Draft editorial amendment to the approved baseline and monitoring methodology AM0093

"Avoidance of landfill gas emissions by passive aeration of landfills"

I. SOURCE, DEFINITIONS AND APPLICABILITY

Sources

This baseline and monitoring methodology is based on elements from the following approved baseline and monitoring methodology and proposed new methodology:

- NM0333 "Avoidance of landfill gas emissions by passive aeration of landfills" prepared by Tokyu Construction Co., Ltd.;
- AM0083 "Avoidance of landfill gas emissions by in-situ aeration of landfills".

This methodology also refers to the latest approved versions of the following tools:

- Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion;
- Tool to calculate baseline, project and/or leakage emissions from electricity consumption;
- Tool for the demonstration and assessment of additionality;
- Methodological tool "Tool to determine methane Emissions avoided from disposal of waste at a solid waste disposal sites"; and
- ~~Tool to determine the mass flow of a greenhouse gas in a gaseous stream.~~

For more information regarding the proposed new methodologies and the tools as well as their consideration by the Executive Board please refer to <http://cdm.unfccc.int/goto/MPappmeth>.

Selected approach from paragraph 48 of the CDM modalities and procedures

"Existing actual or historical emissions, as applicable".

Or

"Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment".

Definitions

For the purpose of this methodology, the following definition applies:

Passive (semi-aerobic) aeration. Passive aeration refers to the construction of a piping system to ventilate the landfill without active venting or overdrawing, usually for the purpose of converting the landfill to semi-aerobic conditions (i.e. MCF of around 0.5). Ventilation equipment generally consists of vertical perforated pipes and horizontal perforated pipes. Leachate drainage pipes are also set to keep the internal-water level low. Air is naturally introduced into the landfill without mechanical injection, through convection caused by temperature difference between the ambient air and the landfill.

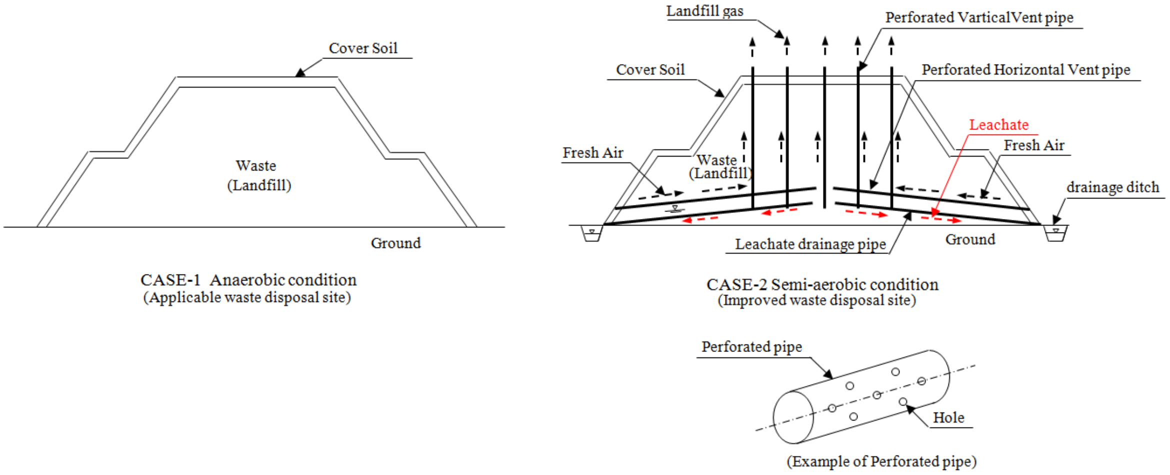

Figure 1: Illustration of a passive aeration system

Applicability

This methodology applies to project activities that treat landfilled waste on-site by means of passive (semi-aerobic) aeration, with the objective of avoiding anaerobic degradation processes and achieving aerobic degradation. By aerating the landfilled waste, landfill gas (LFG) emissions are avoided.

The methodology is applicable under the following conditions:

- The project activity involves the treatment of landfilled waste in closed landfills or closed landfill cells aiming at reducing landfill gas emissions in cases where the baseline scenario is the partial or total atmospheric release of landfill gas. Closed cells of operating landfills might be eligible as long as they are physically distinct from the remaining parts of the landfill. This means that their infrastructure is independent from other cells outside the project boundary, comprising e.g. separate leachate drainage system, separate covers etc. No migration of landfill gas and leachate between the cells covered under the project activity and other cells is allowed;
- If mandatory environmental regulations require the collection and flaring of landfill gas, the corresponding compliance rate is below 50% in the host country. If the monitored compliance with the regulations rate exceeds 50%, the project activity shall receive no further credits, as the assumption that the policy is not enforced in the host country is no longer tenable;
- Vertical venting wells should be placed in a grid (lattice) form. The distance (pitch) between adjacent vertical venting wells shall not be more than 40 metres, and venting wells shall be placed in a way to ensure that the number of venting wells is more than one per 7,646[1] cubic metres of waste volume as determined by the documents on landfill design. If the project activity is implemented for landfill areas where the actual depth is less than 10 meters, a minimum value of 10 meters shall be applied for the calculation of the spacing of venting wells in these areas. This is proposed to ensure that the well spacing is not too wide and enough oxygen is provided to form a sufficiently aerobic biodegradation environment. Height

[1] The Technical Manual TM5-814-5 on Sanitary Landfill by the U.S. Department of. Army (1994) states that "No design procedure is available to calculate the number of vents required, but one vent per 10,000 cubic yards of waste may be sufficient."

and volume of the landfill should be determined according to the landfill's management record. Alternatively, the landfill height is determined by a geographical survey of the top and the bottom level of the landfill, or according to the landfill plan;

- Existing LFG collection systems do not continue to operate during the baseline campaign or after the implementation of the project activity;
- Leachate is not re-circulated during the baseline campaign unless it can be proved that this has been a practice over the last five years.

In addition, the applicability conditions included in the tools referred to above apply.

Finally, this methodology is only applicable if the most plausible baseline scenario is partial or total atmospheric release of landfill gas from the closed landfill or the closed landfill cells.

II. BASELINE METHODOLOGY PROCEDURE

Identification of the baseline scenario

Project participants shall apply the following steps to identify the baseline scenario:

Step 1: Identify plausible alternative scenarios

Project participants should use Step 1 of the latest version of the "Tool for the demonstration and assessment of additionality" to identify all realistic and credible baseline alternatives. In doing so, relevant policies and regulations related to the management of landfill sites should be taken into account. Such policies or regulations may include mandatory landfill gas capture or destruction requirements because of safety issues or local environmental regulations. Other policies could include local policies promoting productive use of landfill gas such as those for the production of renewable energy or policies on proper after-care of abandoned landfills. In addition, the assessment of alternative scenarios should take into account local economic and technological circumstances.

(1) National and/or sectoral policies and circumstances must be taken into account in the following ways:

- In Sub-step 1b of the "Tool for the demonstration and assessment of additionality", the project developer must show that the project activity is not the only alternative that is in compliance with all regulations (e.g. because it is required by law);
- The project developer must monitor all relevant policies and circumstances at the beginning of each crediting period and adjust the baseline accordingly.

(2) Alternatives for the treatment of existing waste in the absence of the project activity (passive aeration of landfills) i.e. the scenario relevant for estimating baseline methane emissions to be analyzed should include, *inter alia*:

LFG1: The project activity (passive aeration of landfills) or any other form of aeration not implemented as a CDM project;

LFG2: No or partial collection and combustion of LFG from the landfill;

LFG3: LFG collection and combustion system, with or without energy generation;

LFG4: Landfill mining, where the landfill is opened and all existing waste is recycled and/or composted.

Step 2: Exclusion of alternatives

Step 2 and/or Step 3 of the latest approved version of the "Tool for the demonstration and assessment of additionality" shall be used to assess which of these alternatives should be excluded from further consideration (e.g. alternatives facing prohibitive barriers or those clearly economically unattractive).

Step 3: Selection of baseline scenario

Where more than one credible and plausible alternative remains, project participants shall, as a conservative approach use the alternative baseline scenario that results in the lowest baseline emissions as the most likely baseline scenario. In assessing these scenarios, any regulatory or contractual requirements should be taken into consideration.

