Revised Monitoring Plan

Revision of Monitoring Plan Version 1, 25/03/2010

Project Title: **Loma Los Colorados Landfill Gas Project**

Project Number: 0822

SECTION D. Application of a monitoring methodology and plan

D.1. Name and reference of approved monitoring methodology applied to the project activity:

Approved Consolidated monitoring methodology ACM0001: "Consolidated monitoring methodology for landfill gas project activities", version 4, 28 July 2006.

ACM0001 states:
"The flare efficiency shall be calculated as product of (i) fraction of time the gas is combusted in the flare; and (ii) the efficiency of the flaring process. Efficiency of the flaring process is defined as fraction of methane completely oxidized by the flaring process.

"If an enclosed flare is used, the project participants shall measure and quantify the efficiency of the flare (% of methane completely oxidized by combustion in the flare) on a yearly basis, with the first measurement to be made at the time of installation. The measured value of the efficiency of the flare shall be applicable for the period up to the next measurement. In case the yearly measurement of efficiency of the flare is not performed, the efficiency of the flare shall be a default value of 90%. If the last measured value of the efficiency of the flare is lower than 90%, then the last lower measured value shall be used.

"For open flares, if the efficiency of the flare is not measured, a conservative destruction efficiency factor of 50% should be used."

The proposed project involves possible energy use of landfill gas collected. In this context the approved consolidated monitoring methodology, ACM0001 states:

> *"In this case a baseline methodology for electricity and/or thermal energy displaced shall be provided or an approved one used, including the ACM0002 "Consolidated Methodology for Grid-Connected Power Generation from Renewable". If capacity of electricity generated is less than 15MW, and/or thermal energy displaced is less than 54 TJ (15GWh), small-scale methodologies can be used."*

The present PDD uses ACM0002, version 6. The proposed project would be able to generate less than 15 MW up to 2015, and somewhat higher in subsequent years. Currently, KDM is authorized to generate up to 3 MW, but given that they will probably be allowed to generate more power in the future, we propose to use the more general methodology ACM0002 for the entire crediting period.

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

The applicability of the methodology was listed in Sec. B.1.1, where it was shown that the proposed project fits within the conditions of applicability of the methodology.

D.2. 1. Option 1: Monitoring of the emissions in the project scenario and the baseline scenario

Option not selected.

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 *(Please use numbers to ease cross-referencing to D.3)*	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 CO_2 equ.)

Not applicable.

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 *(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

D.2.1.4. Description of formulae used to estimate baseline emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

Not applicable.

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

In landfill gas recovery projects, methane emissions in the baseline can only be estimated using a theoretical model, not measured directly. Similarly, remaining methane emissions (from incomplete coverage) after landfill gas capture system has been installed, cannot be measured either. However, the reduction in emissions from the project activity corresponding to what is actually captured can be determined with very high accuracy from monitoring. Thus Option 2 is applicable for landfill gas recovery projects, and is chosen here.

There are additional emissions reductions associated with energy use of landfill gas. This PDD considers the possibility that recovered landfill gas would be used to generate electricity. In this case the emissions reductions are given by the product of the electricity generated and the emissions factor for electricity generation, as described in ACM0001. Thus, this component of emissions reductions can also be determined by monitoring electricity generation. The present PDD uses ACM0002, version 6.

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	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	For how long is archived data to be kept?	Comment
1. $LFG_{total,y}$	Total amount of landfill gas captured	m^3	m/c	Continuous measurement, weekly recording	100%	electronic	During the crediting period and 2 years after	Measured by a thermal mass flow meter. Data to be aggregated monthly and yearly.
2. $LFG_{flare,y}$	Amount of landfill gas flared	m^3	m/c	Continuous measurement, weekly recording	100%	electronic	During the crediting period and 2 years after	Measured by a thermal mass flow meter. Data to be aggregated monthly and yearly.
3.$LFG_{electricity,y}$	Amount of landfill gas combusted in power plant	m^3	m/c	Continuous measurement, weekly recording	100%	electronic	During the crediting period and 2 years after	Measured by a thermal mass flow meter. Data to be aggregated monthly and yearly.
4. *FE*	Flare/combustion efficiency, determined by the operation hours (1) and the methane content in the gas exhaust gas (2)	%	m/c	(1) Continuous Enclosed flare shall be monitored yearly, with the first year measurement to be made at the time of installation. (see Comments)	n/a	electronic	During the crediting period and 2 years after	1) The flare operation shall be continuously monitored by continuous measurement of operation time of flare using a run time meter connected to a flame detector or a flame continuous temperature controller, irrespective of whether the flare efficiency is monitored. (2) Periodic measurement of methane content of flare exhaust gas. (3) The enclosed flares shall be operated and maintained as per the specifications prescribed by the manufacturer.

