



**CLEAN DEVELOPMENT MECHANISM
PROJECT DESIGN DOCUMENT FORM (CDM-PDD)
Version 02 - in effect as of: 1 July 2004)**

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**SECTION A. General description of project activity****A.1 Title of the project activity:**

>> Montevideo Landfill Gas Capture and Flare Project

Date of this document, PDD Version 01: November 2005

A.2. Description of the project activity:

>> The purpose of the proposed project activity is the capturing and flaring of the LFG generated at Montevideo's landfill, Uruguay.

The proposed project activity will contribute to mitigate the GHG emissions through the destruction of the methane contained in the landfill gas (LFG). It is expected that this contribution avoids the emission of 2,383,000 ton CO₂e to the atmosphere over a period of 21 years starting in 2007. The project activity will generate Certificates of Emission Reductions (CERs) and revenues through the selling of CERs in the Clean Development Mechanism. The revenues obtained will contribute to eliminate the barriers preventing the implementation of this project.

The proposed activity will also contribute to the sustainable development of the city of Montevideo improving the current solid waste management and the environmental conditions in the surroundings of the landfill site by decreasing emissions from other harmful component in the LFG as well as explosion and fire risks.

Currently, the Municipality of Montevideo owns and operates the landfill, therefore any revenue coming from the exploitation of the landfill gas, including revenues coming from CERs sales, will be administered by the Municipality to improve landfill operation.

For the construction, operation and maintenance of the proposed LFG capture plant, the Municipality of Montevideo will call for an international bidding.

The Municipality of Montevideo, through its División Limpieza, also coordinates and executes the activities related to MSW collection and transport, and final disposal operations in the landfill. División Limpieza also manages an organic waste treatment program, the so-called TRESOR that makes use of specific urban organic waste streams coming from food markets and tree trimming for composting.

The proposed project activity is in line with a Master Plan for Solid Waste Management for city of Montevideo and the Metropolitan Area currently under development. This Plan is financed by the BID's loan No. 948/OC-UR as part of Subprogram B of the Montevideo Sanitation Program Stage III. The Plan is being realized by the private consultant FICHTNER GmbH & Co. KG. since September 2003.

According to the first draft of the Plan, its main objectives are to develop a more efficient and sustainable MSW management, to minimize environmental and health impacts produce by the MSW management, to integrate the MSW management to other activities related to environmental, public health, and economic activities, and to achieve the sustainability of the MSW management proposed.

The capture of methane from landfills is also included as a goal of Uruguay's national strategy related to climate change. The following legislation supports this strategy:

- Law 16517 that approved the United Nations Framework Convention of Climate Change in 1994,
- Law 17279 that approved the Kyoto Protocol in 2000 (The Kyoto Protocol was later ratified in February 2001),



- Ministerial Resolution RM 505/94 that created the Climate Change Unit under the National Direction for the Environment in 1994, and
- Ministerial Resolution RM 341/01 that designated the Climate Change Unit as the Designated National Authority of the Clean Development Mechanism in 2001.

The proposed project activity will contribute to developing and implementing a new technology, improving the demand of local labor, and encouraging the local supply of equipment and other components for the construction and operation of the LFG capture plant. These activities will add to local know-how and therefore increasing the possibility to replicate the project activity throughout the region.

Overall, the proposed activity will establish a better practice for urban solid waste management and landfill gas recovery in Uruguay where open dumps are still the common practice throughout the country. Project activities will also demonstrate the advantage of the GHG emission market and Kyoto mechanisms to finance new technologies and management in the public sector that may contribute to a sustainable development.

A.3. Project participants:

>>

Name of Party involved (host) indicates a host Party)	Private and/or public entity(ies) project participants (as applicable)	Kindly indicate if the Party involved wishes to be considered as project participant (Yes/No)
Uruguay (host)	- Municipality of Montevideo: Sponsor of the project	No
Spain	- International Bank for Reconstruction and Development as the Trustee of the Spanish Carbon Fund	Yes

A.4. Technical description of the project activity:**A.4.1. Location of the project activity:**

>>

A.4.1.1. Host Party(ies):

>> Uruguay

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

>> Department of Montevideo

A.4.1.3. City/Town/Community etc.:

>> Montevideo

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

>> The proposed project activity will be carried out at the Montevideo's landfill. The city of Montevideo is the capital of Uruguay, one of the smallest countries in Latin America. The Department of Montevideo concentrates approximately 1,350,000 inhabitants, 40% of Uruguay total population. Both the local government of the Department of Montevideo and the national government's headquarters are located in this city.



Figure 1. Location of Uruguay and Montevideo

The region has mild weather with an annual precipitation rate of approximately 900 mm/year.

The landfill site is called the Waste Disposal Unit and is located at Carrasco Norte, in the suburbs of Montevideo. The site has an electrical substation located approximately 500-1,000 m away, and a main gas pipeline at approximately 1,000 m.

The landfill site was selected in 1990 due to the good soil conditions for this type of activity. Waste disposal at the landfill started that same year and it is expected to continue until 2011 according to the



estimated capacity of approximately 10.5 million metric tons of municipal solid waste (MSW). Currently, about 1,300 ton/day (or 475,000 ton/yr) of MSW are filling the landfill.

Most of the MSW disposed at the landfill comes from the Montevideo's metropolitan area, with a small fraction coming from the nearby town of Canelones. Approximately 90 percent of the MSW transported to the landfill is collected by the municipal waste transport system, while the other 10 percent is collected and transported by private companies.

The landfill consists of two main areas: Cells 6/7 and Cell 8. Cells 6/7 have been in operation since 1990 and have approximately 6.7 million tons of MSW in place over an area of approximately 30 ha; although some waste is still being disposed in these cells, they are scheduled to be capped in 2005. Cells 6/7 have a total height of approximately 20-25 m, and have neither a bottom synthetic liner nor a leachate collection system. Cell 8 is in operation since 2002; it has an area of 40 ha and a total capacity of approximately 4 million tons of waste. Up to date, approximately 750,000 tons of MSW have been disposed at this cell. The final height of Cell 8 is expected to reach approximately 30-35 m by 2011. Currently, the landfill does not have an active landfill gas collection and treatment system, and LFG is passively released to the atmosphere.

Widespread scavenging is not permitted at the landfill, however a limited number of people are allowed to work inside the landfill site to recover materials from a fraction of the waste; these operations occur off the landfill working area.

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

>>The proposed project activity of *Landfill Gas Capture and Flaring* may be included in the Sectoral Scope 13: Waste handling and disposal.

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

>> The engineering design for the LFG capturing and flaring will be based on an active LFG collection system. The system will have five basic components:

- a) *collection system*: wells, well-heads and pipelines system to capture, control, monitor and transport LFG to the extraction system.
- b) *external leachate system*: pumps and collection pipelines. According to SCS pre-feasibility study and based on the results of the pump test realized, it is expected high leachate levels throughout the landfill.
- c) *extraction system*: blowers, valves and flow control system.
- d) *condensate system*: traps and knockout vessels, pumps and pipes to remove gas condensates.
- e) *flare system*: enclosed flare to quantify emission reductions and monitor exhaust gas components. According the SCS's pre-feasibility study a 5,000 m³/h flare capacity will be sufficient to handle the maximum project LFG recovery rate under a mid-range scenario.
- f) *monitoring and control system*: to measure LFG flow, composition, temperature and pressure.

Note: In this project, LFG will be combusted in a flare with no energy recovery. However, the utilization of the LFG will be analyzed in the future in the light of the actual recovery LFG rate obtained and other economic factors. This analysis is not included in this document.



A.4.4. Brief explanation of how the anthropogenic emissions of anthropogenic greenhouse gas (GHGs) by sources are to be reduced by the proposed CDM project activity, including why the emission reductions would not occur in the absence of the proposed project activity, taking into account national and/or sectoral policies and circumstances:

>> The proposed project activity will reduce the GHG emissions through the capturing and flaring of the methane contained in the LFG. This project activity will contribute to mitigate a strong greenhouse gas such as methane, and will improve the environmental conditions in the surroundings of the landfill site. The emission reductions (ERs) to be achieved with the proposed project activity will be directly measured according to the Monitoring Plan described in Section D of this document. The estimated annual average ERs for the proposed project activity are 113,500 ton CO₂e per year over the 21-year crediting period starting in 2007.

The emission reductions would not occur in the absence of the project activity due mainly to financial barriers (explained in section B.3) and national circumstances such as a basic environmental legislation that up to date does not enforce the construction of landfills as final disposal technology for municipal solid wastes.

The legal framework for the proposed project activity includes

- Law 9515, passed in 1935, that establishes that Municipalities are responsible for municipal solid waste collection, transport and disposal;
- Law 14466 for the Environment, passed in 1994, that establishes the Environmental Impact Assessment as technical tool for a group of activities including the disposal of toxic waste; and finally,
- Law 17283 for the Protection of the Environment, passed in 2000, that mentions in Article 1, incise C, the necessity of a careful management of wastes, and establishes in Article 21 that the Ministry of Housing, Territory Management, and Environment would legislate with respect to the collection, transport and storage and treatment and final disposal of waste.