The methodology is only applicable if the most plausible baseline scenario is identified as the business-as-usual scenario, i.e. no or partial collection and combustion of LFG from the landfill (LFG2).

Additionality

The additionality of the project activity shall be demonstrated and assessed using the latest version of the "Tool for the demonstration and assessment of additionality" agreed by the CDM Executive Board.[2]

In case the land covered by the landfill can be used for activities generating economic value after aerobic treatment of the waste, an investment analysis is mandatory. For the investment analysis, project participants have to follow the steps as described below:

(a) Identification of possible after-uses: Project participants have to identify all credible and feasible options for the after-use of the landfill site after termination of the project activity. Thereby, relevant regulations and the specific site conditions such as topography and stability have to be taken into account;

(b) Definition of time-lines for the after-use: project participants have to determine the earliest point in time for the after-use;

(c) Definition of land value: For all credible and technically feasible after-use options, corresponding land values have to be defined based on local values for comparable land uses. In the next steps, the after-use option that will lead to the highest revenues has to be considered;

(d) If no after-use is feasible, no revenues by land-reclamation have to be considered for the investment analysis;

(e) If there are feasible and credible options for the after-use of the landfill that will lead to revenues, project participants should use after-tax net present value (NPV) analysis. NPV is estimated by taking into account the costs for the realization of project activity and the later revenues from land reclamation and using an adequate discount rate. The project is additional if the NPV of the project activity is negative.

[2] Please refer to: < http://cdm.unfccc.mt/goto/MPappmeth>.

(f) For the selection of appropriate discount rates and the further realization of the investment analysis, the procedure as per the latest version of the "Tool for the demonstration and assessment of additionality" has to be applied.

If the land covered by the landfill cannot be used after the installation of the project activity, the barrier analysis may be used as per Step 2 of the "Tool for the demonstration and assessment of additionality".

Project boundary

The **spatial extent** of the project boundary encompasses the site of the project activity where the waste is treated. This includes the landfill or the treated landfill cells, on-site electricity consumption, and on-site fuel use.

The greenhouse gases included in or excluded from the project boundary are shown in Table 1.

Table 1: Emissions sources included in or excluded from the project boundary

Source		Gas	Included?	Justification / explanation
Baseline	Emissions from decomposition of waste at the landfill site	CO_2	No	CO_2 emissions from the decomposition of organic waste are not accounted for
		CH_4	Yes	The major source of emissions in the baseline
		N_2O	No	N_2O emissions are small compared to CH_4 emissions from landfills. Exclusion of the gas is conservative
Project activity	On-site fossil fuel consumption due to the project activity	CO_2	Yes	May be an important emission source. It includes fossil fuel consumed by vehicles used on-site
		CH_4	No	Excluded for simplification. This emission source is assumed to be very small
		N_2O	No	Excluded for simplification. This emission source is assumed to be very small
	Emissions from on-site electricity use	CO_2	Yes	May be an important emission source
		CH_4	No	Excluded for simplification. This emission source is assumed to be very small
		N_2O	No	Excluded for simplification. This emission source is assumed to be very small
	Direct emissions from the in-situ aeration of landfill	CO_2	No	CO_2 emissions from the decomposition of organic waste are not accounted for
		CH_4	Yes	The aerobic process may not be complete and result in anaerobic decay. CH_4 may be emitted by the venting pipes and the landfill surface
		N_2O	Yes	May be an important emission source

Project emissions

Project emissions are calculated as follows:

$$PE_y = PE_{EC,y} + PE_{FC,y} + PE_{CH4,a,y} + PE_{N2O,a,y} \tag{1}$$

Where:

PE_y	=	Project emissions in year *y* (t CO_2e)
$PE_{FC,y}$	=	Project emissions from fossil fuel combustion in year *y* (t CO_2e)
$PE_{EC,y}$	=	Project emissions from electricity consumption in year *y* (t CO_2e)
$PE_{CH4,a,y}$	=	Project CH_4 emissions from aeration of the landfill in year *y* (t CO_2e)
$PE_{N2O,a,y}$	=	Project N_2O emissions from aeration of the landfill in year *y* (t CO_2e). If Option 3, the default N_2O emission factor is selected, this component of the projected emissions is included only during the first ten years of the crediting period(s)

Project emissions from electricity consumption

Project emissions from electricity consumption ($PE_{EC,y}$) shall be calculated following the latest version of the "Tool to calculate baseline, project and/or leakage emissions from electricity consumption".

Project emissions from fossil fuel consumption

Project emissions from fossil fuel combustion ($PE_{FC,y}$) shall be calculated following the latest version of the "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion". For this purpose, the processes *j* in the tool corresponds to all fossil fuel combustion on-site for the purposes of the project activity.

Project CH_4 emissions from aeration of the landfill

The project activity may lead to residual methane emissions e.g. due to incomplete aeration and incomplete degradation and as a consequence of the aerobic degradation process itself. Residual methane emissions from aeration of the landfill in year *y* may be estimated using either of the options given below:

Option 1, all venting wells are monitored:

$$PE_{CH4a,y} = GWP_{CH4} \times \sum_k \sum_q (MC_{CH4,v,k,q} \times SG_{v,k,q}) + GWP_{CH4} \times CF \times \sum_i \sum_q (MC_{CH4,s,i,q} \times SG_{s,i,q}) \tag{2}$$

Option 2, a sample of venting wells are monitored:

$$PE_{CH4,a,y} = GWP_{CH4} \times \sum_q (SG_{CH4,v,q}) + GWP_{CH4} \times CF \times \sum_i \sum_q (MC_{CH4,s,i,q} \times SG_{s,i,q}) \tag{3}$$

Where:

GWP_{CH4}	=	Global Warming Potential (GWP) of methane, valid for the relevant commitment period (t CO_2e/t CH_4)
$MC_{CH4,v,k,q}$	=	Monitored methane content in venting well *k* in quarter *q* (t CH_4/m^3)
$SG_{v,k,q}$	=	Volume of LFG from venting well *k* in quarter *q* (m^3)
$MC_{CH4,s,i,q}$	=	Monitored methane content from surface emissions in zone *i* in quarter *q* (tCH_4/m^3)
$SG_{s,i,q}$	=	Volume of surface LFG emissions from zone *i* in quarter *q* (m^3)
k	=	Number of venting wells

i	=	Number of surface zones (see monitoring procedures below)
CF	=	Conservativeness factor. Due to the high degree of uncertainty of surface measurements, a factor of 1.37 is applied
$SG_{CH4,v,q}$	=	Methane emissions from all venting wells in quarter q (t CH_4)
q	=	Quarters

Ex ante estimation of $PE_{CH4,a,y}$ may be done with the latest version of the approved methodological tool "Tool to determine methane Emissions avoided from disposal of waste at a solid waste disposal sites". For *ex ante* estimation, it is assumed that MCF for semi-aerobic landfill is 0.5[3].

The variable $W_{j,x}$ in the methodological tool "Tool to determine methane Emissions avoided from disposal of waste at a solid waste disposal sites" is to be replaced by a variable $W_{dg,exante,j,x}$, which is the amount of organic waste disposed in the landfill in the year x (ton/year). In the tool, x will refer to the year since the landfill started receiving wastes, consistent with Application A in the tool. [x runs from the first year of landfill operation (x=1) to the year for which emissions are calculated (x=y)].

Project N_2O emissions from aeration of the landfill

Emissions of N_2O in year y may be estimated using one of the options given below. *Ex ante* estimation of $PE_{N2O,a,y}$ should be done with Option 3. For Option 1 and 2, procedure given for methane in the monitoring section should be followed, replacing the subscript CH_4 with N_2O.