5. $w_{CH_4,y}$	Methane fraction in the landfill gas	m^3 CH_4/m^3 LFG	m	Continuous measurement, weekly recording	100%	electronic	During the crediting period and 2 years after	Siemens Ultramat 23 continuous gas quality analyser, measures oxygen, methane and carbon dioxide
6. T	Temperature of the landfill gas	°C	m	Continuous measurement, weekly recording	100%	electronic	During the crediting period and 2 years after	Measured to determine the density of methane D_{CH4}. No separate monitoring of temperature is necessary since flow meters to be used here automatically measure and compensate for temperature and pressure, expressing LFG volumes in normalized cubic meters. Additional temperature measurements would be made using LFG Specialties temperature gauges and Pyromation thermocouples.
7. P	Pressure of the landfill gas	Pa	m	Continuous measurement, weekly recording	100%	electronic	During the crediting period and 2 years after	Measured to determine the density of methane D_{CH4}. No separate monitoring of temperature is necessary since flow meters to be used here automatically measure and compensate for temperature and pressure, expressing LFG volumes in normalized cubic meters. Additional pressure measurements would be made using Yokogawa EJA 530A and LFG Specialties pressure gauges.
8. (Regulatory Requirements)	Regulatory requirements relating to landfill gas projects	Text	n/a	At the renewable of crediting period	100%	electronic	During the crediting period and 2 years after	The information though recorded annually, is used for changes to the adjustment factor (AF) or directly $MD_{reg,y}$ at renewal of the crediting period.

9. $EL_{EXP\ LFG,y}$	Total amount of electricity exported out of the project	MWh	m	Continuous measurement, weekly recording	100%	electronic	During the crediting period and 2 years after	Required to estimate the emission reductions from electricity generation from LFG, if credits are claimed. Measured by electric meter.
10. $EL_{IMP,y}$	Total amount of electricity imported to meet project requirement	MWh	m	Continuous measurement, weekly recording	100%	electronic	During the crediting period and 2 years after	Required to determine CO2 emissions from use of electricity or other energy carriers to operate the project activity. The records of any electricity imported in the baseline too should be recorded at the start of project.
11. CEF_y	CO_2 emission factor of the grid	tCO_2/ MWh	c	As specified in ACM0002	100%	electronic	During the crediting period and 2 years after	Calculated as a weighted sum of OM and BM emissions factors
12.(Operational Hours)	Operation of the power plant	Hours	m	annual	100%	electronic	During the crediting period and 2 years after	This is monitored to ensure methane destruction is claimed for methane used in electricity plant when it is operational.
13. $PE_{i,y}$	Project emissions from source I in year y.	tCO_2	c	annual	100%	electronic	During the crediting period and 2 years after	This variable encloses project emissions from fossil fuel combustion in the backup power generator and flare start-up inter alia.

D.2.2.2. Description of formulae used to calculate project emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.):

Emissions reductions are determined directly in this option, and the corresponding formulae are shown in section D.2.4.

D.2.3. Treatment of leakage in the monitoring plan

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 *(Please use numbers to ease cross-referencing to table D.3)*	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

"No leakage effects need to be accounted under this methodology" (from Approved baseline methodology ACM0001: "Consolidated baseline methodology for landfill gas project activities", version 4, July 2006.)

D.2.3.2. Description of formulae used to estimate leakage (for each gas, source, formulae/algorithm, emissions units of CO_2 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 CO_2 equ.)

We need to consider two greenhouse gases: methane (from landfill gas capture and destruction) and carbon dioxide (from electricity generation that would offset emissions from power plants elsewhere in the interconnected power grid.

Methane

The GHG emission reduction associated with methane destruction achieved by the project activity during a given year "y" (ERM_y) is 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 ($MD_{reg,y}$)[1], times the approved GWP Global Warming Potential value for methane (GWP_{CH_4}).

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

Where:

ERM_y is measured in tonnes of CO_2 equivalent (tCO_{2e})

$MD_{project,y}$ and $MD_{reg,y}$ are measured in tonnes of methane (tCH_4)

GWP_{CH_4} = 21 tCO_2e/tCH_4

In the case where the is given/defined as a quantity that quantity will be used.

In cases where regulatory or contractual requirements do not specify $MD_{reg,y}$ an "Adjustment Factor" (AF) shall be used and justified, taking into account the project context.

Even though $MD_{reg,y}$, is not specified in regulatory or contractual requirements, since there are no legal requirements to capture and flare landfill gas in Chile, in recent years a small amount of landfill gas has been collected and flared at this project site. In order to be conservative, we have considered the three-year average (2002-04) mass of methane captured (245 tonnes methane per year) and flared (assuming 100% flare efficiency) to be the baseline. If any such requirements are introduced during the first crediting period, an appropriate absolute value of $MD_{reg,y}$, shall be used and justified in the baseline for the second crediting period, taking into account the project context. Sometimes, $MD_{reg,y}$, is a fraction of the project methane destruction $MD_{project,y}$, and is given by the following equation:

[1] Reg = regulatory and contractual requirements.

$$MD_{reg,y} = MD_{project,y} \cdot AF \qquad (2)$$

where AF is an Adjustment Factor. Note that Eq. (2) and AF are not used in the present PDD.

