturer of the gas analysers and the calibration procedures to be used will be determined through a tender process yet to be completed. This parameter is used to calculate the flare efficiency for enclosed flares with continuous monitoring.

Data / Parameter:	$\mathbf{Fv_{CH4, FG, h}}$
Data unit:	mg/m^3
Description:	Concentration of methane in the exhaust gas of the flare in dry basis at normal conditions in the hour, h
Source of data to be used:	Measured
Value of data applied for the purpose of calculating expected emission reductions in section B.5	N/A
Description of measurement methods and procedures to be applied:	Continuous measurement using a gas analyser. Values to be averaged hourly or at a shorter time interval.
QA/QC procedures to be applied:	Analysers to be calibrated periodically, according to manufacturer's recommendations.
Any comment:	The specific type and manufacturer of the gas analysers and the calibration procedures to be used will be determined through a tender process yet to be completed. This parameter is used to calculate the flare efficiency for enclosed flares with continuous monitoring.

Data / Parameter:	**FE**
Data unit:	%
Description:	Flare efficiency (combustion efficiency)
Source of data to be used:	Calculated
Value of data applied for the purpose of calculating expected emission reductions in section B.5	100% The methane destruction efficiency of enclosed flares at 1 000 ^{o}C is typically greater than 99%.

Description of measurement methods and procedures to be applied:	In the case of enclosed flares with continuous monitoring, flare efficiency is 0% if T_{flare} is below 500°C for more than 20 minutes during the hour. If T_{flare} remains above 500°C for more than 40 minutes during the hour, then FE is calculated as per the "*Tool to determine project emissions from flaring gases containing methane*".
QA/QC procedures to be applied:	N/A
Any comment:	The specific type and manufacturer of the flares will be determined through a tender process that is currently underway, however the flares will be capable of continual monitoring.

Data / Parameter:	$\mathbf{T_{LFG}}$
Data unit:	°C
Description:	Temperature of landfill gas
Source of data to be used:	Measured
Value of data applied for the purpose of calculating expected emission reductions in section B.5	N/A
Description of measurement methods and procedures to be applied:	Continuous monitoring using a thermometer Data will be aggregated monthly and yearly.
QA/QC procedures to be applied:	Thermometers to be subject to regular maintenance and calibration to ensure accuracy.
Any comment:	Measured to determine the density of methane.

Data / Parameter:	$\mathbf{P_{LFG}}$
Data unit:	Pa
Description:	Pressure of landfill gas
Source of data to be used:	Measured
Value of data applied for the purpose of calculating expected emission reductions in section B.5	N/A
Description of measurement methods and procedures to be applied:	Continuous monitoring using a pressure meter. Data will be aggregated monthly and yearly.
QA/QC procedures to be applied:	Pressure transducers to be subject to regular maintenance and calibration to ensure accuracy.
Any comment:	Measured to determine the density of methane.

Data / Parameter:	**$PE_{flare, y}$**
Data unit:	tCO_{2e}
Description:	Project emissions from flaring of the residual gas stream in year y
Source of data to be used:	Calculated
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Assumed 0 as 100% flare efficiency has been presumed at temperatures of 1000 ^{o}C.
Description of measurement methods and procedures to be applied:	To be calculated as outlined in the "*Tool to determine project emissions from flaring gases containing methane*".
QA/QC procedures to be applied:	The QA/QC procedures will be compliant with the recommended calibration and maintenance guidelines for site-specific instrumentation and with selected data archiving protocols, so that the resulting data are consistent with Kyoto EB guidelines for this methodology.
Any comment:	The specific type and manufacturer of the flares will be determined through a tender process that is currently underway, however the flares will be capable of continual monitoring.

Data / Parameter:	**$t_{generator, y}$**
Data unit:	Days
Description:	Number of days that the back-up generator is used during year y.
Source of data to be used:	Measured
Value of data applied for the purpose of calculating expected emission reductions in section B.5	11 days According to EMM, back-up generators are expected to be used for about 5 days per annum. 11 days was used to obtain a conservative estimate of emissions from the diesel generators in Section B.5.
Description of measurement methods and procedures to be applied:	N/A
QA/QC procedures to be applied:	N/A
Any comment:	

B.7.2 Description of the monitoring plan:

The amount of methane will be determined by monitoring the amount of landfill gas and the temperature, pressure and composition of the landfill gas - specifically the percentage methane in the landfill gas. The methane combusted will be determined by continuous monitoring of the flare temperature and hence destruction efficiency. The monitoring will be done to allow appropriate use of the procedure described in the "Tool to determine project emissions from flaring gases containing methane".