In addition to current legislation that does not enforce LFG capture and treatment, there are no economic incentives (such as tax credits to capture and burn methane from landfill gas) other than the incentive from the CDM.

Under this scenario, it is clear that without the income from the selling of CERs in the CDM, the project activity would not be carried out and the current practice in relation to solid waste management and landfills operation will continue throughout the country, noticeably, the uncontrolled release of the LFG into the atmosphere without any treatment. This situation is assumed as the most likely future scenario in the absence of the proposed CDM activity.



A.4.4.1. Estimated amount of emission reductions over the chosen crediting period:

>>

Year	Annual estimation of emission reductions in tons of CO ₂ e
	First 7-year crediting period
2007	236,009
2008	234,272
2009	233,152
2010	232,457
2011	232,110
2012	249,840
2013	195,507
Average first 7-year period	230,478
Total first 7-year period	1,613,347
Second 7-year crediting period	
2014	154,144
2015	122,550
2016	98,398
2017	79,816
2018	65,557
2019	54,499
2020	46,292
Average second 7-year period	88,751
Total second 7-year period	621,256
Third 7-year crediting period	
2021	37,224
2022	29,933
2023	24,070
2024	19,355
2025	15,564
2026	12,515
2027	10,064
Average third 7-year period	21,247
Total third 7-year period	148,726
Total estimated reductions (tons of CO ₂ e)	2,621,885
Total number of crediting years	21
Annual average over the crediting period of estimated reductions (tons of CO ₂ e)	113,492

The details of the emission reductions estimation are given in Section E.

A.4.5. Public funding of the project activity:

>> No public funding from Annex I parties is involved in this project.

**SECTION B. Application of a baseline methodology****B.1. Title and reference of the approved baseline methodology applied to the project activity:**

>> The applied baseline methodology is the approved ACM0001: “Consolidated baseline methodology for landfill gas project activities”

B.1.1. Justification of the choice of the methodology and why it is applicable to the project activity:

>> The selected methodology ACM0001 is applicable to landfill gas capture and flare project activities where the baseline scenario is the total release of the landfill gas to the atmosphere.

B.2. Description of how the methodology is applied in the context of the project activity:

>> According to the adopted methodology ACM0001, “the methane destroyed by the project activity ($MD_{project,y}$) during a year is determined by monitoring the quantity of methane actually flared...”

In the proposed project activity, the actual methane destroyed will be obtained from direct measurements of key parameters that in turn will allow calculating the emission reductions.

Following the chosen methodology ACM0001, the emission reductions achieved by the project activity during a given year “y” (ER_y) will be calculated as the difference between the amount of methane actually destroyed during the year ($MD_{project,y}$) and the amount of methane that would have been destroyed during the year in the absence of the project activity ($MD_{reg,y}$), times the approved Global Warming Potential value for methane (GWP_{CH4}).

$$ER_y = (MD_{project,y} - MD_{reg,y}) \cdot GWP_{CH4}$$

where:

ER_y emission reductions [ton CO₂e/year]

$MD_{project,y}$ is the methane destroyed by flaring [ton CH₄/year]

$MD_{reg,y}$ is the methane that would have been destroyed during the year in the absence of the project activity [ton CH₄/year]. $MD_{reg,y} = MD_{project,y} \times AF$, where for the proposed project activity AF is zero because collection and destruction of landfill methane are not mandated by legislation or contractual agreement that requires the collection and destroying of specific percentage of the generated methane, as explained in Section A.4.4.

GWP is the Global Warming Potential value for methane 21 [ton CO₂e/ton CH₄]

The methane destroyed by the project activity $MD_{project,y}$ during a year is determined by monitoring the quantity of methane actually flared:

$$MD_{project,y} = MD_{flared,y}$$

$$MD_{flared,y} = LFG_{flared,y} \cdot W_{CH4,y} \cdot D_{CH4} \cdot FE$$

where:

$MD_{flared,y}$ is the quantity of methane destroyed by flaring [ton CH₄/year]



$LFG_{flared,y}$ is the quantity of landfill gas flared during the year (see Table D.2.2.1, ID 1)
 $w_{CH_4,y}$ is the methane fraction of the landfill gas (see Table D.2.2.1, ID 5)
 D_{CH_4} is the methane density (see Table D.2.2.1, ID 4)
 FE is the flare efficiency (see Table D.2.2.1, ID 6)

Details of how the ACM0001 methodology is applied in the context of the proposed project activity are fully described in Section D.

No leakage effects need to be accounted under this methodology.

B.3. 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:

>> The ACM0001 methodology requires the use of the “*Tool for the demonstration and assessment of additionality*” to prove the additionality of the project activity. The following analysis provides the most recognized basis for the demonstration of project additionality:

Step 0. Preliminary screening based on the starting date of the project activity

The first crediting period is expected to start on April 1, 2007; since all necessary local permits, and CDM validation and registration are expected to be finished before this date, the crediting period will commence after the registration of the project activity. As a result, Step 0 is not applicable.

Step 1: Identification of alternatives to the project activity consistent with current laws and regulations

Sub-step 1a. Define alternatives to the project activity

Three realistic and credible alternatives to the proposed project activity have been identified :

Alternatives of proposed project activity	Probability of scenario
No capture of LFG from Montevideo landfill (Baseline scenario)	Most probable: this is the current situation and the baseline scenario. No economic benefits would be obtained from LFG capture and flare, and no legal bounds are established either.
LFG capture and flare outside the CDM	Very low probability: the high costs for the construction and operation for the LFG recovery plant are difficult to afford without financial assistance. Montevideo Municipal budget does not contemplate funding sources to support these type of environmental projects.
LFG capture and electricity generation	Low probability: high investment costs for construction and operation for the LFG recovery and power plant and low electricity prices make this alternative unlikely.

Sub-step 1b. Enforcement of applicable laws and regulations:

There is no specific legislation in Uruguay that enforce or ban the activities described. The proposed project activity and the alternatives identified are in compliance with all applicable laws.

**Step 2: Investment analysis***Sub-step 2a. Determine appropriate analysis method*

The proposed project activity will not generate financial or economic benefits other than the CDM related income, therefore Sub-step 2b. Option I applies.

Sub-step 2b. Option I. Apply simple cost analysis

The prefeasibility study performed by SCS Engineers in 2005 shows a negative Net Present Value of US\$ 4,600,000 for the proposed project activity when no CDM related income is considered (over a 21-year period and assuming an annual interest rate of 8%). The required initial investment reaches US\$ 1,600,000.

As mentioned above, the proposed project activity of LFG capture and flare will not produce economic benefit other than CDM related income.

Since the proposed project activity is not financially attractive, Step 4 follows.

Step 4: Common practice analysis

As mentioned above, the current situation at Montevideo's landfill with respect to LFG release to the atmosphere is the extended common practice throughout the country wherever landfills are in operation.

Sub-step 4a. Analyze other activities similar to the proposed project activity

There is one LFG-to-energy project in operation in Uruguay. This demonstrative project was developed at Las Rosas' landfill in the Department of Maldonado and inaugurated in 2004. The project, which generates electricity through two 400-kW gas generators, was completely funded by the Global Environment Facility (GEF). Due to the lack of local experience and technology for LFG recovery in Uruguay, the LFG recovery plant construction and equipment provision were carried out by a foreign constructor.

A 20-year life cycle cost analysis of the Maldonado's project shows a negative Net Present Value of approximately one million dollars.

Sub-step 4b. Discuss any similar options that are occurring

No other similar activities are currently observed in Uruguay.

Step 5: Impact of CDM registration

The proposed project activity will reduce greenhouse gas emissions, thereby contributing to mitigate climate change. The reduction will generate certified emission reductions (CERs) to be sold through the CDM. The income generated from the selling of CERs will eliminate the main barriers preventing the implementation of this project.

The project will also deliver local community benefits related to the creation of new jobs during the construction, operation and maintenance stages of the LFG recovery plant and to the possibility of attracting new players to bring the capacity to implement the new technology.

Finally, the replication of the project activities in other towns around the country will trigger environmental awareness related to waste management, renewable energy resources and climate change in the involved communities.

B.4. Description of how the definition of the project boundary related to the baseline methodology selected is applied to the project activity:

>> According to the consolidated baseline methodology ACM0001, the project boundary is the site of the project activity where the LFG is captured and destroyed. The baseline scenario of the project activity shall cover the landfill site.

Figure 2 shows the basic operations involved in the MSW management in Montevideo, including the proposed project activity. The dashed line defines the project boundary.