We provide an *ex ante* estimate of methane emission reductions, by projecting the future GHG emissions of the landfill, using a model. $MD_{project,y}$ will be determined *ex post* by metering the actual quantity of methane captured and destroyed once project activity is operational. The methane destroyed by the project activity ($MD_{project,y}$) during a year is determined by monitoring the quantity of methane actually flared or otherwise combusted for electricity generation.

$$MD_{project,y} = MD_{flared,y} + MD_{electricity,y} \qquad (3)$$

$$MD_{flared,y} = LFG_{flare,y} \cdot w_{CH_4,y} \cdot D_{CH_4} \cdot FE \qquad (4)$$

Where:

$MD_{flared,y}$ is the quantity of methane destroyed by flaring during the year measured in cubic meters (m^3)

$LFG_{flared,y}$ is the quantity of landfill gas flared or during the year measured in cubic meters (m^3)

$w_{CH_4,y}$ is the average methane fraction of the landfill gas as measured during the year and expressed as a fraction (in m^3CH_4/m^3LFG)

FE is the flare efficiency (the fraction of the methane destroyed)

D_{CH_4} is the methane density expressed in tonnes of methane per cubic meter of methane (tCH_4/m^3CH_4).

To be conservative in the estimation of $MD_{flared,y}$, , the flare efficiency (*FE*) was assumed to be 98%, based on the most conservative value given by the enclosed flare provider. Technical documentation sent by the equipment provider states:
"Destruction efficiency – 99% overall destruction of total hydrocarbons. 98% destruction efficiency for NMOCs. Guaranteed to meet EPA emission standards for landfill gas disposal in enclosed type flares. The designed operating temperature is 1600ºF."

$$MD_{electricity,y} = LFG_{electricity,y} \cdot w_{CH_4,y} \cdot D_{CH_4} \qquad (5)$$

Where:

$MD_{electricity,y}$ is the quantity of methane destroyed by generation of electricity during the year measured in cubic meters (m^3)

$LFG_{electricity,y}$ is the quantity of landfill gas fed into electricity generator during the year measured in cubic meters (m^3)

$w_{CH_4,y}$ is the average methane fraction of the landfill gas as measured during the year and expressed as a fraction (in m^3CH_4/m^3LFG)

D_{CH_4} is the methane density expressed in tonnes of methane per cubic meter of methane (tCH_4/m^3CH_4).

Carbon dioxide

There are reductions in carbon dioxide emissions from electricity generated using landfill gas, since this would replace emissions from power plants elsewhere. The present PDD uses ACM0002, version 6. The proposed project could be able to generate less than 15 MW up to 2015, and somewhat higher in subsequent years. Currently, KDM is authorized to generate up to 3 MW, but given that they will be probably allowed to generate more power in the future, we propose to use the more general methodology ACM0002 for the entire crediting period.

Carbon dioxide emissions reductions during a given year y ($_{y}ERC$) are given by:

$$ERC_y = EL_y \bullet CEF_y \qquad (7)$$

where

ERC_y is measured in tonnes of CO_2 (tCO_{2e})

EL_y is the net quantity of electricity exported during the year *y*, MWh, given by:

$$EL_y = EL_{EXPLFG,y} - EL_{IMP,y}$$

where

$EL_{EXPLFG,y}$ is the net quantity of electricity exported during year *y*, produced using landfill gas, MWh

$EL_{IMP,y}$ is the net incremental electricity imported, defined as difference of project imports less any imports of electricity in the baseline, to meet the project requirements, MWh

Note that "exported" here refers to the project activity: landfill gas collection, flaring, and electricity generation (if any). Thus exported electricity could supply other power needs at the landfill, e.g. leachate treatment, office use, etc., that are *not* associated with the landfill gas collection, flaring and use. Exported electricity could also leave the site and be supplied to the grid.

For the same reason, "imported" refers to any electricity taken (from the grid) by the project activity, principally for blowers used in landfill gas extraction. Such imports may be present in the baseline as well, corresponding to LFG extraction in the baseline, as in the case of the proposed project.

CEF_y is the emissions factor for electricity generation, tCO_2/MWh, given by:

$$CEF_y = \frac{CEF_{OM,y} + CEF_{BM,y}}{2} \qquad (8)$$

where

$CEF_{OM,y}$ is the operating margin emission factor, tCO_2/MWh, and

$CEF_{BM,y}$ is the build margin emission factor, tCO_2/MWh.

The emissions factor is determined using the approved consolidated methodology ACM0002 (ver 6), requiring a determination of the Build Margin, the

Operating Margin and a Combined Margin.