To ensure correct monitoring:

- The installation of appropriate monitoring equipment, including continuous flow meters and analysers as required, has been made a condition of the award of the contract for the flare supply and maintenance
- A suitably qualified independent consulting firm will be contracted to undertaken the required monitoring and data record-keeping, data quality assurance (including equipment calibration as required) and data aggregation.

Parameters that will be monitored and the frequency of monitoring are described in section B7.1.

Monitoring as required in terms of the EIA authorisation will also be conducted. This will include:

- The development of a formal monitoring plan as stipulated in the Record of Decision (RoD) authorising the project activity. Such plan is to address the monitoring of surface water, groundwater and air quality and is to be developed within three months of receipt of the RoD.
- The undertaking of a risk assessment and monitoring of compliance with the resulting risk management implementation plan.
- Keeping an incidents and complaints register and a record of all measures taken to address incidents and complaints.

B.8 Date of completion of the application of the baseline study and monitoring methodology and the name of the responsible person(s)/entity(ies)

Date of completion: 28 June 2007

PDG
PostNet Suite #259
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Houghton, 2041, SOUTH AFRICA
Contact: Kim Palmer or Michael Goldblatt
Email: kim@pdg.co.za or mike@pdg.co.za

In conjunction with :

Landfills +, Inc.
1144 N President Str
Wheaton, Illinois 60187 USA
Contact: Jean E. Bogner, PhD
Email: jbogner@landfillsplus.com

Jones and Wagener Consulting Civil Engineers

PO Box 1434
Rivonia, 2128, SOUTH AFRICA
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Email: shamrock@jaws.co.za

SECTION C. Duration of the project activity / crediting period

C.1 Duration of the project activity:

C.1.1. Starting date of the project activity:

November 2007

C.1.2. Expected operational lifetime of the project activity:

Landfill gas will be produced at the landfill sites for the full lifespan of the sites, shown in the table below. The extraction system and landfill gas flares will remain in use until no longer required and will be maintained/replaced as needed.

Site name	Anticipated site lifespan
Weltevreden	Until 2037
Rooikraal	Until 2039
Rietfontein	Until 2037
Simmer & Jack	Including adjacent land recently purchased by the EMM until 2019

C.2 Choice of the crediting period and related information:

C.2.1. Renewable crediting period

C.2.1.1. Starting date of the first crediting period:

01/11/2007

C.2.1.2. Length of the first crediting period:

Seven years

C.2.2. Fixed crediting period:

C.2.2.1. Starting date:

Not applicable

C.2.2.2. Length:

Not applicable

SECTION D. Environmental impacts

D.1. Documentation on the analysis of the environmental impacts, including transboundary impacts:

The project will result in decreased emissions of methane, a potent greenhouse gas. In addition, the collection and destruction of landfill gas, which contains numerous hydrocarbon trace components, will reduce odour nuisances and the impact of the landfill operation on local air quality. Worker health and safety on the site will also be improved.

The Gauteng Department of Agriculture, Conservation and Environment (GDACE), the relevant provincial South African authority required an Environmental Impact Assessment (EIA) for this project. As agreed with the authorities, a Scoping Report was prepared with a focus on air quality issues. The EIA concluded that no significant negative environmental impacts are expected from the project activity. The positive impacts of the proposed project activity significantly outweigh the minor negative impacts.

D.2. If environmental impacts are considered significant by the project participants or the host Party, please provide conclusions and all references to support documentation of an environmental impact assessment undertaken in accordance with the procedures as required by the host Party:

No significant negative environmental impacts are expected to result from the project activity. On the contrary, the project will upgrade the local waste management practice to a higher standard and will lead to a reduction in global greenhouse gas emissions. In addition, the project will lead to a reduction in odourous gases being emitted from the landfills and reductions in trace component emissions, some of which can be detrimental to local air quality.