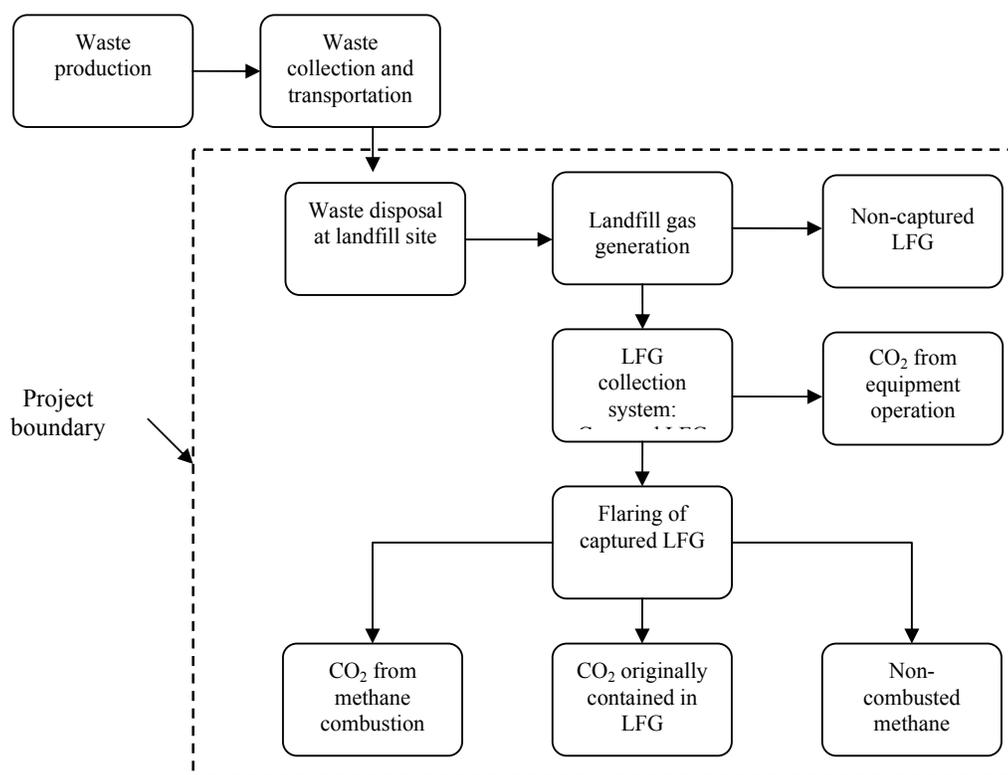


Figure 2. MSW operations, project activity and project boundary for Montevideo Landfill Gas Capture and Flare Project

According to the approved consolidated baseline methodology ACM0001 under the title Project Boundary, neither CO₂ emissions from the combustion of the methane nor CO₂ emissions originally contained in LFG shall be accounted for.

CO₂ emissions related to equipment operation within the boundary are mainly due to electricity used by LFG blowers. These emissions were estimated based on the electricity consumption (460 MWh/year) and the emission factor of the electricity grid (0.39 ton CO₂/MWh); calculations yield 180 ton CO₂e/year. These emissions are approximately 0.16 % of the estimated annual emission reductions and therefore they will not be taken into account.

Baseline emissions –emissions that would happen in the absence of the project activity- were estimated using the First Order Decay model (IPCC, 1996), based on information about municipal solid waste in Montevideo's metropolitan area and other technical parameters related to the landfill site (details are



described in Annex 3). As a result of applying the FOD model, an average of **173,447** ton CO₂e/year would freely migrate to the atmosphere within the boundary of the proposed project activity during the 21-year crediting period starting in 2007. These are the **baseline emissions**.

The methodology to determine the baseline scenario and baseline emissions for the project activity is given in Annex 3.



B.5. Details of baseline information, including the date of completion of the baseline study and the name of person (s)/entity (ies) determining the baseline:

>> The details to determine the baseline scenario and baseline emissions are given in Annex 3.

Date of completion of the baseline study: October 2005.

The College of Engineering of the National University of the Center of Buenos Aires Province has determined the baseline.

Contact persons:

Gabriel Blanco (gblanco@fio.unicen.edu.ar)

Estela Santalla (esantall@fio.unicen.edu.ar)

**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:**

>> LFG recovery plant construction: from 10/01/2006 to 01/31/2007

LFG recovery plant start up: from 02/01/2007 to 03/31/2007

Project activities regarding CERs crediting period: from 04/01/2007

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

>> 21 years

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:**

>> 04/01/2007

C.2.1.2. Length of the first crediting period:

>> 7 years

C.2.2. Fixed crediting period:**C.2.2.1. Starting date:**

>> Not applicable

C.2.2.2. Length:

>> Not applicable

**SECTION D. Application of a monitoring methodology and plan****D.1. Name and reference of approved monitoring methodology applied to the project activity:**

>> The Monitoring Plan (MP) for the Montevideo Landfill Gas Capture and Flare Project was developed according to the approved consolidated monitoring methodology ACM0001: “Consolidated monitoring methodology for landfill gas project activities”.

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

>> The selected methodology ACM0001 is applicable to “landfill gas capture project activities where the baseline scenario is the partial or total atmospheric release of the gas and the project activities include the situation of flaring the captured gas”. This is the case for the proposed project activity.

The monitoring methodology is based on direct measurement of the amount of landfill gas captured and destroyed at the flare platform.

The Monitoring Plan for the proposed project activity provides for direct measurement of the quantity and quality of LFG flared. This plan also includes periodic monitoring for updates of Uruguay’s legislation and regulatory requirements through the official websites of the Dirección Nacional de Medio Ambiente DINAMA (<http://www.dinama.gub.uy>) and the Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente MVOTMA (<http://www.mvotma.gub.uy>).

The main variables that need to be determined are the quantity of methane actually captured ($MD_{project,y}$) and the quantity of methane flared ($MD_{flared,y}$).

To determine these variables, the following parameters will be monitored:

- The amount of landfill gas fed to the flare ($LFG_{flare,y}$) will be measured continuously using a continuous flowmeter.
- The fraction of methane in the landfill gas ($w_{CH_4,y}$) will be measured with periodical measurements, at a 95% confidence level, using a calibrated portable gas analyzer and taking a statistically valid number of samples.
- Temperature (T) and pressure (p) of the landfill gas will be measured to determine the density of methane in the landfill gas.
- The flare efficiency (FE), measured as the fraction of time in which the gas is combusted in the flare multiplied by the efficiency of the combustion process. This combustion efficiency is initially assumed at 97% and will be periodically verified through laboratory analysis to determine the methane content in the flare emissions.
- Periodic monitoring for updates of Uruguay’s legislation and regulatory requirements.

Please, refer to Table D.2.2.1. for detailed data measurement and recording frequency.

The quantities of electricity to operate the LFG pumping equipment are negligible and therefore they will not be considered (see Section B.4.).

With regard to changes in the baseline scenario due to changes in the legislation, no legal bound to enforce LFG recovery is foreseen in the near future.



D.2.1. Option 1: Monitoring of the emissions in the project scenario and the baseline scenario

>> Option 1 is not applicable. Option 2: *Direct monitoring of emission reductions from the project activity* is applied.

D.2.1.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:

ID number <i>(Please use numbers to ease cross-referencing to D.3)</i>	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/paper)	Comment

D.2.1.2. Description of formulae used to estimate project emissions (for each gas, source, formulae/algorithm, emissions units of CO₂ equ.)

>>

D.2.1.3. Relevant data necessary for determining the baseline of anthropogenic emissions by sources of GHGs within the project boundary and how such data will be collected and archived :

ID number <i>(Please use numbers to ease cross-referencing to table D.3)</i>	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/paper)	Comment

D.2.1.4. Description of formulae used to estimate baseline emissions (for each gas, source, formulae/algorithm, emissions units of CO₂ equ.)

>>



D.2.2. Option 2: Direct monitoring of emission reductions from the project activity (values should be consistent with those in section E).

D.2.2.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:

ID number (Please use numbers to ease cross-referencing to table D.3)	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment*
1. $LFG_{flared,y}$	Flow of LFG flared	Flowmeter	m ³ /h	m	Continuously	100%	electronic/paper	Data will be aggregated monthly and yearly
2. T	Temperature of LFG	Temperature sensor	°C	m	Daily	100%	electronic/paper	Data will be used to calculate the methane density.
3. P	Pressure of LFG	Pressure Sensor	kPa	m	Daily	100%	electronic/paper	Data will be used to calculate the methane density.
4. D_{CH4}	Methane density in LFG	Calculation	ton CH ₄ /m ³ CH ₄	c	Daily	100%	electronic/paper	To be used to calculate the methane destroyed.
5. $w_{CH4,y}$	Methane fraction in LFG	Gas analyzer	m ³ CH ₄ /m ³ LFG	M	Daily	Sample	electronic/paper	To be used to calculate the methane destroyed

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6. <i>FE</i>	Combustion efficiency	Estimation	%	E	Quarterly	100%	electronic/paper	The estimated combustion efficiency will be quarterly verified through lab analysis to determine the methane content in the exhaust gas
	Flare availability	Timer	%	M	Continuously	100%	electronic/paper	Data will be aggregated monthly and yearly
7	Legislation and regulatory requirements related to LFG	Official website	Test	n/a	Annually	100%	electronic/paper	Required for any changes to the adjustment factor (AF) or directly $MD_{reg,y}$

* All archived data will be kept for two years after the end of the crediting period or the last issuance of CERs for this project activity, whichever occurs later.