ACM0002 indicates four different procedures for determining the operating margin. These are denominated:

(a) Simple Operating Margin
(b) Simple Adjusted Operating Margin
(c) Dispatch Data Analysis Operating Margin
(d) Average Operating Margin.

ACM further states that the Simple OM, simple -adjusted OM, and average OM emission factors can be calculated using either of the two following data vintages for years(s) *y*:

- (*ex-ante*) the full generation-weighted average for the most recent 3 years for which data are available at the time of PDD submission, if or,
- the year in which project generation occurs, if $EF_{OM,y}$ is updated based on ex-post monitoring. The choice between ex-ante and ex-post vintage should be specified in the PDD, and cannot be changed during the crediting period.

The proposed project will use ex-ante vintage using data from the three 2003, 2004 and 2005. Of the three choices for calculating Operating Margin, we choose the most complete “Simple Adjusted Operating Margin”, since the Chilean power sector has the data to support this calculation.

Details of equations and procedures for calculating the Operating Margin, Build Margin, and Combined Margin emissions factor for power generation are given in Annex 3.

The Combined Margin emissions factor will be used to determine CO_2 emissions offset by the electricity generation using LFG.

Note that, LFG will be collected for some time before power generation equipment is installed and operational. For this period, operating the landfill gas collection equipment will require electricity to be imported from the grid. For this period, an increase in demand on the interconnected power system caused by the consumption by the LFG collection will be met by increased generation from existing power plants. Thus, for the periods when the LFG collection system consumes power from the grid, and no power is generated on site, so that there are CO_2 emissions from power generation elsewhere in the grid. To calculate these emissions associated with this electricity consumption, we use the Operating Margin as the applicable emissions factor. Note that the Operating Margin is larger than the Combined Margin, increasing project emissions, and is therefore also the more conservative choice.

Considering both methane and carbon dioxide emissions, total emissions reductions, ERT_y are given by:

$$ERT_y = ERM_y + ERC_y$$

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.
1-3 LFG_y	Low	Project proponent (KDM) will use continuous mass flow meters to measure flow rates. An independent company (JHG), accredited by the Health and Environment Department will conduct contrasting and date checking twice a year. JHG will use an anemometer and procedure CH-2 specified by the Chilean government.
4. FE	Medium	Regular maintenance will ensure optimal operation of flares. Flare efficiency will be checked yearly. The enclosed flares shall be operated and maintained as per the specifications prescribed by the manufacturer. Flare efficiency is determined by measurement of methane content in LFG before and after flaring. The instruments for measurement of methane content will be contrasted by the independent company JHG four times a year (see below). Note, however, if a new monitoring methodology is approved before and during project execution, replacing this requirement with an alternative, simpler, procedure, project sponsors propose to use the simplified procedure. See explanation in Section D.1
5. $w_{CH4,y}$	Low	KDM will measure methane content using a continuous gas analyser (Siemens Ultramat 23). The independent company JHG will verify instruments with reference instruments, four times a year.
6. T	Low	KDM will make continuous temperature measurements through the thermal mass flow meter (to correct for density) as well as using a temperature gauge. JHG will contrast these measurements with a certified thermocouple.
7. P	Low	KDM will undertake continuous pressure measurements using a pressure gauge as well as within the thermal mass flow meter (to correct for density). These measurements will be contrasted by JHG twice a year using the CH-2 method specified by the Chilean government.
8.(Regulatory Requirements)	None	Legal document.
9-11 EL_y	Low	Electric meters are quite accurate. Moreover, the meter will be calibrated periodically.
12. (Operating Hours)	Low	The kWh meter will be subject to regular maintenance and testing regime to ensure accuracy.
13. $PE_{i,y}$	Low	Project emissions will be calculated by multiplying the amount of fossil fuels combusted by its emission factor. The amount of fuel is strictly controlled on site by the project developer and electronically registered perdiodically.

The landfill operator, KDM, has extensive experience in quality control procedures.

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

The overall management structure responsible for project monitoring is as follows. The KDM Technical Team who are responsible for the day-to-day operation of the landfill gas collection, flaring, and use system would also be responsible for monitoring key variables required for meeting the CDM monitoring requirements.

Data monitoring will be conducted by Landfill Gas Technical Operators supervised by the Landfill Gas Project Engineer, all of them belonging to the Engineering Department of KDM S.A., the project proponent. Other staff persons will be assigned by the Landfill Gas Project Engineer to assist in the monitoring tasks, as needed.

Certain activities (calibration of flow meters and electric meters) would be conducted by independent, outside laboratories, with the data archived by the KDM Engineering Department.

KDM is a company certified under ISO 9001 and 14001. This means that KDM is obliged to qualify its personnel under rigorous procedures at the beginning of the project and on a monthly basis afterwards. In the first phase of the project, KDM will count on supervision from the flare supplier for training, commissioning and start-up. In a second phase, i.e. if the power generation is chosen, KDM will also acquire either from equipment supplier and/or specialist consultant all the services needed for training related to the operation of the LFG generation system. KDM staff to be trained are those with extensive experience at the landfill.