An EIA was undertaken for all 4 sites as required by domestic legislation. The relevant authorising authority, the Gauteng Department of Agriculture, Conservation and Environment, has provided a Record of Decision for all 4 sites in terms of Regulations R1182 and 1183 (as amended) promulgated under Section 21, 22, 26 and 28 of the Environment Conservation Act (Act 73 of 1989). The Records of Decision authorise the project activities and are site specific to the 4 sites under consideration. These Records of Decision are attached.

SECTION E. Stakeholders' comments

E.1. Brief description how comments by local stakeholders have been invited and compiled:

As part of the EIA process a thorough public participation exercise was undertaken. Preliminary consultations were undertaken by the applicant prior to contracting the environmental consultant.

Subsequent discussions between GDACE and the environmental consultant and a pre-consultation meeting were held on 15 November 2005.

Supporting documentation to be made available was to include:

- A background information document.
- Locality and site plans for all sites as well as schematic diagrams showing the location of the flares.
- Copies of the permits for all sites.
- A brief description of the proposed project procedure, detailing the public participation process and specialist studies to be undertaken.

The steps taken in the formal public participation process are outlined below.

- **Interested and Affected Party (I&APs) Database**: Based on experience in the field of environmental consulting, and previous work undertaken in the province, the environmental consultant provided an existing database of regulatory authorities, businesses, Community Based Organisations and Non-Governmental Organisations plus additional names supplied by the EMM and the consultant team for the initial distribution of background information. The Landfill Monitoring Committees for the respective sites were also included as an important part of the consultation process as representatives of potentially affected parties. The database was expanded as other stakeholders registered following the advertisements and the public meetings.
- **Background Information Document**: The second step in the public participation process was the production and distribution of a Background Information Document to I&APs on the initial database. This document provided a brief background to the project and allowed those interested in the project to make informed contributions to the process. The background documents for the different sites are very similar with the exception of site specific differences and schedules, as determined during the process.
- **Advertisements and notifications**: It is a legal requirement to advertise the commencement of the EIA process and the issuance of a Record of Decision (ROD) in both a local and regional newspaper. The first advertisement gives a description of the proposed activity and provides a time period for I&APs to register as interested parties, while the latter informs I&APs of the decision reached by the GDACE and allows them to appeal it. These requirements have been complied with. Further, an on-site notice was placed at the entrance to each of the landfill sites giving notice of the proposed activity:

- **Stakeholder meetings**: A public meeting for each site was held during the week 6 to 9 February 2006 as follows:
    - 6 February 2006: Simmer and Jack Landfill
    - 7 February 2006: Rooikraal Landfill
    - 8 February 2006: Rietfontein Landfill
    - 9 February 2006: Weltevreden Landfill

The objectives of the meetings were to introduce the proponent and the project team; explain the proposed project; register I&APs; and identify issues and concerns relating to the project. . I&APs were also invited to submit comments in writing after the meetings.

E.2. Summary of the comments received:

Specific issues and concerns raised by stakeholders, and comments made by them were recorded. The main issues, benefits and concerns raised can be summarised as follows:

- Will the project create jobs? It was noted that about 10 long term jobs will be created, and temporary jobs will be available during the construction phase.
- Will there be any impacts on people living close to the landfill sites? It was noted that local air quality will improve as a result of the proposed project due to the extraction and combustion of landfill gas. The potential for migration of landfill gas will also be reduced.
- The proposed project was widely felt to be a beneficial one.

In summary the EIA public participation process concluded that the general view was that the project would be beneficial as the impacts are mostly positive, and there is the potential for economic returns.

E.3. Report on how due account was taken of any comments received:

Due account was taken of all comments received. The responses to the comments can be grouped into four categories:

Comments not relevant to the project process:

Certain comments were received that were not relevant to the project itself but rather to ancillary activities on the landfill sites. For example, issues related to the planned site expansions independent of the CDM project. These comments were noted and the stakeholders referred to the responsible official within the municipality for further attention.

Comments related to inadequate or incorrect information:

Some comments were requests for information or were based on erroneous information. In these cases the stakeholder was provided with the correct information needed. For example, questions were asked about whether the project could capture and store the carbon released from the flares. It was explained that this was technically and financially not feasible.