D.2.2.2. Description of formulae used to calculate project emissions (for each gas, source, formulae/algorithm, emissions units of CO₂ eq.):

>> Not applicable. In this project and according to ACM0001, project emissions will not be monitored nor measured, instead emission reductions will be directly measured, as explained in Section D.2.4.

D.2.3. Treatment of leakage in the monitoring plan

>>No leakage will be considered for the project activity

D.2.3.1. If applicable, please describe the data and information that will be collected in order to monitor leakage effects of the project activity

ID number <i>(Please use numbers to ease cross-referencing to table D.3)</i>	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/paper)	Comment

D.2.3.2. Description of formulae used to estimate leakage (for each gas, source, formulae/algorithm, emissions units of CO₂ equ.)

>> Not applicable



D.2.4. Description of formulae used to estimate emission reductions for the project activity (for each gas, source, formulae/algorithm, emissions units of CO₂ equ.)

>> According to the chosen methodology ACM0001, the emission reductions achieved by the project activity during a given year “y” (ER_y) will be calculated as the difference between the amount of methane actually destroyed during the year ($MD_{project,y}$) and the amount of methane that would have been destroyed during the year in the absence of the project activity ($MD_{reg,y}$), times the approved Global Warming Potential value for methane (GWP_{CH_4}).

$$ER_y = (MD_{project,y} - MD_{reg,y}) \cdot GWP_{CH_4} \quad (1)$$

where:

ER_y emission reductions [ton CO₂e/year]

$MD_{project,y}$ is the methane destroyed by flaring [ton CH₄/year]

$MD_{reg,y}$ is the methane that would have been destroyed during the year in the absence of the project activity [ton CH₄/year]. $MD_{reg,y} = MD_{project,y} \times AF$, where, for the proposed project activity AF is zero because collection and destruction of landfill methane are not mandated by legislation or contractual agreement that requires the collection and destroying of specific percentage of the generated methane, as explained in Section A.4.4. GWP is the Global Warming Potential value for methane 21 [ton CO₂e/ton CH₄]

The methane destroyed by the project activity $MD_{project,y}$ during a year is determined by monitoring the quantity of methane actually flared:

$$MD_{project,y} = MD_{flared,y} \quad (2)$$

$$MD_{flared,y} = LFG_{flared,y} \cdot w_{CH_4,y} \cdot D_{CH_4} \cdot FE \quad (3)$$

where:

$MD_{flared,y}$ is the quantity of methane destroyed by flaring [ton CH₄/year]

$LFG_{flared,y}$ is the quantity of landfill gas flared during the year (see Table D.2.2.1, ID 1)

$w_{CH_4,y}$ is the methane fraction of the landfill gas (see Table D.2.2.1, ID 5)

D_{CH_4} is the methane density (see Table D.2.2.1, ID 4)

FE is the flare efficiency (see Table D.2.2.1, ID 6)

In order to calculate the quantity of landfill gas flared during the year ($LFG_{flared,y}$) the estimated methane to be generated in the landfill in that year ($CH_{4,y}$) is divided by the methane content in the LFG (w_{CH_4}) and multiplied by the LFG recovery efficiency (RE) assumed at 50 % for this project.

Multiplying $LFG_{flared,y}$ by the methane content in LFG ($w_{CH_4,y}$), the methane density (D_{CH_4}) and the flare efficiency (FE), the methane destroyed by flaring

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($MD_{flared,y}$) is obtained. This value constitutes a measurable and verifiable amount that will be determined according to the modalities and procedures of the Monitoring Plan described in Annex 4.

In order to calculate the emission reductions (ER_y) in tons of CO_2e , the quantity of methane destroyed by flaring $MD_{flared,y}$ is multiplied by the Global Warming Potential (GWP) for methane.

D.3. Quality control (QC) and quality assurance (QA) procedures are being undertaken for data monitored		
Data (Indicate table and ID number e.g. 3.-1.; 3.2.)	Uncertainty level of data (High/Medium/Low)	Explain QA/QC procedures planned for these data, or why such procedures are not necessary.
Table D.2.2.1. ID.1	Low	Flowmeter will be subject to regular maintenance according to the technical specifications from the manufacturers to ensure accuracy and good performance.
Table D.2.2.1. ID.2-3	Low	Temperature and pressure sensors will be subject to regular maintenance according to the technical specifications from the manufacturers to ensure accuracy and good performance.
Table D.2.2.1. ID.5	Low	Gas analysers (LFG quality) will be subject to regular maintenance and calibration procedures according to the technical specifications from the manufacturers to ensure accuracy and good performance.
Table D.2.2.1. ID.6	Medium	Regular maintenance will ensure optimal operations of the flare. Flare efficiency will be checked quarterly to verified deviation from the estimated value of combustion efficiency.
Table D.2.2.1. ID.6	Low	Timer device will be subject to regular maintenance to ensure accuracy.

D.4 Please describe the operational and management structure that the project operator will implement in order to monitor emission reductions and any leakage effects, generated by the project activity

>> In order to monitor emission reductions, the project operator will follow the Monitoring Plan and the procedures established in the guidelines for LFG plant operation and monitoring, as described in Annex 4.

D.5 Name of person/entity determining the monitoring methodology:

>> The entity that determined the Monitoring Plan and methodology is the College of Engineering of the UNCPBA

Contact persons:

Gabriel Blanco (gblanco@fio.unicen.edu.ar)

Estela Santalla (esantall@fio.unicen.edu.ar)

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**SECTION E. Estimation of GHG emissions by sources****E.1. Estimate of GHG emissions by sources:**

>> The anthropogenic emissions that would occur within the boundary of the project when the project activities (i.e., LFG capture and destruction) are in operation can be described as follow:

1. methane emissions due to the non-captured LFG.
2. methane emissions in the flare exhaust due to the flare efficiency.
3. CO₂ emissions in the flare due to the CO₂ contained in the captured LFG that remain unchanged during the combustion process.
4. CO₂ emissions in the flare due to the combustion of methane.
5. CO₂ emissions due to equipment operation within the boundary.

Sources of emissions (3) and (4) are part of the natural CO₂ biological cycle and therefore neutral to the atmosphere; these CO₂ emissions are not considered in this project.

CO₂ emissions resulting from equipment operation within the boundary (5) are mainly due to electricity used by LFG blowers. These emissions were estimated based on the electricity consumption (460 MWh/year) and the emission factor of the electricity grid (0.39 ton CO₂/MWh); calculations yield 180 ton CO₂e/year. These emissions are approximately 0.16 % of the estimated emission reductions and therefore they will not be taken into account.

The emissions of GHG by sources within the project boundary are the methane emissions due the non-captured LFG (1) and the methane emissions in the flare due to the flare efficiency (2). Both sources of anthropogenic GHG are defined as the project emissions (PE_y) and can be estimated from the following equation:

$$PE_y = CH_{4,y} \cdot D_{CH_4} \cdot (1-RE) \cdot GWP_{CH_4} + CH_{4,y} \cdot D_{CH_4} \cdot RE \cdot (1-FE) \cdot GWP_{CH_4}$$

Where the first term of the right member of the equation represents the non-captured LFG due to recovery efficiency (in ton CO₂e/year), the second term represents the amount of non-combusted methane due to flare efficiency (in ton CO₂e/year).

$CH_{4,y}$ is the total methane generated at the landfill (in m³ of CH₄ per year), and is obtained by using the FOD model explained in Annex 3.

Assuming a LFG recovery efficiency (RE) of 65 % from 2007 to 2011 and 70% for the following years until 2027 (this scenario is explained in Annex 3), a flare efficiency (FE) of 93.1% (described below in Section E.5), the methane density at 15°C and 101 kPa¹, a methane content of 50%, and a Global Warming Potential² (GWP) for methane of 21, the estimated annual average **project emissions** (PE) are **59,955** ton CO₂e/year over the 21-year period starting in 2007.

¹ Annual average environmental climate conditions at Montevideo

² The approved Global Warming Potential value for methane (GWP_{CH_4}) is 21 tCO₂e/tCH₄ according to Miscellaneous Parameters in ACM0001/Version 1 of the Approved consolidated monitoring methodology ACM0001 CDM, EB, 3 September 2004

**E.2. Estimated leakage:**

>> No leakage was considered for the project activity according methodology applied ACM0001.

E.3. The sum of E.1 and E.2 representing the project activity emissions:

>> The chosen baseline methodology ACM001 directly calculates the emission reductions but for a first estimation, as E.2 is zero E.3 is equal to E.1, that is **59,955** ton CO₂e/year over the 21-year crediting period.

E.4. Estimated anthropogenic emissions by sources of greenhouse gases of the baseline:

>> The GHG emissions by sources of the baseline are represented by the amount of methane contained in the landfill gas ($CH_{4,y}$) that is currently release to the atmosphere (see Section B.5.)

According to information given by the División Limpieza of the Municipality of Montevideo, Montevideo's landfill is filling at an average of 1,300 tons of MSW per day. Up to date, a total of 6,700,000 tons of MSW have already been disposed in the still active cells 6/7 and another 750,000 in cell 8. SCS Engineers assumes that MSW disposed at Montevideo's landfill contains more than 58% organic matter of fast degradability rate and approximately 10% of components of middle degradability rate (see Annex 3 *Methane Generation Rate*). Using the First Order Decay (FOD), it is estimated that an average of 2,830 m³/h of LFG will be released to the atmosphere during the 21-year crediting period starting in 2007. This estimated value corresponds to an annual average of emissions of **173,447** ton CO₂e/year and represents the **baseline emissions**.