One measurement involves the methane content of the flare combustion products, needed to determine what fraction of methane captured and sent to the flare did indeed burn. Project proponent expects to acquire equipment to do these measurements in-house. However, if this is not feasible, then an outside laboratory would be contracted to undertake these measurements on a yearly basis.

The determination of emissions factor for electric power generation requires a great deal of data on power plants recently built and in operation. This determination would be contracted to a consulting company specialising in such data collection and analysis. The consultant would be required to submit complete documentation so that the calculation procedure is transparent, and that the results can be independently verified. The procedure should be similar to that shown in Annex 3 of this PDD.

All data recorded would be transferred to and stored as electronic spreadsheets and other electronic files. Calibration certificates would be stored as paper copies, although scanned copies may also be stored electronically.

All data would be subject to quality control procedures as described in Section D.3, above, and subject to Internal Audit from KDM Central Offices in Santiago.

Following the internal audit, the electronic data would be used in a spreadsheet procedure in order to calculate emissions reductions. The original data, the calculation procedures and the resulting emission reductions will be verified by an independent Designated Operational Entity (DOE). The DOE would issue a Verification Report based on its findings and submit it to the CDM Executive Board for the issuance of CERs.

The operational and management structure for specific monitoring tasks is described in the following table:

#	Task name	Responsible	Frequency	Internal procedures of Quality Control	Documentation
1	Reading of landfill gas capture and gas flared/used	Engineering Department of KDM	Weekly. Data will be entered into a spreadsheet on a weekly basis, permitting continuous monitoring.	Yes	The data will be monitoring and filed by the KDM Engineering Department.
2	Calibration of the flow meters	External calibration laboratory	Every 2 years.	Yes	Calibration certificate will be issued by the Calibration Laboratory. This certificate will be filed by the KDM Engineering Department
3	Measurement of flare/combustion efficiency	Engineering Department of KDM	Yearly.	Yes	The measured value would be recorded in a file with the date of measurement. This file will be completed and filed by the person responsible for data filing and the Head of the Engineering Department. This value would be used for estimating ERM until next measurement of flare efficiency.

4	Measurement of the methane content in the exhaust gas of flare	Engineering Department of KDM (if feasible) or by external laboratory.	Yearly, in order to determine flare efficiency, above.	Yes	The measured value would be recorded in a file with the date of measurement. This file will be completed and filed by the person responsible for data filing and the Head of the Engineering Department. This value would be used until next measurement of methane content of exhaust gas.
5	Measurement of methane fraction in the landfill gas	Engineering Department of KDM or external laboratory	Continuous measurement, recording on a weekly basis.	Yes	Measured value will be used, together with corresponding measurements of pressure, temperature and flow rate of landfill gas, and other parameters that are periodically upgraded. Measurement of methane fraction would be recorded in an appropriate computer file, which would indicate start and end time of measurements corresponding to each data file. The data records will be filed by the person responsible for data filing and the Head of the Engineering Department.
6	Measurement of Pressure and Temperature	Engineering Department of KDM	Weekly. Data will be entered into a spreadsheet on a weekly basis, permitting continuous monitoring.	Yes	Daily data on pressure and temperature would be recorded in a spreadsheet file. The data records will be filed by the person responsible for data filing and the Head of the Engineering Department.
7	Sustainability indicators file	Engineering Department KDM	Annual	Yes	This data file will be completed and filed by the person responsible for data filing and the Head of the Engineering Department..
8	Monitoring of regulatory requirements relating to landfill gas projects	Engineering Department KDM	Annual	No	The Head of the Engineering Department will prepare the report on the current situation with respect to legal requirements.
9	Electricity exported and imported from the grid	Engineering Department KDM	Hourly	Yes	Data tables showing date, hour, and meter reading to be recorded in a spreadsheet file, and filed by the person responsible for data filing and the Head of the Engineering Department.

10	Electric meter calibration	External calibration laboratory	Twice a year	Yes	Calibration certificate will be issued by the Calibration Laboratory. This certificate will be filed by the KDM Engineering Department.
11	Calculation of emissions factor for electric power generation in the interconnected grid.	Outside consultant	Yearly	No	Report showing the determination of emissions factor as the arithmetic mean of operating margin and build margin emissions factor will be filed by the Engineering Department. This factor and the annual electricity generation will be used to determine CO_2 emissions reductions.
12	Internal Audit	KDM Central Office in Santiago.	Twice a year (July and December)	Yes	The internal auditor will prepare a report to the Manager of the landfill site and the Head of the Engineering Department on the state of items 1 to 8. In case of non conformity, they will attempt to resolve problems prior to the annual Verification carried out by a Designated Operational Entity. A copy of this report should be filed in the Central Office and the Engineering Department.
13	Fossil Fuel consumption metering	KDM Biogas plant management	Every time fuel is required for the different consumption sources	Yes	KDM has an operative instructive which describes and require procedures to record fuel consumption from each source.