Option 1, all venting wells are monitored:

$$PE_{CH4a,y} = GWP_{N2O} \times \sum_k \sum_q (MC_{N2O,v,k,q} \times SG_{v,k,q}) + GWP_{N2O} \times CF \times \sum_i \sum_q (MC_{N2O,s,i,q} \times SG_{s,i,q}) \quad (4)$$

Option 2, a sample of venting wells are monitored:

$$PE_{CH4,a,y} = GWP_{N2O} \times \sum_q (SG_{N2O,v,q}) + GWP_{N2O} \times CF \times \sum_i \sum_q (MC_{N2O,s,i,q} \times SG_{s,i,q}) \quad (5)$$

Where:

GWP_{N2O}	=	Global Warming Potential (GWP) of N_2O, valid for the relevant commitment period (t CO_2e/t N_2O)
$MC_{N2O,v,k,q}$	=	Monitored N_2O content in venting well k in quarter q (t N_2O/m^3)
$SG_{v,k,q}$	=	Voume of LFG from venting well k in quarter q (m^3)
$MC_{N2O,s,i,q}$	=	Monitored N_2O content from surface emissions in zone i in quarter q (t N_2O /m^3)
$SG_{s,i,q}$	=	Vlume of surface LFG emissions from zone i in quarter q (m^3)
k	=	Number of venting wells
i	=	Number of surface zones (see monitoring procedures below)
CF	=	Conservativeness factor. Due to the high degree of uncertainty of surface measurements, a factor of 1.37 is applied
$SG_{N2O,v,q}$	=	N_2O emissions from all venting wells in quarter q (t N_2O)
q	=	Quarters

Option 3, default emission factor:

$$PE_{N2O,a,y} = GWP_{N2O} \times EF_{N2O} \times \sum_i W_{T,i} \quad (6)$$

[3] Table 3.1, Volume 5, Chapter 3 (Solid Waste Disposal) of IPCC 2006 Guidelines.

Where:

GWP_{N2O}	=	Global Warming Potential of nitrous oxide, valid for the relevant commitment period (t CO_2e /t N_2O)
EF_{N2O}	=	Default emission factor for N_2O emissions from the aerated landfill (0.00002 t N_2O/t waste-yr)[4]. The N_2O emissions are distributed over the first ten years of the crediting period(s)
$W_{T,i}$	=	Total waste quantities in landfill zone *i* (t)

Baseline emissions

$$BE_y = BE_{FOD,y} \times R \quad \textbf{(7)}$$

Where:

BE_y	=	Baseline emissions in year *y* (t CO_2e)
$BE_{FOD,y}$	=	Methane that would be produced in the landfill in the absence of the project activity in year *y* (t CO_2e)
R	=	Ratio between the actual methane measured and the methane estimated using the FOD model during the baseline campaign, estimated as per equation (10) below. If *R* is greater than 1, a value of 1 shall be used

Ex ante estimation of BE_y

The *ex ante* estimation of the methane generation from the landfill in the absence of the project activity (aeration of landfills) may be done with the latest version of the approved methodological tool "~~Tool to determine methane~~ Emissions avoided from ~~disposal of waste at a~~ solid waste disposal sites". The tool estimates methane generation adjusted for, using adjustment factor (f_y), any landfill gas in the baseline that would have been captured and destroyed to comply with relevant regulations or contractual requirements, or to address safety and odor concerns. The variable $W_{j,x}$ in the methodological tool "~~Tool to determine methane~~ Emissions avoided from ~~disposal of waste at a~~ solid waste disposal sites" is to be replaced by a variable $W_{dg,exante,j,x}$, which is the amount of organic waste disposed in the landfill in the year x.

Ex post estimation of $BE_{FOD,y}$

At the project start, project participants have to do a statistically sampling and analysis of the existing waste to determine the methane generation potential, as described in the monitoring section below. Then, baseline emissions shall be recalculated with the analytically determined value for the methane generation potential (L_0) before the start of the project as per following equation:

$$BE_{FOD,y} = \varphi \times (1-f) \times GWP_{CH4} \times (1-OX) \times MCF \times \sum_i W_{dg,i} \times L_{0,i} \times e^{-k_{CH4}(y-x)} \times (1-e^{-k_{CH4}}) \quad \textbf{(8)}$$

[4] Due to the lack of data on N2O emissions from aerobic landfills, a conservative N_2O emission factor of 0.2 kg N_2O per tonne of treated waste , which is based on the latest available data for such emissions from composting. This value may be revised in the future when more data is available on N2O emissions from aerobic treatment of waste.

Where:

φ	=	Default model correction factor to account for model uncertainties (0.9)
f	=	Fraction of methane captured and flared
GWP_{CH4}	=	Global Warming Potential (GWP) of methane, valid for the relevant commitment period (t CO_2e/t CH_4)
OX	=	Oxidation factor (reflecting the amount of methane from the landfill that is oxidized in the soil or other material covering the waste)
MCF	=	Methane correction factor. MCF values according to the latest version of the methodological tool "~~Tool to determine methane~~ Emissions ~~avoided~~ from ~~disposal of waste at a~~ solid waste disposal sites" have to be applied
$W_{dg,i}$	=	Amount of biodegradable waste in landfill zone *i* (t). Estimated as per equation (9) below
$L_{0,i}$	=	Potential methane generation capacity of the waste in landfill zone *i* as determined by sampling and lab analysis (t CH_4/t Waste) once before start of the project activity as per the monitoring methodology described below
k_{CH4}	=	Methane generation rate. k_{CH4} value as per table in the data and parameters not monitored section below is used.
x	=	The year of start of aeration (yr)
i	=	Landfill zone category (index). Depending on the characteristics and tipping history of the landfill, the landfill is subdivided into different zones with different characteristics and methane generation potential and landfilled waste quantities determined separately for each zone

Estimation of the amount of biodegradable waste in landfill zone i ($W_{dg,i}$)

With increasing landfill age a clear separation of waste components becomes very difficult. Therefore, the same samples taken to determine L_o shall be classified into biodegradable and non-degradable materials (by mass). The fraction of degradable waste shall be determined and applied to the total waste quantities in the closed landfill or closed cell to determine the value of $W_{dg,i}$:

$$W_{dg,i} = f_{dg,i} \times W_{T,i} \tag{9}$$

Where:

$W_{dg,i}$	=	Amount of biodegradable waste in landfill zone *i* (t)
$f_{dg,i}$	=	Fraction of biodegradable waste in landfill zone *i*
$W_{T,i}$	=	Total waste quantities in landfill zone *i* (t)

Estimation of R from a Baseline Campaign

Methane emissions shall be measured prior to the installation of project venting wells and the start of the aeration of the landfill, to check the validity of the FOD model. This baseline campaign will last for at least three (3) months. Existing gas venting and leachate drainage wells have to stay open for one week prior to the measurements in order to vent trapped CH_4. The leachate drainage wells are capped or closed again before conducting the baseline campaign and will be kept closed throughout the campaign to avoid any kind of air venting effect, which might affect the estimation of emissions. Recording of the measurements during the baseline campaigns should only start after one week from closure of the leachate drainage wells. The ratio between the actual methane measured and the methane estimated using the FOD model should be used to adjust the estimated baseline emissions using the FOD model as follows:

$$R = \frac{BE_{CH4,bl-campaign}}{BE_{FOD,bl-campaign}} \quad \textbf{(10)}$$

Where:

R	=	Ratio between the actual methane measured and the methane estimated using the FOD model during the baseline campaign. If R is greater than 1, a value of 1 shall be used
$BE_{CH4,bl\text{-}campaign}$	=	Methane produced in the landfill in the baseline campaign measured and calculated as per equation (11) below. (t CO_2e)
$BE_{FOD,bl\text{-}campaign}$	=	Methane produced in the landfill in the baseline campaign estimated as per equation (12) below. (t CO_2e)

Monthly campaigns for measuring surface emissions are required during the 3-month baseline campaign. Procedure given in the monitoring section should be followed replacing *q* (quarter) with *m* (month). The venting well component, i.e. the first component, should be removed from the equation below if no venting wells existed before the start of the project activity.

$$BE_{CH4,bl\_campaign} = GWP_{CH4} \times \sum_{k} \sum_{m} (MC_{CH4,v,k,m} \times SG_{v,k,m}) + GWP_{CH4} \times \sum_{i} \sum_{m} (MC_{CH4,s,i,m} \times SG_{s,i,m}) \quad \textbf{(11)}$$

Where:

GWP_{CH4}	=	Global Warming Potential (GWP) of methane, valid for the relevant commitment period (t CO_2e/t CH_4)
$MC_{CH4,v,k,m}$	=	Monitored methane content in venting well *k* in month *m* during the baseline campaign (t CH_4/m^3)
$SG_{v,k,m}$	=	Volume of LFG from venting well *k* in month *m* during the baseline campaign (m^3)
$MC_{CH4,s,i,m}$	=	Monitored methane content of surface emissions in zone *i* in month *m* during the baseline campaign (t CH_4/m^3)
$SG_{s,i,m}$	=	Volume of surface LFG emissions from zone *i* in month *m* during the baseline campaign (m^3)
m	=	Months
i	=	Landfill zone category (index). Depending on the characteristics and tipping history of the landfill, the landfill is subdivided into different zones with different characteristics and methane generation potential and landfilled waste quantities determined separately for each zone

$$BE_{FOD,bl\_campaign} = \varphi \times GWP_{CH4} \times (1-OX) \times MCF \times \sum_{i} W_{dg,i} \times L_{0,i} \times e^{-k_{CH4}(m-x)/12} \times (1-e^{-k_{CH4}/12}) \quad \textbf{(12)}$$

Where:

φ	=	Default model correction factor to account for model uncertainties (0.9)
GWP_{CH4}	=	Global Warming Potential (GWP) of methane, valid for the relevant commitment period (t CO_2/t CH_4)
OX	=	Oxidation factor (reflecting the amount of methane from the landfill that is oxidized in the soil or other material covering the waste)
MCF	=	Methane correction factor. MCF values according to the latest version of the methodological tool "~~Tool to determine methane~~ Emissions ~~avoided~~ from ~~disposal of waste at a~~ solid waste disposal sites" have to be applied
$W_{dg,i}$	=	Amount of biodegradable waste in landfill zone *i* (t). Estimated as per equation (9)above

$L_{0,i}$	=	Potential methane generation capacity of the waste in landfill zone *i* as determined by sampling and lab analysis (t CH_4/ t Waste) once before start of the project activity
k_{CH4}	=	Methane generation rate. k_{CH4} value as per table in the data and parameters not monitored section below is used
x	=	Month of start of baseline campaign (months)
m	=	Month for estimating methane emission during baseline campaign (months)
i	=	Landfill zone category (index). Depending on the characteristics and tipping history of the landfill, the landfill is subdivided into different zones with different characteristics and methane generation potential and landfilled waste quantities determined separately for each zone

Leakage

No leakage will occur due to the project activity.

Emission reductions

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y \quad (13)$$

Where:

ER_y	=	Emission reductions in year *y* (t CO_2e)
BE_y	=	Baseline emissions in year *y* (t CO_2e)
PE_y	=	Project emissions in year *y* (t CO_2e)

Changes required for methodology implementation in 2nd and 3rd crediting periods

Changes as required in the tools referred to above apply.

Data and parameters not monitored

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

Data / Parameter:	GWP_{CH4}
Data unit:	tCO_2e/tCH_4
Description:	Global warming potential of CH_4
Source of data:	IPCC 2nd assessment report
Measurement procedures (if any):	21 for the first commitment period
Any comment:	Shall be updated according to any future COP/MOP decisions

Data / Parameter:	GWP_{N2O}
Data unit:	tCO_2e/tN_2O
Description:	Global warming potential of N_2O
Source of data:	IPCC 2nd assessment report
Measurement procedures (if any):	310 for the first commitment period
Any comment:	Shall be updated according to any future COP/MOP decisions

Data / Parameter:	f
Data unit:	-
Description:	Fraction of methane captured and flared
Source of data:	Written information from the operator of the solid waste disposal site and/or site visits at the solid waste disposal site
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter:	OX
Data unit:	-
Description:	Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)
Source of data:	Conduct a site visit at the solid waste disposal site in order to assess the type of cover of the solid waste disposal site. Use the IPCC 2006 Guidelines for National Greenhouse Gas Inventories for the choice of the value to be applied
Measurement procedures (if any):	Use 0.1 for managed solid waste disposal sites that are covered with oxidizing material such as soil or compost. Use 0 for other types of solid waste disposal sites
Any comment:	-

Data / Parameter:	MCF
Data unit:	-
Description:	Methane correction factor
Source of data:	IPCC 2006 Guidelines for National Greenhouse Gas Inventories
Measurement procedures (if any):	Use the following values for MCF: • 1.0 for **anaerobic managed solid waste disposal sites**. These must have controlled placement of waste (i.e. waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include at least one of the following: (i) cover material; (ii) mechanical compacting; or (iii) leveling of the waste; • 0.5 for **semi-aerobic managed solid waste disposal sites**. These must have controlled placement of waste and will include all of the following structures for introducing air to the waste layers: (i) permeable cover material; (ii) leachate drainage system; (iii) regulating pondage; and (iv) gas ventilation system; • 0.8 for **unmanaged solid waste disposal sites ñ deep and/or with high water table**. This comprises all SWDS not meeting the criteria of managed SWDS and which have depths of greater than or equal to 5 meters and/or high water table at near ground level. Latter situation corresponds to filling inland water, such aspond, river or wetland, by waste; • 0.4 for **unmanaged-shallow solid waste disposal sites**. This comprises all SWDS not meeting the criteria of managed SWDS and which have depths of less than 5 metres
Any comment:	The methane correction factor (MCF) accounts for the fact that unmanaged SWDS produce less methane from a given amount of waste than managed SWDS, because a larger fraction of waste decomposes aerobically in the top layers of unmanaged SWDS

<table>
<tr><td>Data / Parameter:</td><td>k_{CH4}</td></tr>
<tr><td>Data unit:</td><td>1/yr</td></tr>
<tr><td>Description:</td><td>Methane generation rate</td></tr>
<tr><td>Source of data:</td><td>Table below</td></tr>
<tr><td>Measurement procedures (if any):</td><td>With increasing landfill age a clear separation of waste components becomes very difficult. The decay constant k for the biodegradable waste is determined based on the specific waste age and the landfill characteristic (location in boreal or tropical climate, dry or wet) from table below:
<table>
<tr><td rowspan="2">Waste age</td><td colspan="2">MAT ≤ 20°C; boreal</td><td colspan="2">MAT > 20°C; tropical</td></tr>
<tr><td>Dry (MAP/PET <1)</td><td>Wet (MAP/PET >1)</td><td>Dry</td><td>Wet</td></tr>
<tr><td>a≤ 2</td><td>0.045</td><td>0.100</td><td>0.055</td><td>0.170</td></tr>
<tr><td>2 < a ≤ 10</td><td>0.035</td><td>0.060</td><td>0.045</td><td>0.100</td></tr>
<tr><td>a > 10</td><td>0.030</td><td>0.045</td><td>0.035</td><td>0.050</td></tr>
</table>
This table gives average values for certain waste ages. This adaptation is based on the assumption, that within two years the rapidly degrading components (like e.g. food waste) have become widely bio-converted (i.e. k = mean value of rapidly, moderately and slowly degrading material according to the classification made in the methodological tool “~~Tool to determine methane~~ Emissions ~~avoided~~ from ~~disposal of waste at a~~ solid waste disposal sites”). From two to ten years, the moderately degrading components become bio-converted (i.e. k = mean value of moderately and slowly degrading material according to the classification made in the methodological tool “~~Tool to determine methane~~ Emissions ~~avoided~~ from ~~disposal of waste at a~~ solid waste disposal sites”). For waste ages > 10 years, only the values for the slowly degradable components are applied</td></tr>
<tr><td>Any comment:</td><td>Document in the CDM-PDD the climatic conditions at the SWDS site temperature, precipitation and, where applicable, evapotranspiration. Use long-term averages based on statistical data, where available. Provide references</td></tr>
</table>

<table>
<tr><td>Data / Parameter:</td><td>$W_{dg,exante,j,x}$</td></tr>
<tr><td>Data unit:</td><td>ton</td></tr>
<tr><td>Description:</td><td>Amount of biodegradable waste disposed in the landfill in the year x</td></tr>
<tr><td>Source of data:</td><td>Project participants</td></tr>
<tr><td>Measurement procedures (if any):</td><td>The estimation should be done by one of the following procedures:
• Assessment of the different waste types j through sampling at the landfill site;
• Utilization of data from previous studies on the waste types j in the landfill;
• Using a default value for the share of biodegradable waste, calculated as the sum of the categories “Food waste”, “Paper/Cardboard”, “Wood” and “Textiles”, applicable for the region where the project is located, in Table 2.3 of the IPCC national greenhouse gas inventories (2006), volume 5, chapter 2</td></tr>
<tr><td>Any comment:</td><td>-</td></tr>
</table>