Details of the baseline emissions estimation are given in Annex 3.

E.5. Difference between E.4 and E.3 representing the emission reductions of the project activity:

>> In this project and according to the chosen methodology ACM0001, the emissions reductions (ERs) will be directly measured at the landfill site once the LFG recovery plant is installed and operating, as described in the Monitoring Plan in Section D.

However, a preliminary estimation of ERs has been performed by using the baseline emissions, the formulae given in Section D.2.4., and assuming values for several parameters that will be actually measured and monitored during project operations (see Section D.2.)

The parameters are:

- the recovery efficiency (*RE*) of the LFG collection system was estimated of 65% from 2007 to 2011 and 70% for the following years until 2027 (this scenario is explained in Annex 3 *LFG System Coverage*).
- the flare efficiency (*FE*) was calculated as the flare availability (fraction of time in which the gas is combusted) assumed at 96% multiplied by the combustion efficiency (fraction of methane actually destroyed). The standard combustion efficiency given by flare manufacturers is 99%; however, a conservative value of 97% is assumed for this project. Using these two figures the estimated flare efficiency is 93.1%. *Note: During the project operations the flare availability will be continuously recorded and the combustion efficiency will be quarterly verified through lab analysis to determine the methane content in the exhaust gas.*
- The methane content (w_{CH_4}) in LFG assumed of 50%. *Note: During the project operations the methane content in LFG will be daily measured and recorded.*



- The methane density (D_{CH_4}) at 15°C and 101 kPa: of 0.678 kg/m³. *Note: During the project operations the methane density of LFG will be daily calculated by measuring temperature and pressure.*
- The Global Warming Potential (GWP) for methane of 21 tCO₂e/tCH₄,

Thus, the estimated annual average **emission reductions** for the proposed project activity according the formulae given in Section D.2.4. are **113,492** ton CO₂e/year over the 21-year crediting period starting in 2007.

Figure 3 shows the evolution of baseline emissions and emission reductions within the boundary of the project over the crediting life in tons of CO₂ equivalent.

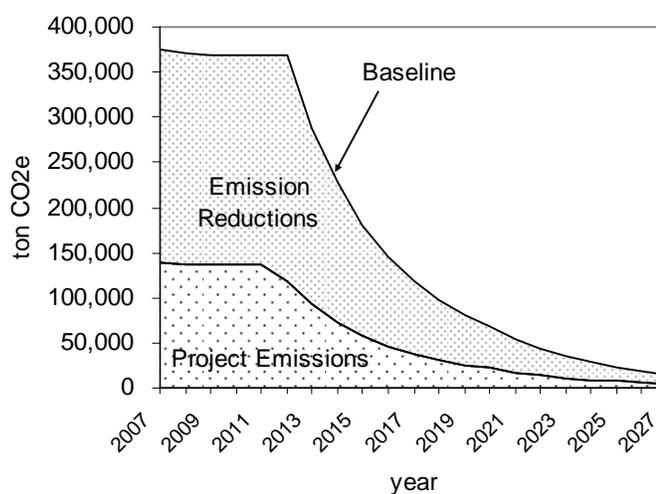


Figure 3. Evolution of baseline emissions (estimated), emissions reductions (to be measured but previously estimated) and project emissions (estimated) for Montevideo Landfill Gas Capture Project

The **emission reductions** represent the amount of methane actually destroyed and constitute a measurable and verifiable amount that will be determined according to the Monitoring Plan developed in Section D.

**E.6. Table providing values obtained when applying formulae above:**

>> Table 2 shows the estimated annual ERs during the crediting period of the project.

Table 2. Baseline emissions and emission reductions (in ton CO₂e)

Year	Baseline emissions <i>ton CO₂e</i>	Cumulative Baseline emissions <i>ton CO₂e</i>	Emission Reductions <i>ton CO₂e</i>	Cumulative Emission Reductions <i>ton CO₂e</i>
2007	374,320	374,320	236,009	236,009
2008	371,565	745,885	234,272	470,280
2009	369,789	1,115,674	233,152	703,432
2010	368,687	1,484,361	232,457	935,890
2011	368,136	1,852,498	232,110	1,168,000
2012	367,953	2,220,450	249,840	1,417,840
2013	287,934	2,508,384	195,507	1,613,347
2014	227,016	2,735,400	154,144	1,767,491
2015	180,487	2,915,887	122,550	1,890,041
2016	144,916	3,060,803	98,398	1,988,439
2017	117,549	3,178,352	79,816	2,068,255
2018	96,549	3,274,901	65,557	2,133,812
2019	80,264	3,355,165	54,499	2,188,311
2020	68,176	3,423,341	46,292	2,234,603
2021	54,822	3,478,164	37,224	2,271,827
2022	44,084	3,522,248	29,933	2,301,760
2023	35,449	3,557,697	24,070	2,325,830
2024	28,506	3,586,202	19,355	2,345,185
2025	22,922	3,609,124	15,564	2,360,749
2026	18,432	3,627,557	12,515	2,373,265
2027	14,822	3,642,378	10,064	2,383,329
Annual average:	173,447		113,492	

Total emission reductions during the 21-year crediting life starting in 2007 are **2,383,329** ton CO₂e, and the annual average ERs for the same period are **113,492** ton CO₂e/year.

**SECTION F. Environmental impacts****F.1. Documentation on the analysis of the environmental impacts, including transboundary impacts:**

>> An environmental impact assessment (EIA) has been carried out by the Municipality of Montevideo. The objective of this EIA was to identify the effects of the project activities on both the biophysical components of the environment and the socio-economical aspects of Montevideo community, and to provide measures and procedures to mitigate possible negative effects. In addition, the EIA proposes an Environmental Management Plan (EMP) that provides for actions to take to prevent and/or mitigate the identified possible environmental impacts indicating who is responsible to carry out the actions.

The EIA also establishes an Environmental Contingency Plan (ECP) that provides for procedures in case of emergencies that can put at risk the health of plant operators or the environment.

Finally, EIA provides for an Environmental Monitoring Plan (EMoP) that verifies the effectiveness of the actions established by the EMP through the monitoring of certain environmental parameters, such the quality of surrounded air, water, and soil, flare emissions and equipment operation and maintenance.

For further information about the EIA, please contact the Municipality of Montevideo (see Annex 1 for contact person).

F.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:

>> Overall, the conclusions of the EIA do not show negative environmental impacts of significance. By the contrary, the proposed project activity would have positive impacts on the biophysical components by reducing GHG emissions and destroying potentially harmful components in the LFG, and on the socio-economical aspects by implementing new technologies and triggering climate change awareness in the community. In addition, the implementation of the proposed project activity and the commitment with the CDM will allow not only improvements in the landfill operation in the short term but also to establish sustainable MSW management practices in the long run.

For further information about the EIA, please contact the Municipality of Montevideo (see Annex 1 for contact person).

**SECTION G. Stakeholders' comments**

>>

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

>>> In October 2005, the Municipality of Montevideo carried out a workshop to introduce the proposed project activity to the Montevideo's community. The event was open to the public and widely promoted through the local media. Besides, a number of institutions and individuals were specially invited to participate. The institutions that attended the workshop included private companies, NGOs, public institutions, workers unions, international cooperation agencies, among others. The attended institutions are listed below:

- Montevideo legislative body (Junta Departamental Montevideo)
- Municipality of Canelones
- Municipality of Colonia
- Climate Change Unit of Uruguay
- National Direction of Energy
- Ministry of Agriculture and Fishing
- Coast Guard
- Spanish International Cooperation Agency
- Fichtner Consultants
- LK Sur
- AIDIS (International Association of Sanitary Engineering)
- Environmental Consortium Del Plata
- CEUTA
- Aborgama
- Cavo
- Ibirapita Union
- C.S.I.
- San Vicente Organization
- GEA Environmental Consultants
- El Abrojo
- C.P.P. People Participation Center
- CEMPRE
- Union of Municipal Solid Waste Workers
- Busqueda Magazine

During the workshop, introduced by the Director of the Department of Environmental Development of Montevideo, Mrs. Alejandra Ostria, different aspects of the project, such as social, environmental, economical and technical issues, were outlined to the more than 70 attendees.

After the presentations, the audience was invited to an open session of questions and comments.

The workshop was entirely recorded and questions and comments received are summarized in the following section.

G.2. Summary of the comments received:

>>> The questions asked during the workshop were, for the most part, oriented to environmental issues and possible negative impacts on the environment. This was in part due to the lack of information among the



audience about the technology to be implemented in the proposed project activity. This lack of information was clearly shown by the questions related to basic technical issues about landfill gas and landfill gas recovery.

Few questions addressed economic issues related to the project and to the CDM as financing source.

No questions or comments were recorded regarding social aspects such as local labour demand and the like.