Information about monitoring equipment:

1. Flow Meter:

   - Range: 850 – 3150 SCFM
   - Accuracy: ±1.5% of reading + 15.75 SCFM

- It will be cleaned every 2 months and the accuracy will be verified at least once a year. This can be done using a Pitot tube with liquid filled manometer.
- Calibration will be done if the annual verification of accuracy using the Pitot tube is found to be inaccurate. A hand-held calibrator will be used.

2. Gas Analyzer:

- CH_4 and CO_2:
  - Range: 0 – 100%
  - Accuracy: ±1.2%

- O_2:
  - Range: 0 – 25%
  - Accuracy: ±0.1875%
  - The accuracy of the gas analyzer will be verified at least once per year. Such verification will be done throughout the comparison of the analyzer measurement with the label of a patron/standard gas balloon.
  - The calibration will be done any time when the biogas flow verification performed as above demonstrates that the accuracy is without the established range of both the analyzer and the standard gas.

Other environmental indicators.

The environmental approval given by the Chilean Environmental Commission (CONAMA) requires the monitoring of data other than those required by the CDM methodology. These include the measurements of other components of LFG collected: carbon dioxide and oxygen content, to be measured continuously; hydrogen sulphide on a daily basis; nitrogen on a quarterly basis; lower heating value (from methane content) on a daily basis. These requirements also include measurements following LFG flaring, to include: temperature and flow rate of exhaust gases, on a continuous basis; moisture content, particulate matter, carbon dioxide, oxygen, carbon monoxide, sulphur dioxide, nitrogen oxides, non methane hydrocarbons (NMHC), and halogenated compounds, all on a quarterly basis; and dioxin and furans annually. A variety of test procedures have been established by the Chilean government for these measurements. USEPA protocols are used for halogenated compounds, dioxin and furanes.

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

Monitoring methodology prepared by: Ana Luisa Vergara, Gautam Dutt, and Pablo Marchisio, MGM International (not a project participant).

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Annex 4

MONITORING PLAN

The monitoring methodology used for this project is ACM0001, with minor adjustments for application to the conditions of this project.

The project involves landfill gas capture and flaring. Some gas will be used for power generation at the landfill site. ACM0001 provides guidance and equations for these applications. ACM0001 also provides for the case that LFG is used to generate thermal energy (e.g. in a boiler) at the landfill site.

Figure A.4.1 shows the overall monitoring scheme as presented in ACM0001.