Data / Parameter:	EF_{N20}
Data unit:	t N_2O/t waste/yr
Description:	Default emission factor for N_2O emissions from the aeration
Source of data:	Research literature
Measurement procedures (if any):	Default value of 0.02 kg N_2O/t waste-yr
Any comment:	The N_2O emissions are distributed over the first ten years of the crediting period(s)

Data / Parameter:	$f_{dg,i}$
Data unit:	dimensionless
Description:	Fraction of degradable waste in landfill zone *i*
Source of data:	Landfill historical data
Measurement procedures (if any):	The same samples taken to determine L_o shall be classified into degradable and non degradable materials (by mass) to determine this parameter
Monitoring frequency:	Once at the start of the project activity
QA/QC procedures:	To be compared to data for waste classification per type of waste, if available
Any comment:	-

Data / Parameter:	$W_{T,i}$
Data unit:	ton
Description:	Total waste quantities in landfill zone *i*
Source of data:	Landfill historical data
Measurement procedures (if any):	Volume and density shall be measured before the project start (by geodetic surveys and test excavation)
Monitoring frequency:	Once at the start of the project activity
QA/QC procedures:	To be checked against data for historical waste quantities
Any comment:	The value is assumed to be constant; this is conservative. The value has to be available at validation

Data / Parameter:	A_i
Data unit:	m^2
Description:	Area of landfill zone *i*
Source of data:	Project
Measurement procedures (if any):	By geodetic surveys
Monitoring frequency:	Once at the start of the project activity
QA/QC procedures:	To be checked against data from existing maps
Any comment:	-

Data / Parameter:	$A_{v,k}$
Data unit:	m^2
Description:	Cross-sectional area of venting well *k*
Source of data:	Project specification
Measurement procedures (if any):	None
Monitoring frequency:	Upon installation
QA/QC procedures:	None
Any comment:	-

Data / Parameter:	A_v
Data unit:	m^2
Description:	Total cross sectional area of venting wells installed
Source of data:	Project specification
Measurement procedures (if any):	By project specification
Monitoring frequency:	Once at the start of the project activity
QA/QC procedures:	None
Any comment:	-

Data / Parameter:	N_v
Data unit:	dimensionless
Description:	Total number of installed venting wells
Source of data:	Project participants
Measurement procedures (if any):	-
Monitoring frequency:	Once at the start of the project activity
QA/QC procedures:	None
Any comment:	-

III. MONITORING METHODOLOGY

The project participants using this methodology should note that there are references to UK and German guidelines for measurement of surface emissions of landfill. The project participants can also use any other national or international guidelines comparable to the guidelines referred under this methodology, if they can demonstrate its comparability in the CDM-PDD.

All data collected as part of monitoring should be archived electronically and be kept at least for two (2) years after the end of the last crediting period. 100% of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted with calibrated measurement equipment according to relevant industry standards.

In addition, the monitoring provisions in the tools referred to in this methodology apply.

Subject to the applicability condition regarding the well spacing, the exact mesh size has to be defined based on landfill characteristics (permeability, depth, etc.). Venting wells and flux box plots are to be placed in a lattice (grid) form as follows:

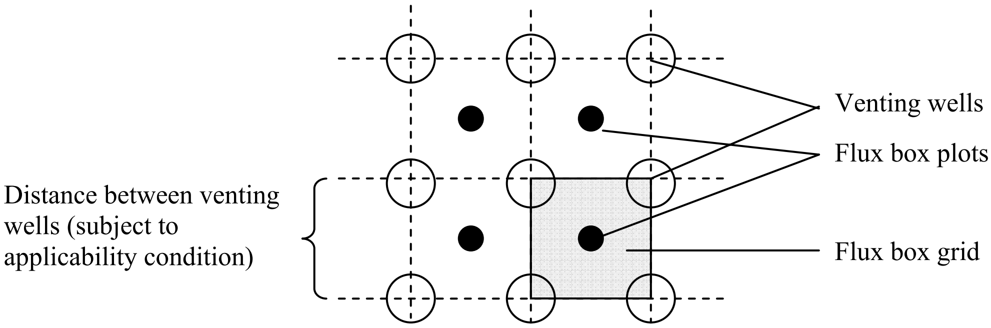

Figure 2: Schematic diagram of venting wells and flux box plots after implementation

Aeration will lead to vented and surface emissions that both have to be monitored. At the same time, L_o will decrease over time as a consequence of the accelerated degradation. Therefore, L_o should also be monitored by sampling and analysis of the landfilled waste for the purpose of calculating baseline emissions.

Procedure for monitoring of methane emissions

To monitor actual methane emissions from the aerated landfill, both surface and vented emissions have to be measured. The same procedure should be followed to monitor the N_2O emissions unless Option 3, the default emission factor was selected.

Monitoring these emissions will comprise metering the flow rate of the corresponding emission source and analyzing methane concentrations in this flow. The measurement of methane content should be measured at the same time of measuring the flow.

During all periodic measurements of vented emissions and surface emissions, particular attention has to be paid to representative sampling as per the above mentioned standards. Project participants have to ensure that:

- The sampled time intervals cover all typical climatic conditions, including different seasons, weather conditions etc.;
- At least one measurement for surface emissions is done during the three (3) coldest months of the year (where maximum methane emissions are expected).

Project participants shall document all discrete measurements of exhaust emissions in a measurement protocol.

1. Monitoring Vented Emissions

Frequency and duration of survey: Measurement should be carried out at least four (4) measurement campaigns per year, i.e. quarterly. For each quarter, one representative day should be selected, and the measurements should only be conducted during still air and during falling air pressure, 3 times in the morning and 3 times in the evening during a measuring day to calculate an average value.

Method of monitoring flow: A flow meter or a vane type anemometer or a hot-wire anemometer should be used to measure the velocity of the landfill gas flow. Measurements should be conducted by inserting the anemometer through a side hole in the gas well at a depth > 1 m from the upper end of the gas well (in order to minimise the influence of air turbulence). The gas velocity should be measured at 1/6 of the pipe diameter away from the centre of the pipe intersection, as the flow velocity is the highest in the middle of the pipe and slower towards the side.

Method of monitoring methane content: The method for measuring the methane content in the gases emitted from the landfill site include analysis with gas chromatography, using a concentration meter based on an optical sensor and a concentration meter based on a fixed sensor. The required performance of the concentration meter consists of a high diffusion rate and a high accuracy that sufficiently supports gas concentration change. In addition, since the purpose is to measure the concentration in the landfill site, the meter is also required to allow easy measurement, be sturdy and fuss-free in maintenance and inspection. Optical sensor based concentration meters would meet these requirements, and a dual-wavelength infrared methane gas concentration meter is the most appropriate type of concentration meter. In accordance with the flow rate measurement, the measuring point should be > 1m below the upper end of the gas well. The gas composition should be measured three (3) times and the average value of these readings should be applied for each sample.

If the landfill gas flow and the methane content are not measured on the same wet basis or dry basis, the calculation of methane emissions should be adjusted as per the latest version of the methodological tool "~~Tool to determine methane~~ Emissions ~~avoided~~ from ~~disposal of waste at a~~ solid waste disposal sites".

Two options can be used for monitoring vented emissions. Project participants can use either option, provided that they are stated in the PDD.[5]

1.1. Option 1, all venting wells are monitored:

The same procedure should be applied to determine the LFG emissions from venting wells during the baseline campaign ($SG_{v,k,m}$), replacing the subscript of q with m.

In this option, landfill gas flow and methane content are monitored in all of the venting wells installed as a result of project activity.

For each quarterly measurement $V_{v,k,q}$, average landfill gas flux is calculated. $SG_{v,k,q}$ is calculated in venting well k over quarterly length s, as follows.

$$SG_{v,k,q} = S \times V_{v,k,q} \times A_{v,k} \qquad \textbf{(14)}$$

Where:

$SG_{v,k,q}$	=	Volume of LFG from venting well k in quarter q (m^3)
S	=	Total duration of quarter q (sec)
$V_{v,k,q}$	=	Monitored LFG flow velocity of venting well k in quarter q (m/ sec)
$A_{v,k}$	=	Cross-sectional area of venting well k (m^2)

5 For subsequent change in the method of monitoring, a request for deviation is required.

1.2. Option 2, a sample of venting wells are monitored:

Where not all venting wells are monitored, statistically derive the methane flux in quarter q to be used for the purpose of calculating project emissions. The number of sample points selected is determined by using the formula from "Monitoring Landfill Gas Surface Emissions" by the U.K. Environment Agency (2011).[6]

$$n_k \geq 6 + 0.15\sqrt{\sum_i A_i} \ \textbf{ and } \ n_k \geq 30 \tag{15}$$

Where:

n_k	=	Total number of sampled venting wells
A_i	=	Area of landfill zone i (m^2)

Thus, a landfill with an area of 100,000 m^2 would require a minimum of 53 points. The number of measurement points must not be below 30 so as to ensure robust measurements.