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

>> During the open session for questions and comments, the representatives of Municipality of Montevideo were able to answer all questions asked, remarking the positive environmental impacts that the proposed project activity would bring in relation with greenhouse gas emission reductions, harmful LFG components destruction, and the possibility to establish better practices for landfill operation by participating in the CDM.

Annex 1**CONTACT INFORMATION ON PARTICIPANTS IN THE PROJECT ACTIVITY**

Organization:	Municipality of Montevideo
Street/P.O.Box:	
Building:	
City:	
State/Region:	Montevideo
Postfix/ZIP:	
Country:	Uruguay
Telephone:	
FAX:	
E-Mail:	
URL:	
Represented by:	
Title:	Technical Coordinator
Salutation:	Mr.
Last Name:	Garino
Middle Name:	
First Name:	Esteban
Department:	Environmental Development
Mobile:	
Direct FAX:	19501955
Direct tel:	19502063
Personal E-Mail:	egarino@piso3.imm.gub.uy

Organization:	DNA of Spain
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Street/P.O.Box:	Plaza San Juan De La Cruz
Building:	
City:	Madrid
State/Region:	
Postfix/ZIP:	28071
Country:	Spain
Telephone:	915976026
FAX:	915975991
E-Mail:	sgpccc@mma.es
URL:	
Represented by:	
Title:	General Secretary
Salutation:	
Last Name:	Gonzalo Aizpiri
Middle Name:	
First Name:	Arturo
Department:	Department of Prevention of Pollution and Climate Change
Mobile:	
Direct FAX:	
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Personal E-Mail:	sgpccc@mma.es

Organization:	The World Bank
Street/P.O.Box:	1818 H Street, NW
Building:	
City:	Washington
State/Region:	District of Columbia
Postfix/ZIP:	DC 20433
Country:	United States
Telephone:	1-202-473-1359
FAX:	1-202-522-7432
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URL:	www.carbonfinance.org
Represented by:	
Title:	Project Manager
Salutation:	Mr
Last Name:	Kossoy
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Direct FAX:	1-202-473-1359
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Annex 2



INFORMATION REGARDING PUBLIC FUNDING

There is no public funding from Annex I parties in this project.

Annex 3**BASELINE INFORMATION**

The lack of legislation that enforces LFG capture and treatment and of economic benefits (such as tax credits to capture and burn methane from landfill gas) other than the incentive from the CDM, makes it clear that without the income from the selling of CERs, the project activity would not be carried out and the current practice in relation to solid waste management and landfills operation will continue throughout the country, noticeably, the uncontrolled release of the LFG into the atmosphere without any treatment.

Based on the previous considerations, the existing municipal solid waste management in Montevideo is assumed as the most likely future scenario in the absence of the proposed CDM activity; therefore the baseline scenario. This baseline scenario includes MSW collection, disposal in the landfill, compaction and daily cover, and the release of the LFG to the atmosphere through vent ducts without any treatment.

For baseline information purposes, a pre-feasibility study done by SCS Engineers will be taken into account in relation to LFG generation and recovery estimations. This study was prepared for the World Bank in June 2005.

In order to estimate the potential LFG generation rate for the landfill, SCS Engineers utilized its in-house model that employs a first-order decay equation identical to the algorithm in the U.S. Environmental Protection Agency (EPA) landfill gas emissions model (LandGEM). It requires the site's waste disposal history and employs a first-order exponential decay function, which assumes that LFG generation is at its peak following a time lag representing the period prior to methane generation. The EPA model assumes a one-year time lag between placement of waste and LFG generation. After one year, the model assumes that LFG generation decreases exponentially as the organic fraction of waste is decomposed. The following equation represents the first order decay equation to estimate the maximum expected LFG generation rate:

$$Q_M = \sum_{i=1}^n 2kL_oM_i e^{-kt_i}$$

where:

- Σ: sum from opening year (i=1) through year of projection (n);
- Q_M: maximum expected LFG generation flow rate (m³/yr);
- k: methane decay rate constant (1/yr);
- L_o: ultimate methane generation potential (m³/ton);
- M_i: mass of solid waste disposed in the ith year (ton);
- t_i: age of the waste disposed in the ith year (years).

SCS Engineers has developed a first-order decay model for estimating the LFG generation potential of landfills, a modified version of the EPA's LandGEM, based on actual LFG collection/recovery data from over 150 sites across the U.S. The model contemplates the effect of the rainfall on methane recovery potential (L_o), the decay rate constant (k), and the effect of the coverage of the LFG collection system (defined as that fraction of the landfill under LFG active collection) such as:

- well spacing and depth
- depth of well perforations
- presence of a flexible membrane liner (FML) or low permeability cover system



- landfill type and depth
- condition of LFG collection system, and
- other design and operational issues.

The following criteria and assumptions have been used by SCS Engineers to estimate the projected LFG recovery rates for the landfill through 2030:

- *waste filling history*: historical disposal rates through September 2004 were provided by Montevideo's landfill personnel. Based on recent waste disposal rates, future filling rates are conservatively assumed to remain at approximately 475,000 tons per year until site closure. Site closure is expected at the end of 2011.
- *methane content in LFG*: estimates future methane contents at 50 percent based on actual measurements at the landfill site.
- *methane generation rate (k)*: this is the organic matter decay rate and is a function of refuse moisture content, nutrient availability, pH, and temperature. SCS Engineers developed various levels of "wet" and "dry" site k-values from its database of LFG recovery data. For the Montevideo's landfill evaluation, SCS Engineers used three different k values based on the degradability of the waste components.
- *methane generation potential (L_o)*: assumed as the total amount of methane that a unit mass of waste will produce given enough time. L_o is a function of the organic content of the waste. It is theoretically independent of moisture, but the site operational data analysed by SCS Engineers has found the L_o to be suppressed in dry sites as compared to wet sites, indicating that the L_o may be limited below a certain moisture threshold. Therefore, SCS Engineers derived various levels of "wet" and "dry" site L_o values from its database of LFG recovery data. For Montevideo's landfill, SCS Engineers started with a default L_o value based on the average annual precipitation, and then adjusted this value based on the ratios of organic and moisture contained in U.S. waste and waste at the landfill.
- *LFG system coverage or recovery efficiency*: according to SCS Engineers, system coverage is a measure of the fraction of the waste mass which is under LFG active collection, and takes into account whether the landfill is closed or active, the type of well construction and gas system construction, the level of operation that is provided, the likelihood that system components such pipes and wells may be damaged by landfill operations and/or settlement, how quickly damaged pipes and wells and other equipment are likely to be repaired, leachate levels in wells, and other factors. This value falls within the range of 0% (for no gas collection system) to 100% (for a comprehensive collection system over a closed landfill with excellent construction and operation). In spite of SCS Engineers evaluated three system coverage scenarios in order to develop a range of estimates of predicted recovery for the baseline scenario, the mid-range recovery scenario, assumed as a moderately high level of skill and effort, is employed in the operation and maintenance of the collection system. The values adopted are 65 percent during the years that the landfill is operating, and 70 percent after site closure in 2011. SCS Engineers considers the mid-range recovery scenario to be its best estimates of likely recovery and recommends their use in the economic evaluation.

**Waste filling history**

According to SCS Engineers pre-feasibility study, the landfill is filling at a rate of about 1,300 tons per day, or approximately 475,000 tons per year. Filling rates are measured every day by using an on-site scale. At this current filling rate and total volume, the landfill is anticipated to reach capacity in 2011.

The majority of the MSW filled at the Landfill comes from the city of Montevideo, with a small fraction coming from the nearby town of Canelones. Approximately 90 percent of the MSW transported to the landfill is collected by the city, while the other 10 percent is collected by private companies.

Table A3.1 summarizes the history of waste disposal at the landfill and the projected future filling rates.

*Table A3.1. Historical disposal and projection at Montevideo's landfill until 2011
(Source: SCS Engineers, Pre-Feasibility Study, Montevideo Landfill, 2005)*

Year	Waste disposed ton	Cumulated Waste disposed ton
1990	306,150	306,150
1991	346,850	653,000
1992	290,215	943,215
1993	321,340	1,264,555
1994	417,520	1,682,075
1995	404,684	2,086,759
1996	495,189	2,581,948
1997	586,684	3,167,632
1998	676,199	3,843,831
1999	659,275	4,503,106
2000	593,627	5,096,733
2001	637,166	5,733,899
2002	509,206	6,243,105
2003	466,530	6,709,635
2004	465,000	7,174,635
2005	468,000	7,642,635
2006	475,000	8,110,635
2007	475,000	8,578,635
2008	475,000	9,046,635
2009	475,000	9,515,635
2010	475,000	9,982,635
2011	475,000	10,450,635
2012	0	10,450,635
2013	0	10,450,635
2014	0	10,450,635
2015	0	10,450,635
2016	0	10,450,635
2017	0	10,450,635
2018	0	10,450,635
2019	0	10,450,635
2020	0	10,450,635
2021	0	10,450,635
2022	0	10,450,635



2023	0	10,450,635
2024	0	10,450,635
2025	0	10,450,635
2026	0	10,450,635
2027	0	10,450,635

Notes:

1. Data provided by the City of Montevideo
2. Past data based on weights measured by site scale
3. 2004 data based on data provided through August and prorated for the rest of the year
4. Future filling rates based assume current filling rate remains constant

Methane generation rate (k):

The methane generation rate (k) value reflects the fraction of waste that decays in a given year and produces methane. SCS Engineers has assigned k values to different portions of the waste stream, based on their relative decay rates. Because landfill moisture content significantly affects decay rates, the values of the decay rates for the fast, medium, and slow decaying waste fractions will vary with moisture as well. The values for all three methane generation rates used for preliminary modelling at the Montevideo’s landfill are as follows:

- fast-decaying waste: $k = 0.28$ per year.
- medium-decaying waste: $k = 0.056$ per year.
- slowly-decaying waste: $k = 0.014$ per year.