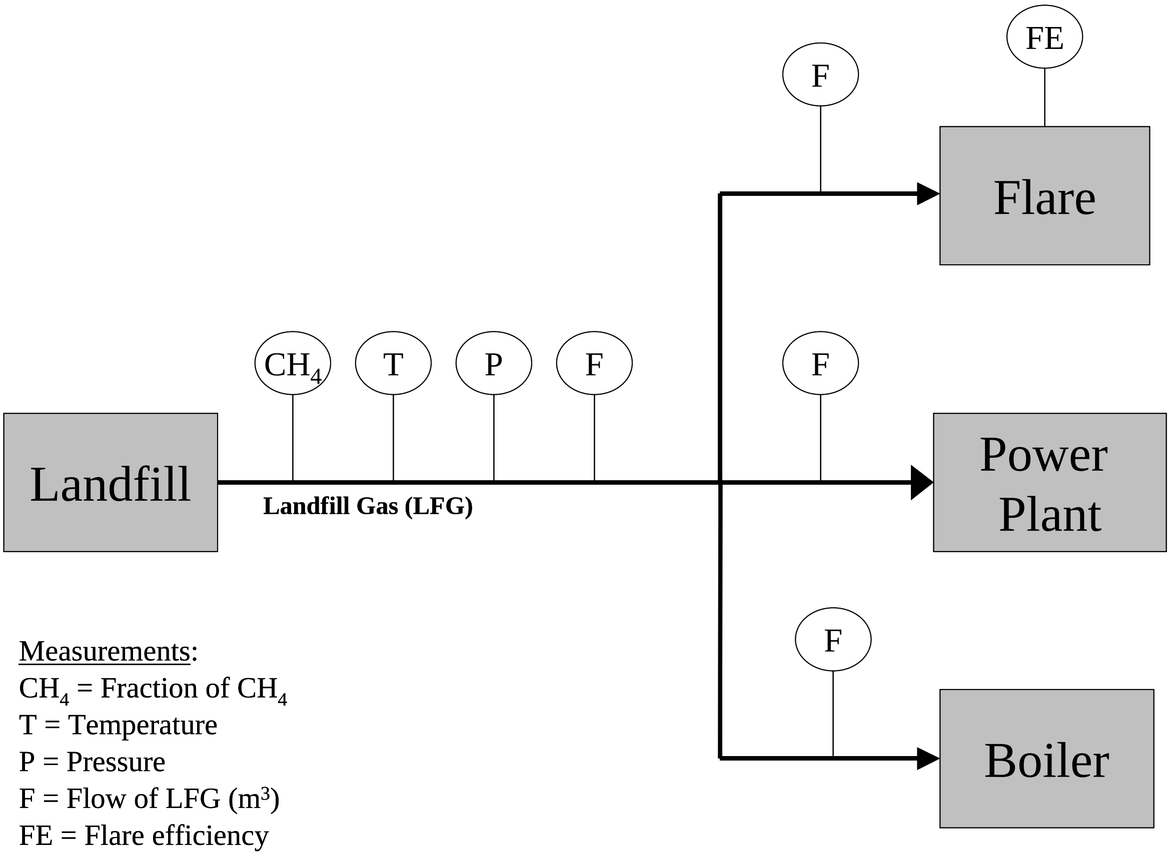

Figure A.4.1: Key Data Points for Monitoring (from ACM0001)
(Note: In this project, "Boiler" indicates users of LFG as fuel off-site)

The specific project is not expected to involve LFG use to generated thermal energy use on site.

The monitoring procedure, including relevant equations, are summarised in Section D of the PDD. Here we provide some additional details on how the procedure would be applied to the specific project activity.

The monitoring requirements for estimating methane and carbon dioxide emissions reductions are considered separately.

Methane

Ex ante estimates of methane emissions reductions shown in this PDD were based on a model of landfill gas production and assumptions on how much of the total production would be captured for flaring or energy use. Actual emissions reductions would be based on monitored data on methane actually captured and burnt.

The monitoring plan requires direct measurement of the amount of landfill gas captured and the amount of landfill gas destroyed in one of three ways: at the flare platform, for electricity generation, and sold for use as fuel off-site. Thus four measurements of methane flow rate are involved, shown as “F” in Figure A.4.1. Each flow rate is measured as a volume flow rate, compensated for temperature and pressure in order to measure and record flow rate at standard temperature (0 C) and pressure (1.013 bar). The methane content of landfill gas collected is measured at a point in the landfill gas extraction system where all of the collected gas passes. The compensated flow rates of landfill gas at the four measurement points (total LFG collected, and LFG sent to flare, electricity generation, and injected to pipeline for sale) are multiplied by the methane fraction of landfill gas and methane density at standard temperature and pressure (0.7168 kg/m^3) in order to determine the mass flow rates of methane at each of the four locations.

Note that Eq. 4 of Section D.2.4 (based on ACM0001) states the following:

$$MD_{flared,y} = LFG_{flare,y} \cdot w_{CH_4,y} \cdot D_{CH_4} \cdot FE$$

Where:

$MD_{flared,y}$ is the quantity of methane destroyed by flaring during the year measured in cubic meters (m^3)

$LFG_{flared,y}$ is the quantity of landfill gas flared or during the year measured in cubic meters (m^3)

$w_{CH_4,y}$ is the average methane fraction of the landfill gas as measured during the year and expressed as a fraction (in m^3CH_4/m^3LFG)

FE is the flare efficiency (the fraction of the methane destroyed)

D_{CH_4} is the methane density expressed in tonnes of methane per cubic meter of methane (tCH_4/m^3CH_4).

There are similar equations (5 and 7) in Section D.2.4 for methane used for electricity generation and for total methane destroyed:

$$MD_{electriciy,y} = LFG_{electricity,y} \cdot w_{CH_4,y} \cdot D_{CH_4} \cdot FE$$

$$MD_{total,y} = LFG_{total,y} \cdot w_{CH_4,y} \cdot D_{CH_4} \cdot FE$$

In this last formula $MD_{total,y}$ is the total quantity of methane generated and $LFG_{total,y}$ is the total quantity of landfill gas collected.

Here all the measured variables are shown as their annual average values. This is not strictly the correct way of determining the total amount (mass) of methane destroyed annually. Rather, the annual mass of

methane destruction should be determined as the sum of the hourly mass flows of methane destruction, i.e.

$$MD_{flared,y} = (\sum_{i=1}^{8760} LFG_{flare,\,i} \cdot w_{CH_4,\,i}) \cdot D_{CH_4} \cdot FE \qquad \text{(A.4.1)}$$

where

$LFG_{flare,\,i}$ is the flow rate at standard temperature and pressure of LFG sent to the flare during hour "i",

$w_{CH_4,\,i}$ is the average methane concentration of LFG collected during the same hour "i"

The mass of methane used to generate electricity ($MD_{electricity,y}$) each year is determined similarly, by summing hourly values over the year.

In the above equation, a single value of flare efficiency (FE) is shown. Since ACM0001 (version 4) requires FE to be measured yearly, the mass flow of methane flared also would need to be determined on a yearly basis. The mass of methane flared during each quarter would be determined by summing hourly values as indicated above, using value of FE as measured at the start of each year.