Sampling points should be selected in a representative and random manner. One of the possible ways is by numbering the location of the grid venting wells in an orderly manner (e.g. 1, 2, … from a corner of a landfill zone) and numbering the venting wells within each landfill zone continuously. The starting point where the measurement is taken should be selected randomly (e.g. by using a random number generator such as http://www.random.org) and thereafter at a regular interval of the ratio of the total number of wells and n_k. For example, if 53 wells from 160 venting wells are to be sampled, 160 divided by 53 is approximately 3, and therefore every 3rd well should be monitored.

Under Option 2, for each quarterly measurement q, the methane emissions are calculated as follows:

Step 1: Obtain methane flux of each venting well

$$F_{CH4,v,k,q} = V_{v,k,q} \times MC_{CH4,v,k,q} \tag{16}$$

Where:

$F_{CH4,v,k,,q}$	=	Methane flux of sampled venting well k in quarter q (t CH_4/ m^2-sec)
$V_{v,k,q}$	=	Monitored landfill gas flow velocity of sampled venting well k in quarter q (m/ sec).
$MC_{CH4,v,k,q}$	=	Monitored methane content from venting well k in quarter q (t CH_4/m^3)

Step 2: Obtain area-adjusted mean methane flux (μ) for each quarter q

$$\mu F_{CH4,v,q} = \frac{\sum_k \left(F_{CH4,v,k,q} \times A_{v,k}\right)}{\sum_k A_{v,k}} \tag{17}$$

Where:

$\mu F_{CH4,v,q}$	=	Mean methane flux of sampled venting wells in quarter q (t CH_4/ m^2-sec)
$F_{CH4,v,k,,q}$	=	Methane flux of sampled venting well k in quarter q (t CH_4/ m^2-sec)
$A_{v,k}$	=	Cross-sectional area of sampled venting well k (m^2)

[6] Environment Agency: UK: Guidance on monitoring landfill gas surface emissions, March 2011, available at < http://publications.environment-agency.gov.uk/PDF/GEHO0311BTOL-E-E.pdf >.

Step 3: Calculate the sample standard deviation (σ)

$$\sigma F_{CH4,v,q} = \sqrt{\frac{N_v - n_k}{N_v - 1} \sum_{k=1}^{n_k} \frac{(F_{CH4,v,k,q} - \mu F_{CH4,v,q})^2}{n_k - 1}} \quad \textbf{(18)}$$

Where:

$\sigma N_{CH4,v,k,q}$	=	Standard deviation of methane gas flux in quarter q (t CH_4/ m^2-sec)
n_k	=	Total number of sampled venting wells
N_v	=	Total number of installed venting wells[7]
$\mu F_{CH4,v,q}$	=	Mean methane flux of sampled venting well in quarter q (t CH_4/ m^2-sec)
$F_{CH4,v,q}$	=	Methane flux of sampled venting well k in quarter q (t CH_4/ m^2-sec)

Step 4: Calculate the 95% confidence interval

$$\mu F_{CH4,v,q} - t \times \frac{\sigma F_{CH4,v,q}}{\sqrt{n_k}} \le F_{CH4,v,q} \le \mu F_{CH4,v,q} + t \times \frac{\sigma F_{CH4,v,q}}{\sqrt{n_k}} \quad \textbf{(19)}$$

Where:

$F_{CH4,v,q}$	=	Calculated methane flux in quarter q (t CH_4/ m^2-sec).
$\mu F_{CH4,v,q}$	=	Mean methane flux of sampled venting well in quarter q (t CH_4/ m^2-sec)
$\sigma N_{CH4,v,q}$	=	Standard deviation of methane gas flux in quarter q (t CH_4/ m^2-sec)
t	=	Upper critical value of the student t distribution for a confidence level of 95% with degrees of freedom n_k-1
n_k	=	Total number of sampled venting wells

In case of the project emissions, the upper bound of the 95% confidence interval obtained from above should be used to ensure conservativeness. In case of the baseline campaign, the lower bound of the 95% confidence interval should be used.

$$SG_{CH4,v,q} = s \times F_{CH4,v,q} \times A_v \quad \textbf{(20)}$$

Where:

$SG_{CH4,v,q}$	=	Methane emissions from all venting wells in quarter q (t CH_4)
S	=	Total duration of quarter q (sec)
$F_{CH4,v,q}$	=	Calculated methane flux in quarter q (t CH_4/ m^2-sec).
A_v	=	Total cross sectional area of venting wells installed (m^2)

2. Monitoring Surface Emissions

The surface emissions are to be monitored using the flux box method as described in VDI guideline 3790[8] or in the UK environment agency guidance (2011), whereby both passive and active flux boxes are admissible. At least four (4) measurement campaigns should be carried out per year i.e. quarterly.

[7] The term $\frac{N_v - n_k}{N_v - 1}$ is the finite population correction factor to correct for the case when the population is finite, as in this case.

[8] VDI Guideline 3790 Environmental meteorology - Emissions of gases, odours and dusts form diffuse sources; Part 1 Fundamentals (2005); Part 2 Landfills (2000), available in English at <www.beuth.de>.

Each campaign consists of a statistically valid number of single measurements that must be distributed over the entire surface. The closed landfill or landfill cell is to be subdivided into different zones with distinctive characteristics with regard to expected surface emissions. The above cited guideline gives references on the definition of such zones with distinctive surface emission characteristics. For each identified sub-zone, the number of monitoring locations and the average spacing between them should be chosen in accordance with the UK environment agency guidance, in a manner specified in option 2 of monitoring vented emissions. Average surface emissions should be assessed for each zone individually. As a result of the flux box measurements, a flux density of the landfill gas in (mg/m^2*s) can be calculated for each measurement. The UK environment agency guidance describes in detail data processing and calculation procedures. Then, average surface emissions flow rate can be calculated for each zone by multiplying with the corresponding size of the zone.

2.1. Determination of the monitored methane content of surface emissions during aeration in zone *i* in the year *y* ($MC_{CH4,s,i,q}$)

The same procedure should be applied to determine the methane content of surface emissions during the baseline campaign ($MC_{CH4,s,i,m}$), replacing the subscript of *q* with *m*.

Number of sampling points according to the UK environment agency guidance (2011) is defined as:

$$n_i = 6 + 0.15\sqrt{A_i} \tag{21}$$

Where:

n_i	=	Number of monitoring locations in zone *i*
A_i	=	Area of zone *i* (m^2)

Step 1: Calculate sample mean (μ) for each zone i and quarter q

$$\mu MC_{CH4,s,i,q} = \frac{\sum_{c=1}^{n_i} MC_{CH4,s,i,c,q}}{n_i} \tag{22}$$

Where:

$\mu MC_{CH4,s,i,q}$	=	Mean methane content from surface emissions in zone *i* in quarter *q* (t CH_4/m^3)
$MC_{CH4,s,i,c,q}$	=	Monitored methane content from surface emissions in zone *i* in location *c* in quarter *q* (t CH_4/m^3)
n_i	=	Number of monitoring locations in zone *i* as per guidance from the UK environment agency (function of the zone size)

Step 2: Calculate the sample standard deviation (σ)

$$\sigma MC_{CH4,s,i,q} = \sqrt{\frac{\sum_{c=1}^{n_i} (MC_{CH4,s,i,c,q} - \mu MC_{CH4,s,i,q})^2}{n_i - 1}} \tag{23}$$

Where:

$\sigma MC_{CH4,s,i,q}$	=	Standard deviation of monitored methane content from surface emissions in zone *i* in quarter *q* (t CH_4/m^3)
$\mu MC_{CH4,s,i,q}$	=	Mean methane content from surface emissions in zone *i* in quarter *q* (t CH_4/m^3)
$MC_{CH4,s,i,c,q}$	=	Monitored methane content from surface emissions in zone *i* in location *c* in quarter *q* (t CH_4/m^3)
n_i	=	Number of monitoring locations in zone *i* as per guidance from the UK environment agency (function of the zone size)