To estimate the model parameter methane generation rate (k) for Montevideo’s landfill, SCS Engineers took into consideration the typical composition of waste buried in the landfill. SCS Engineers compared site waste composition data from the landfill with U.S. EPA’s waste characterization data. These data are presented in Table A3.2.

Table A3.2. Montevideo MSW composition and methane generation rate values according wastes degradability

(Source: SCS Engineers, Pre-Feasibility Study, Montevideo Landfill, 2005)

Components	Montevideo’s landfill ¹	Degradability category	Methane generation rate k
Organics	58.3	Fast	0.28
Other organics ²	1.0	Fast	0.28
Paper (included cardboard)	10.5	Medium	0.056
Wood	0.6	Slow	0.014
Rubber, leather, textiles	2.7	Slow	0.014
Plastics ²	18.1	Inert	0
Metals	1.5	Inert	0
Glass	3.4	Inert	0
Other inorganics	3.9	Inert	0

Notes:

1. Data provided by the City of Montevideo.
2. Data provided for landfill included organics as one category. SCS assumes that Food comprises 75 percent of Organic Waste, and Green Waste comprises 25 percent of Organic Waste.
3. Diapers and hygienic towels (as reflected in the Montevideo data) are assumed to consist of 80 % plastics, and 20 percent “other organic” material.



The procedure for developing k values for Montevideo’s landfill based on a landfill experiencing 1,000 mm/year of precipitation was determined using the percentages of fast, medium, and slow-decaying waste components in the U.S. waste stream and the Montevideo disposal quantity data. The resulting k values are then used in a 3-k model run for Montevideo’s landfill using the Montevideo’s waste component percentages.

According to SCS Engineers pre-feasibility study, a plot of the LFG generation rate vs. time for solid wastes that are high in food waste, green waste, and other similar readily-degraded wastes, as in Montevideo’s waste stream will show a steeper slope (reaching peak flows more rapidly), but a lower sustainable long term LFG yield than the one the from waste with slower-degrading components. In the model, this effect is reflected by the parameter k.

Methane Generation Potential (L_0)

The L_0 value was derived by modifying an estimated L_0 value of 93.6 m³/ton for U.S. landfills that experience 1,000 mm per year of precipitation (the amount of rainfall at Montevideo’s landfill). The modification is based on the ratios of organic waste percentages and dry waste contents of U.S. vs. Montevideo’s landfill waste. Table A3.3 summarizes the calculation of the L_0 value.

Table A3.3: Calculation of the L_0 Value
(Source: SCS Engineers, Pre-Feasibility Study, Montevideo Landfill, 2005)

	US landfills	Montevideo landfill	Ratio Montevideo /US
Organic, %	68.2	73.1	1.07
Dry weight, %	80.3	54.4	0.678
L_0 value, m ³ /ton	93.6	68.0	0.727

The value for the methane generation potential (L_0) for the Montevideo’s landfill is estimated at 68.0 m³/ton of MSW.

The higher organic content will tend to increase the potential for methane generation per ton of waste. Conversely, however, the increased moisture content (which is inert) will tend to decrease the potential for methane generation per tonne of waste. In the model, these effects are reflected by the parameter L_0 .

Baseline emissions

As a result of the LFG pumping test performed by SCS Engineers in 2005, LFG generation potential is estimated to be about 10% below FOD model estimation. This is partially explained by interferences caused by high levels of leachate found in the landfill’s cells.

According to the previous considerations, an average of 2,833 m³/hr of LFG will be generated during the 21-year credit period starting in 2007.

During the 2007-2011 period, when landfill is in operation, an LFG generation average of 6,052 m³/hr is expected, while during the period from 2012 to 2027 a fast decrease in LFG generation is expected and an average of 1,827 m³/hr of LFG is estimated.



This scenario corresponds to an annual average of **173,447** ton CO₂e/year for the period 2007-2027 and represents the **baseline emissions**. Table A3.4 summarizes the baseline emissions in tons of CO₂e per year during the crediting period and during the open and close periods of the current active cell 6/7.

Table A3.4. Baseline emissions according estimations of potential LFG generation

Year	Potential LFG Generation Rate m³/hr	Baseline Emissions ton CO₂e
2007	6,114	374,320
2008	6,069	371,565
2009	6,040	369,789
2010	6,022	368,687
2011	6,013	368,136
Average during landfill operations:	6,052	370,500
2012	6,010	367,953
2013	4,703	287,934
2014	3,708	227,016
2015	2,948	180,487
2016	2,367	144,916
2017	1,920	117,549
2018	1,577	96,549
2019	1,311	80,264
2020	1,114	68,176
2021	895	54,822
2022	720	44,084
2023	579	35,449
2024	466	28,506
2025	374	22,922
2026	301	18,432
2027	242	14,822
Average after landfill closure:	1,827	111,868
Annual average (2007-2027):	2,833	173,447
Total baseline scenario emissions:		4,020,739



Annex 4

MONITORING PLAN

A4.1. Purpose of the Monitoring Plan

In the context of the Clean Development Mechanism (CDM) of the Kyoto Protocol, monitoring describes the systematic surveillance of a project's performance by measuring and recording performance-related indicators relevant to the project or activity. Verification is the periodic auditing of monitoring results, the assessment of achieved emission reductions (ER) and of the project's continued conformance with all relevant project criteria.

This document contains the Monitoring Plan (MP) for the Montevideo Landfill Gas Capture and Flare Project. It describes the requirements for the collection, processing and auditing of data from the project for the purpose of calculating and verifying the ERs the project has produced.

A4.2. Overview

According to the approved consolidated monitoring methodology ACM0001 applied for this project activity, the monitoring methodology is based on direct measurement of the amount of landfill gas captured and destroyed at the flare platform. The Monitoring Plan provides for direct measurement of the quantity and quality of LFG flared and the non-combusted methane in the flare.

Daily on-site measurements of both the LFG volumetric flow and the fraction of methane in the LFG will be performed to calculate the amount of methane in the LFG captured. LFG temperature and pressure will be daily measured and recorded in order to calculate the methane density and therefore mass flow. Finally, methane content in the exhaust gases will also be monitored to verify the flare efficiency and to correct the amount of methane actually destroyed by the project activity.

The amount of methane determined through direct monitoring and measurement of the captured LFG minus the non-combusted methane emitted in the flare represents the actual methane emissions avoided by the project activities, that is, the Emission Reductions (ERs) of this project.

The Monitoring Plan also includes periodic monitoring for updates of Uruguay's legislation and regulatory requirements through the official websites of the Dirección Nacional de Medio Ambiente DINAMA (<http://www.dinama.gub.uy>) and the Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente MVOTMA (<http://www.mvotma.gub.uy>).

A4.3. Monitoring and calculation of Emission Reductions

The emission reductions from the Montevideo Landfill Gas Capture and Flare Project result from the avoided landfill methane emissions due to the collection and flaring (and conversion to CO₂) of the methane contained in the landfill gas.

The amount of methane recovered will be determined by on-site daily measurements from flow meters and gas analysers. These two measurements will be adjusted for the flare efficiency represented by the

fraction of methane in LFG that is not combusted in the flare but emitted to the atmosphere. The flare efficiency will be quarterly verified through lab analysis to determine the methane content in exhaust gas.

Thus, the amount of methane in the exhaust gas will be discounted from the product of the LFG captured (flow meter) and the methane content (gas analyzer). The resulting amount of methane must be multiplied by the methane density (ton/m^3) at the corresponding temperature and pressure to obtain the methane emission reductions of the project activities in tons of CH_4 . In order to obtain the result in tons of CO_2 equivalent, the tons of CH_4 will be multiplied by the methane Global Warming Potential. Finally, the time that the flare is in operation will be continuously recorded to calculate the amount of methane actually destroyed.

According to the applied methodology, leakage -defined as the net change of anthropogenic emissions by sources of GHG that occurs outside the project boundary that is measurable and attributable to the CDM project activity- will not be considered.

The performance indicators, key data needs, and monitoring procedures are described in Table A4.1. Figure A4.1 shows the basic scheme of the monitoring plan.