Once the components of methane destroyed in any of the two ways have been determined, the total mass of methane destroyed in each year can be determined using the following equation:

$$MD_{project,y} = \min\ (MD_{total,y} + MD_{flared,y} + MD_{electricity,y} \qquad \text{(A.4.2)}$$

Then, the emissions reductions associated with methane destruction are then determined by Eq (1) of Section D.2.4:

$$ERM_{y} = (MD_{project,y} - MD_{reg,y}) \cdot GWP_{CH_4} \qquad \text{(A.4.3)}$$

Where:

ERM_y is measured in tonnes of CO_2 equivalent (tCO_{2e})

$MD_{project,y}$ and $MD_{reg,y}$ are measured in tonnes of methane (tCH_4)

For reasons explained in Section D.2.4, $MD_{reg,y}$ is a fixed number, equivalent to 245 tonnes/year, for the first crediting period of this project, while GWP_{CH_4} = 21 tCO_2e/tCH_4, again for the first commitment period of the Kyoto Protocol (until 2012).

In order to determine if an adjustment needs to be made for the second and third crediting periods, KDM would monitor relevant regulations for LFG project activities periodically, and make modifications on the value of $MD_{reg,y}$, accordingly.

Note that the measurement equipment for gas quality (humidity, particulate, etc.) is sensitive, so a strong QA/QC procedure for the calibration of this equipment is needed.

Carbon dioxide

In this project, carbon dioxide emissions reductions may also result from power generation using landfill gas (which is a renewable fuel and therefore produces no net carbon dioxide emissions). The electricity produced here offsets emissions from power plants elsewhere in the system.

Carbon dioxide emissions reductions during a given year y (ERC_y) are given by Eq (7) of Section D.2.4 of the PDD:

$$ERC_y = EL_y \bullet CEF_y \qquad \text{(A.4.4)}$$

where

ERC_y is measured in tonnes of CO_2 (tCO_{2e})

EL_y is the net quantity of electricity exported during the year *y*, MWh, given by:

$$EL_y = EL_{EXP\ LFG,y} - EL_{IMP,y} \qquad \text{(A.4.5)}$$

where

$EL_{EXP\ LFG,y}$ is the net quantity of electricity exported during year *y*, produced using landfill gas, MWh

$EL_{IMP,y}$ is the net incremental electricity imported, defined as difference of project imports less any imports of electricity in the baseline, to meet the project requirements, MWh

Note that "exported" here refers to the project activity: landfill gas collection, flaring, and electricity generation (if any). Thus exported electricity could supply other power needs at the landfill, e.g. leachate treatment, office use, etc., that are *not* associated with the landfill gas collection, flaring and use. Exported electricity could also leave the site and be supplied to the grid.

For the same reason, "imported" refers to any electricity taken (from the grid) by the project activity, principally for blowers used in landfill gas extraction. Such imports may be present in the baseline as well, corresponding to LFG extraction in the baseline, as in the case of the proposed project.

CEF_y is the emissions factor for electricity generation, tCO_2/MWh.

Parameters to be monitored in order to determine carbon dioxide emissions reduction from electricity generation are listed below:

- Net electricity output of the LFG generation system, which would be measured using an electric meter. This amount of electricity may be sent to the rest of the landfill (not a part of the project activity) or sold to the grid. Electricity sold to the grid will be measured in any case, since it is the basis for transactions in the wholesale power market. While it is not necessary to measure the electricity sent to other uses on site, this is also recommended.
- When electricity is not generated, any electricity purchased from the grid to meet project requirements should be monitored using an electric meter. Even in this case, Eq. A.4.5 remains valid, though the value for emissions reductions is negative. The value should be recorded as "project emissions."

In each case, electric meters shall be calibrated periodically according to manufacturer recommendations, e.g. every two years.

The determination of CO_2 emissions reductions (or project CO_2 emissions from electricity use when no power is generated) also requires a determination of the emissions factor for power generation in

the interconnected power grid. This emissions factor would be calculated yearly from the most recent data available of the Chilean power system. The procedure to be used, based on the approved consolidated methodology ACM0002, is as shown in Annex 3.

Another source of project CO_2 emissions may arise from any fossil fuel used in the project activity. In such cases, the quantity of fossil fuels required to operate the landfill gas project, including the pumping equipment for the collection system and energy required to transport heat, should be monitored. In projects where LFG gas is captured in the baseline to either meet the regulation or for safety reason, fossil fuel used in the baseline too should be recorded.

Monitored data used to determine methane and carbon dioxide emissions reductions would be recorded in spreadsheets wherever possible (except for such information as regulations), showing calculation procedures. These data should be compiled on an annual basis, be subject to internal audit (see Section D.4) and be available to the Designated Operational Entity in charge of Verification.