Step 3: Calculate the 95% confidence interval

$$\mu MC_{CH4,s,i,q} - t_i \times \frac{\sigma MC_{CH4,s,i,q}}{\sqrt{n_i}} \leq MC_{CH4,s,i,q} \leq \mu MC_{CH4,s,i,q} + t_i \times \frac{\sigma MC_{CH4,s,i,q}}{\sqrt{n_i}} \quad \textbf{(24)}$$

Where:

$\sigma MC_{CH4,s,i,q}$	=	Standard deviation of monitored methane content from surface emissions in zone *i* in quarter *q* (t CH_4/m^3)
$\mu MC_{CH4,s,i,q}$	=	Mean methane content from surface emissions in zone *i* in quarter *q* (t CH_4/m^3)
t_i	=	Upper critical value of the student *t* distribution for a confidence level of 95% with degrees of freedom n_i-1

In case of the project emissions, the upper bound of the 95% confidence interval obtained from the equation above should be used to ensure conservativeness. In case of the baseline campaign, the lower bound of the 95% confidence interval should be used.

2.2. Determination of total volume of surface LFG emissions from zone *i* in quarter *q* ($SG_{s,i,q}$)

The same procedure should be applied to determine the total volume of surface LFG emissions during the baseline campaign ($SG_{s,i,m}$), replacing the subscript of *q* with *m*.

Step 1: Calculate sample mean (μ) for each zone i and quarter q

$$\mu FL_{s,i,q} = \frac{\sum_{c=1}^{n_i} F_{s,i,c,q}}{n_i} \quad \textbf{(25)}$$

Where:

$\mu FL_{s,i,q}$	=	Mean of flux of surface emissions in zone *i* in quarter *q* (m^3/ sec-m^2)
$F_{s,i,c,q}$	=	Flux of surface emissions in zone *i* in location *c* in quarter *q* (m^3/ sec-m^2)
n_i	=	Number of monitoring locations as per guidance from the UK environment agency (function of the zone size)

Step 2: Calculate the sample standard deviation (σ)

$$\sigma FL_{s,i,q} = \sqrt{\frac{\sum_{c=1}^{n_i} (F_{s,i,c,q} - \mu FL_{s,i,q})^2}{n_i - 1}} \quad \textbf{(26)}$$

Where:

$\sigma FL_{s,i,q}$	=	Standard deviation of flux of surface emissions in zone *i* in quarter *q* (m^3/sec-m^2)
$\mu FL_{s,i,q}$	=	Mean of flux of surface emissions in zone *i* in quarter *q* (m^3/ sec-m^2)
$F_{s,i,c,q}$	=	Flux of surface emissions in zone *i* in location *c* in quarter *q* (m^3/ sec-m^2)
n_i	=	Number of monitoring locations as per guidance from the UK environment agency (function of the zone size)

Step 3: Calculate the 95% confidence interval.

$$\mu FL_{s,i,q} - t_i \cdot \frac{\sigma FL_{s,i,q}}{\sqrt{n_i}} \leq F_{s,i,q} \leq \mu FL_{s,i,q} + t_i \cdot \frac{\sigma FL_{s,i,q}}{\sqrt{n_i}} \quad (27)$$

Where:

$F_{s,i,q}$	=	Flux rate surface emissions in zone *i* in quarter *q* (m^3/sec-m^2)
$\sigma FL_{s,i,q}$	=	Standard deviation of flux of surface emissions in zone *i* in quarter *q* (m^3/sec-m^2)
$\mu FL_{s,i,q}$	=	Mean of flux of surface emissions in zone *i* in quarter *q* (m^3/ sec-m^2)
t_i	=	Upper critical value of the student *t* distribution for a confidence level of 95% with degrees of freedom n_i-1

In case of the project emissions, the upper bound of the 95% confidence interval obtained from the equation above should be used to ensure conservativeness. In case of the baseline campaign, the lower bound of the 95% confidence interval should be used.

$$SG_{s,i,q} = F_{s,i,q} \times s \times A_i \quad (28)$$

Where:

$SG_{s,i,q}$	=	Volume of surface LFG emissions from zone *i* in quarter *q* (m^3)
S	=	Total duration of quarter *q* (sec)
A_i	=	Area of zone *i* (m^2)

Procedure for sampling and analyzing the landfilled waste to estimate Lo

The landfilled waste has to be sampled directly before the start of the project activity to determine the initial L_o for baseline emission calculation:

The selection of sampling points and sampling methods of the landfilled waste has to be done as follows:

- Four samples per hectare shall be analyzed. Out of each sampling position, mixed samples should be taken, whereas sub-samples should be taken at least every five (5) meters (measured from landfill surface);
- The samples have to be extracted by vertical drilling from the sampling point at the landfill surface, using a drill and an inner tube diameter of at least 70mm, reaching the bottom of the landfill to represent the waste characteristics over the full depth of the landfill body. The volume of the drilled core is to be recorded. Subsequently, the core is to be differentiated into heaps of similar, characteristic material types (“grab samples”). These heaps are to be photographed and to be described in qualitative terms;

- Processing of the samples shall be done in accordance with internationally recognized standards as LAGA PN98,9 EN TR 15310-3 and -4.10 These standards specify how from each grab sample, sub-samples ("qualified grab samples") are taken and how sub-samples can be mixed to generate a composite sample ("collective sample") from which laboratory samples will be taken;
- The size of the laboratory samples is defined by analytical requirements. An aliquot part of the lab sample should be kept and stored adequately as retain sample until completed verification;
- The measurement of Lo, expressed in (Mg Methane/Mg waste), shall be done applying column/bioreactor tests under anaerobic conditions with a duration of 21 days to the laboratory samples;
- Project participants shall establish a sampling plan and a sampling protocol, including information on location, applied sampling method, number of the sample, quantity, depth. Locations of the sampling points and depths of the sampling should be plotted on a map of the landfill and attached to the sampling protocol;
- For further data processing, in case of project emissions, the upper bound of the 95% confidence interval obtained from the measurements should be used to ensure conservativeness. In case of baseline emissions, the lower bound of the 95% confidence interval should be used.

Data and parameters monitored

Data / Parameter:	Compliance rate
Data unit:	%
Description:	Compliance rate for mandatory environmental regulations regarding the collection and flaring of landfill gas
Source of data:	Official and public data on the landfill operations from government sources, landfill operator unions and associations
Measurement procedures (if any):	-
Monitoring frequency:	At the beginning of each crediting period
QA/QC procedures:	Compare the data collected on compliance with rate of threshold of 50% adopted on the compliance of laws and regulation under this methodology
Any comment:	

[9] LAGA – Länderarbeitsgemeinschaft Abfall, PN 98 "Richtline für das Vorgehen bei physikalischen, chemischen und biologischen Untersuchungen im ZUsammenhang mit der Verwertung/Beseitigung von Abfällen" available in German at <http://www.laga-online.de/mitteilungen/docs/LAGA%20PN%2098.pdf>.

[10] EN TR 15310 "Characterization of waste - Sampling of waste materials"; Part 3 "guidance on procedures for sub-sampling in the field, Part 4 "Guidance on procedures for sample packaging, storage, preservation, transport and delivery.