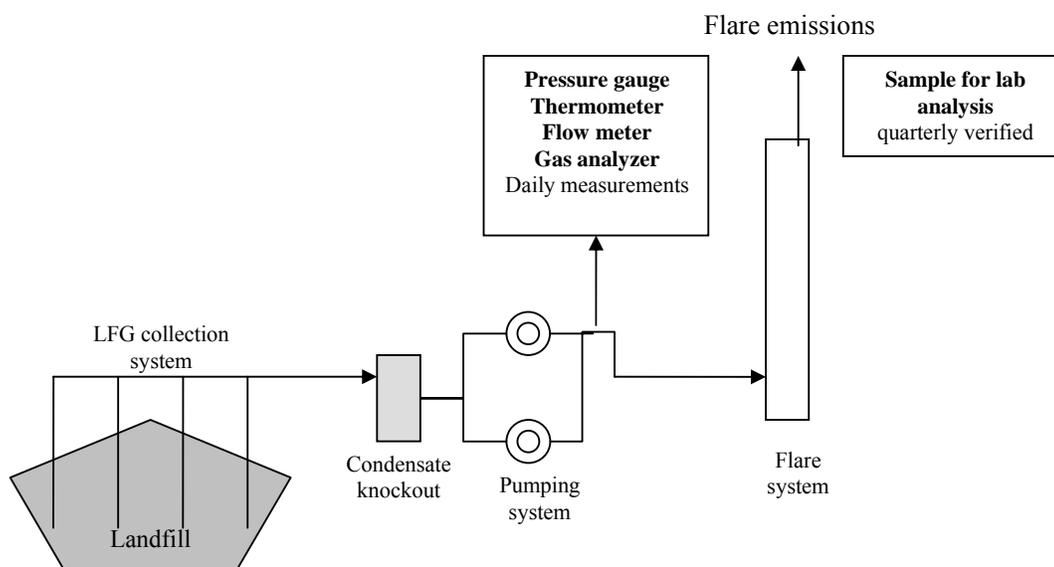


Figure A4.1. Basic scheme of the MP for Montevideo's Landfill Gas Capture and Flare Project

A4.3.1. Monitoring sampling points

The monitoring sampling points to measure the methane content in the LFG and in the flare emissions are shown in Figure A4.2. The point before the flare system will be daily monitored to record the landfill gas flow and the methane content in the LFG. The LFG composition will also be monitored in the wellheads for technical purposes.

The flare emissions will be quarterly monitored through spectrometry analysis to verify the amount of methane in exhaust gas.

In order to achieve a representative sample of the flare emissions, multiple monitoring ports along the flare are necessary due to the variability in the combustion gases emissions profile. According to the characteristics of the flare to be installed, two different planes across the perpendicular sections of the flare stack were defined. As given by the minimum recommendations of the Environment Agency of the United Kingdom, the sample plane must be at least 1 meter from the flare exit and without any flame near the sampling port to avoid uncertainties due the flame chemistry. Four sampling ports at each plane will be arranged (Figure A4.3). The number of sampling ports was determined according to the minimum established by ISO 9096 and from the flare dimensions (approximately 1 meter diameter).

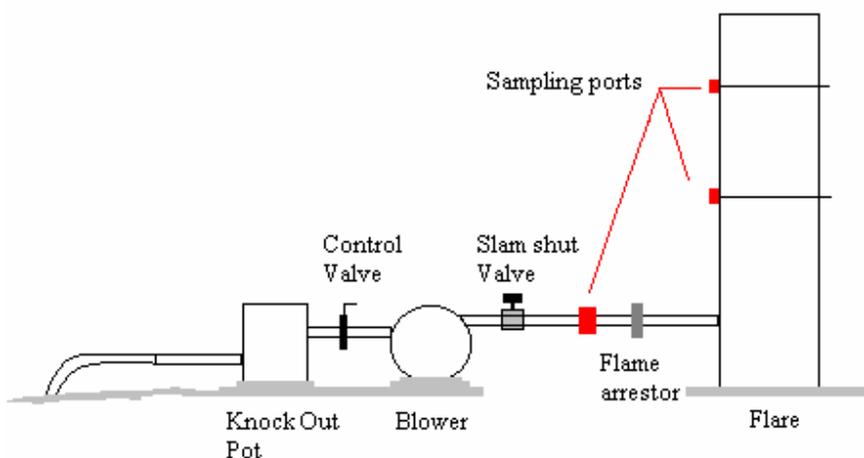


Figure A4.2. Sampling ports and basic arrangement of the flare system

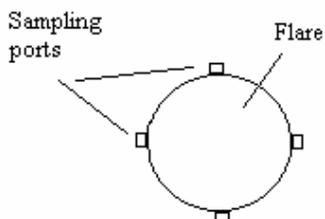


Figure A4.3. Sampling ports at each plane

The combustion efficiency in terms of the percentage of combusted methane will be determined by the difference between the amount of captured methane in LFG (before flare) and the non-combusted methane (from the sampling ports in the flare). This value will be quarterly adjusted.



A4.3.2. Data to be monitored

The information required for the Monitoring Plan of the Montevideo's Landfill Gas Capture and Flare Project in the following Table A4.1.

Table A4.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:								
ID number (Please use numbers to ease cross-referencing to table D.3)	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/paper)*	Comment*
1. $LFG_{flared,y}$	Flow of LFG flared	Flowmeter	m ³ /h	m	Continuously	100%	electronic/paper	Data will be aggregated monthly and yearly
2. T	Temperature of LFG	Temperature sensor	°C	m	Daily	100%	electronic/paper	Data will be used to calculate the methane density.
3. P	Pressure of LFG	Pressure Sensor	kPa	m	Daily	100%	electronic/paper	Data will be used to calculate the methane density.
4. D_{CH_4}	Methane density in LFG	Calculation	ton CH ₄ /m ³ CH ₄	c	Daily	100%	electronic/paper	To be used to calculate the methane destroyed.
5. $w_{CH_4,y}$	Methane fraction in LFG	Gas analyzer	m ³ CH ₄ /m ³ LFG	m	Daily	Sample	electronic/paper	To be used to calculate the methane destroyed
6. FE	Combustion efficiency	Estimation	%	e	Quarterly	100%	electronic/paper	The estimated combustion efficiency will be verified quarterly through lab analysis to determine the methane content in the exhaust gas
	Flare availability	Timer	%	m	Continuously	100%	electronic/paper	Data will be aggregated monthly and yearly

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7.	Legislation and regulatory requirements related to LFG	Official website	Test	n/a	Annually	100%	electronic/paper	Required for any changes to the adjustment factor (AF) or directly MD _{reg,y}
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* All archived data will be kept for two years after the end of the crediting period or the last issuance of CERs for this project activity, whichever occurs later.



A.4.4. Monitoring Plan Management

The Monitoring Plan (MP) will be used by all parties involved in Montevideo's Landfill Gas Capture and Flare Project with responsibilities in the project implementation and verification activities:

The *project sponsor* (Municipality of Montevideo) will oversee the development of the project and will periodically carry out internal audits to assure that project activities are in compliance with operational and monitoring requirements.

The *project operator* (to be designated through a bidding process) will adopt the instructions given in the MP and accomplish all activities related to the implementation of the procedures given in the guidelines for LFG plant operation and monitoring. The main responsibilities of the operator are related to:

- *Data handling*: maintaining an adequate system for collecting, recording and storing data according to the protocols determined in the MP, checking data quality, collection and record keeping procedures regularly.
- *Reporting*: preparing periodic reports that include emission reductions generated and observations regarding MP procedures.
- *Training*: assuring personnel training regarding the performance of the project activities and the MP.
- *Quality control and quality assurance*: complying with quality control and quality assurance procedures to facilitate periodical audits and verification.

A4.5. Quality control and quality assurance procedures

Regarding quality control and quality assurance procedures to be undertaken for the monitored data, the practices to be implemented in the context of the Montevideo's Landfill Gas Capture and Flare Project are as follows:

Gas field monitoring records:

- Daily readings of all field meters will be registered in paper worksheets. Data collected will be entered in electronic worksheets and stored.
- Periodic controls of the LFG field monitoring records will be carried out to check any deviation from the estimated ERs following the guidelines for LFG plant operation and monitoring for correction or future references.
- Recommendations on system and procedures improvements will be presented.
- Periodic reports to evaluate performance and assist with performance management will be elaborated.

Equipment calibration and maintenance:

- Flow meters, gas analyzers and other sensors will be subject to regular maintenance and testing regime according to the technical specifications from the manufacturers to ensure accuracy and good performance.



- Calibration of equipment will be performed periodically according to technical specifications.

Corrective actions:

- Actions to correct deviations from the Monitoring Plan and the guidelines for LFG plant operation and monitoring will be implemented as these deviations are observed either by the operator or during internal audits.
- If necessary, technical meetings between the operator, the developer and the sponsor of the project will be held in order to define the corrective actions to be undertaken.

Site audits:

- The Municipality of Montevideo will make regular site audits to ensure that monitoring and operational procedures are being observed in accordance with the Monitoring Plan and the guidelines for LFG plant operation and monitoring.

Training:

- The operator personnel will be trained in equipment operation, data recording, reports writing, and operation, maintenance and emergency procedures in compliance with the guidelines for LFG plant operation and monitoring.