Comments related to project design and implementation

Some constructive comments were related to project design and implementation. These were noted and will be taken into account in the project process. For example, preference was expressed for employment on the project to be linked to training and skills development. Also, the current site operators requested that attention be given to ensuring that there is proper coordination between the landfill gas recovery project and current site operations to ensure that site operations do not disrupt the project.

Comments requesting further investigations

Some stakeholders asked that the municipality consider further investigations – for example on the productive use of the gas. This was noted and it was explained that this was the intention of the municipality.

Annex 1

CONTACT INFORMATION ON PARTICIPANTS IN THE PROJECT ACTIVITY

Organization:	Ekurhuleni Metropolitan Municipality
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Annex 2

INFORMATION REGARDING PUBLIC FUNDING

Not applicable

Annex 3

BASELINE INFORMATION

An estimation of the potential landfill gas production has been performed by Landfills +, Inc. using the methodology of Van Zanten and Scheepers (1994)[2]. This methodology is based on a multi-component first order kinetic model validated at full-scale landfills. Rather than using the total waste mass, this modelling is based on the biodegradable organic carbon content of various waste fractions. The following assumptions were used for the modelling:

1. Landfill gas (LFG) potential yield assumed to be 1.87 Nm^3 landfill gas/kg organic C.

2. For each fraction, LFG production in Nm^3 in year t =

$$1.87 * \text{tonnes wastes} * 1000 \text{ (kg/tonne)} * \text{organic C fraction} * k * e^{-kt}$$

where k= kinetic constant (1/yr)
and t= time (yr)

(van Zanten and Scheepers, 1994)

The LFG production for each year from the waste inputs for each year was summed to provide the total annual LFG production.

3. Two fractions were used as the basis for estimating LFG generation from the general waste received at the EMM landfill sites. Only general/domestic waste was assumed to be biodegradable. Subtractions from the annual total mass of waste used for theoretical modeling of gas generation included: (1) the mass of incoming biodegradable garden waste that was not landfilled, but composted on site; (2) the mass of landfilled non-domestic waste; and (3) the mass of landfill cover soil. Monthly waste inputs from 2005 were projected until closure in 2012. Other assumptions are given below:

	Dry fraction	Organic C (fraction dry)	k (1/yr)
Domestic putrescibles	0.50	0.80	0.07
Domestic paper	0.75	0.40	0.04

5. The general waste was assumed to be 70% from affluent communities and 30% from non-affluent communities. Assumed waste fraction characteristics were as follows [all mass fractions]:

Affluent general waste assumed to be 0.45 putrescibles [food, garden, etc.] and 0.25 paper. (based on data from the Benoni area from Shamrock, 1998[3]: putrescibles 0.46 and paper 0.24)

[2] Van Zanten, B., and Scheepers, M., 1994, Modelling of Landfill Gas Potentials, Report prepared for International Energy Agency(IEA) Expert Working Group on Landfill Gas, published by Technical University of Lulea, Sweden.

[3] Shamrock, J.R., 1998, A Comparative Study of the Decomposition Processes and Products of Rich and Poor Refuse in South Africa, M.S. thesis, Faculty of Engineering, University of the Witwatersrand, Johannesburg.

Non-affluent general waste assumed to be 0.20 putrescibles and 0.05 paper (based on data from the Wattville area from Shamrock, 1998: putrescibles 0.18 and paper 0.04)

6. For methane recovered, the fraction of waste in place in a given year that could have landfill gas extraction (vertical wells or horizontal collectors) was considered, based on site development plans [result of consultation with EMM]. Then the recovery efficiency was assumed to be 75% and the recovered landfill gas was assumed to contain 40% methane (v/v).

7. Additional assumptions for each of the four EMM sites are given below:

a) Assumptions for Weltevreden
Tons of domestic waste landfilled in 2007 and later years was projected in consultation with EMM. These number reflect subtractions for non-domestic waste and landfill cover soil.

Year	**Domestic waste landfilled (tons)**
1995-1999	78 969
2000	78 969
2001	86 410
2002	113 313
2003	125 248
2004	147 665
2005	155 520
2006	160 186
2007	164 991
2008	169 941
2009	175 039
2010	180 290
2011	185 699
2012	191 270
2013	197 008
2014	202 918
2015	209 006
2016	215 276
2017	221 734
2018	228 386
2019	235 238
2020	242 295
2021	249 564
2022	257 051
2023	264 762
2024	272 705
2025	280 886

b) Assumptions for Rooikraal
Tons of domestic waste landfilled in 2007 and later years was projected in consultation with EMM. These number reflect subtractions for non-domestic waste and landfill cover soil.

Year	Domestic waste landfilled (tons)
2002	307 011
2003	307 011
2004	307 011
2005	307 011
2006	307 011
2007	316 221
2008	325 708
2009	335 479
2010	345 544
2011	355 910
2012	366 587
2013	377 585
2014	388 912
2015	400 580
2016	412 597
2017	424 975

c) Assumptions for Rietfontein
Tons of domestic waste landfilled in 2007 and later years was projected in consultation with EMM. These number reflect subtractions for non-domestic waste and landfill cover soil.

Year	Domestic waste landfilled (tons)
2001	103 568
2002	81 963
2003	75 029
2004	78 139
2005	103 975
2006	107 094
2007	110 307
2008	113 616
2009	117 025
2010	120 536
2011	124 152
2012	127 876

2013	131 712
2014	135 664
2015	139 734
2016	143 926
2017	148 243
2018	152 691
2019	157 272
2020	161 990
2021	166 849
2022	171 855
2023	177 010
2024	182 321
2025	187 790
2026	193 424
2027	199 227
2028	205 204
2029	211 360
2030	217 701
2031	224 232
2032	230 959

d) Assumptions for Simmer and Jack
Tons of domestic waste landfilled in 2007 and later years was projected in consultation with EMM. These number reflect subtractions for non-domestic waste and landfill cover soil.

Year	Domestic waste landfilled (tons)
1983	153 232
1984	153 232
1985	153 232
1986	153 232
1987	153 232
1988	153 232
1989	153 232
1990	153 232
1991	153 232
1992	153 232
1993	153 232
1994	153 232
1995	120 973
1996	127 340
1997	134 042
1998	141 097
1999	148 523

2000	104 227
2001	141 788
2002	158 042
2003	186 412
2004	169 241
2005	110 614
2006	113 932
2007	117 350
2008	120 871
2009	124 497
2010	128 232
2011	132 079
2012	136 041
2013	140 122
2014	144 326
2015	148 656
2016	153 115
2017	157 709
2018	162 440
2019	167 313
2020	172 333
2021	177 503

Formulae used

Greenhouse gas emissions by the baseline during year y (GHGE $baseline_y$) are equal to the amount of methane produced during the year ($CH_4produced_y$) multiplied by the approved Global Warming Potential value for methane (GWP_CH_4):

$$GHGE\ baseline_y = CH_4produced_y \times GWP\_CH_4$$

where GHGE $baseline_y$ is measured in tonnes of CO_2 equivalents (tCO_2e).
$CH_4produced_y$ is measured in tonnes of methane (tCH_4).
the approved Global Warming Potential value for methane (GWP_CH_4) for the first commitment period is 21 $tCO_2e/\ tCH_4$.

The volume of methane produced by the baseline during a given year ($CH_4produced_y$) is equal to the methane content of the landfill gas produced (MC_LFG) multiplied by the volume of landfill gas produced (LFG $produced_y$):

$$CH_4produced_y = MC\_LFG \times LFGproduced_y$$

where CH_4 $produced_y$ is measured in cubic metres (m^3). The volume of methane is converted to tonnes of methane using the molecular weight and molecular volume of methane.
MC_LFG is assumed to be 40%
LFG $produced_y$ is measured in Normal cubic metres (m^3).

Annex 4

MONITORING INFORMATION

Monitoring will be conducted in line with the methodology and monitoring plan outlined in Section B.7. in the body of this document. The EMM is currently in the process of appointing a service provider to conduct monitoring of the project activity.

Annex 5

ENVIRONMENTAL IMPACT ASSESSMENT

Records of Decision authorising the project are attached.