Data / Parameter:	$EC_{PJ,y}$
Data unit:	MWh
Description:	Quantity of electricity consumed by the project in year *y*
Source of data:	Project activity site
Measurement procedures (if any):	Electricity meters
Monitoring frequency:	Continuous measurement and at least monthly recording
QA/QC procedures:	Cross check measurement results with records for purchased electricity
Any comment:	

Data / Parameter:	$L_{0,i}$
Data unit:	t methane/t waste
Description:	Potential methane generation capacity of the waste in landfill zone *i*
Source of data:	Laboratory analysis
Measurement procedures (if any):	$L_{0,i}$ should be analyzed as Biochemical Methane Potential (BMP) according to the methods described by Kelly et al. (2006),[11] Owens & Chenowyth (1993),[12] Hansen et al. (2004)[13] or alternative appropriate standards
Monitoring frequency:	At project start
QA/QC procedures:	See procedures description above
Any comment:	

Data / Parameter:	$F_{s,i,c,q}$
Data unit:	m^3/m^2-sec
Description:	Flux of LFG surface emissions at location c in zone i in quarter q at Normal Temperature and Pressure
Source of data:	Project participants
Measurement procedures (if any):	See the section "Procedure for monitoring of methane emissions"
Monitoring frequency:	See the section "Procedure for monitoring of methane emissions"
QA/QC procedures:	Maintenance and calibration of equipment will be carried out according to internationally recognized standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

[11] Ryan J. Kelly, Bradley D. Shearer, Jongmin Kim, C. Douglas Goldsmith, Gary R. Hater, John T. Novak (2006): Relationships between analytical methods utilized as tools in the evaluation of landfill waste stability, Waste Management, 26, p.1349–1356, download at <http://www.scsengineers.com/Papers/Kelly_WM-Analytical_Tools_LF_Waste_Stability.pdf>.

[12] J.M. Owens, J.M., D.P. Chynoweth, (1993): Biochemical methane potential of municipal solid waste (MSW) components. Water Science and Technology 27 (2), p. 1–14.

[13] Train L. Hansen, Jens Ejbye Schmidt, Irini Angelidaki, Emilia Marca, Jes la Cour Jansen, Hans Mosbaek, Tomas H. Christensen (2004): Method for determination of methane potential of solid organic waste, Waste Management, 24, p. 393-400.

Data / Parameter:	$F_{s,i,c,m}$
Data unit:	m^3/m^2-sec
Description:	Flux of LFG surface emissions at location *c* in zone *i* in month *m* during the baseline campaign at Normal Temperature and Pressure
Source of data:	Project participants
Measurement procedures (if any):	See the section "Procedure for monitoring of methane emissions"
Monitoring frequency:	Monthly during the baseline campaign. See the section "Procedure for monitoring of methane emissions"
QA/QC procedures:	Maintenance and calibration of equipment will be carried out according to internationally recognized standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	$MC_{CH4,s,i,c,q}$
Data unit:	t CH_4/m^3
Description:	Monitored methane content from surface emissions during aeration at location c in zone i in quarter q
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the methane content will be carried out according to the section "Procedure for monitoring of methane emissions", using flame ionization detector, infrared sensors or similar
Monitoring frequency:	See the section "Procedure for monitoring of methane emissions"
QA/QC procedures:	Maintenance and calibration of equipment will be carried out according to internationally recognized standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	$MC_{N2O,s,i,c,q}$
Data unit:	t N_2O/m^3
Description:	Monitored N_2O content from surface emissions during aeration at location *c* in zone *i* in quarter *q*
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the N_2O content will be carried out similar to the section "Procedure for monitoring of methane emissions"
Monitoring frequency:	See the section "Procedure for monitoring of methane emissions"
QA/QC procedures:	Maintenance and calibration of equipment will be carried out according to internationally recognized standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	$MC_{CH4,s,i,c,m}$
Data unit:	t CH_4/m^3
Description:	Monitored methane content from surface emissions during aeration at location *c* in zone *i* in month *m* during the baseline campaign
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the methane content will be carried out according to the section “Procedure for monitoring of methane emissions”, using flame ionization detector, infrared sensors or similar
Monitoring frequency:	Monthly during the baseline campaign
QA/QC procedures:	Maintenance and calibration of equipment will be carried out according to internationally recognized standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	T_s
Data unit:	°C
Description:	Temperature of the surface emissions
Source of data:	Project participants
Measurement procedures (if any):	Measured to determine the density of methane D_{CH4}. No separate monitoring of temperature is necessary when using flow meters that automatically measure temperature and pressure, expressing gaseous emissions volumes in normalized cubic meters
Monitoring frequency:	Quarterly
QA/QC procedures:	Measuring instruments should be subject to a regular maintenance and testing regime in accordance to appropriate national/international standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	P_s
Data unit:	Pa
Description:	Pressure of surface emissions
Source of data:	Project participants
Measurement procedures (if any):	Measured to determine the density of methane D_{CH4}. No separate monitoring of temperature is necessary when using flow meters that automatically measure temperature and pressure, expressing gaseous emissions volumes in normalized cubic meters
Monitoring frequency:	Quarterly
QA/QC procedures:	Measuring instruments should be subject to a regular maintenance and testing regime in accordance to appropriate national/international standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	$V_{v,k,q}$
Data unit:	m/sec
Description:	Monitored velocity of the landfill gas flow from venting well *k* in quarter *q*
Source of data:	Project participants
Measurement procedures (if any):	See the section "Procedure for monitoring of methane emissions"
Monitoring frequency:	See the section "Procedure for monitoring of methane emissions"
QA/QC procedures:	Maintenance and calibration of equipment will be carried out according to internationally recognized standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	$V_{v,k,m}$
Data unit:	m/sec
Description:	Monitored velocity of the landfill gas flow from venting well k in month m during the baseline campaign
Source of data:	Project participants
Measurement procedures (if any):	See the section "Procedure for monitoring of methane emissions"
Monitoring frequency:	See the section "Procedure for monitoring of methane emissions"
QA/QC procedures:	Maintenance and calibration of equipment will be carried out according to internationally recognized standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	$MC_{CH4,v,k,q}$
Data unit:	t CH_4/m^3
Description:	Monitored content of methane in venting well k in quarter q
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the methane content will be carried out according to the section "Procedure for monitoring of methane emissions", using flame ionization detector, infrared sensors or similar
Monitoring frequency:	See the section "Procedure for monitoring of methane emissions"
QA/QC procedures:	Maintenance and calibration of equipment will be carried out according to internationally recognized standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	$MC_{N2O,v,k,q}$
Data unit:	t N_2O/m^3
Description:	Monitored N_2O content in venting well *k* in quarter *q*
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the N_2O content will be carried out according to the section "Procedure for monitoring of methane emissions"
Monitoring frequency:	See the section "Procedure for monitoring of methane emissions"
QA/QC procedures:	Maintenance and calibration of equipment will be carried out according to internationally recognized standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	$MC_{CH4,v,k,m}$
Data unit:	t CH_4/m^3
Description:	Monitored content of methane in venting well k in month m during the baseline campaign
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the methane content will be carried out according to the section "Procedure for monitoring of methane emissions", using flame ionization detector, infrared sensors or similar
Monitoring frequency:	See the section "Procedure for monitoring of methane emissions"
QA/QC procedures:	Maintenance and calibration of equipment will be carried out according to internationally recognized standards. Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	T_v
Data unit:	°C
Description:	Temperature of the vented exhaust emissions
Source of data:	Project participants
Measurement procedures (if any):	Measured to determine the density of methane D_{CH4}. No separate monitoring of temperature is necessary when using flow meters that automatically measure temperature and pressure, expressing gaseous emissions volumes in normalized cubic meters
Monitoring frequency:	Continuous
QA/QC procedures:	Measuring instruments should be subject to a regular maintenance and testing regime in accordance to appropriate national/international standards Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	P_v
Data unit:	Pa
Description:	Pressure of the vented exhaust emissions
Source of data:	Project participants
Measurement procedures (if any):	Measured to determine the density of methane D_{CH4}. No separate monitoring of pressure is necessary when using flow meters that automatically measure temperature and pressure, expressing gaseous emissions volumes in normalized cubic meters
Monitoring frequency:	Continuous
QA/QC procedures:	Measuring instruments should be subject to a regular maintenance and testing regime in accordance to appropriate national/international standards Where laboratory work is outsourced, one which follows rigorous standards (ISO 9001 or local equivalent) shall be selected
Any comment:	

Data / Parameter:	S
Data unit:	Seconds
Description:	Total duration of quarter q
Source of data:	-
Measurement procedures (if any):	Calendar or clock
Monitoring frequency:	Quarterly
QA/QC procedures:	None
Any comment:	To be used for calculating $SG_{v,k,q}$

IV. REFERENCES AND ANY OTHER INFORMATION

Not applicable.

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History of the document

Version	Date	Nature of revision(s)
01.0.1	EB 66, Annex # 2 March 2012	Editorial amendment to change the title of the “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site” to “Emissions from solid waste disposal sites”.
01.0.0	EB 62, Annex 3 15 July 2011	Initial adoption.
Decision Class: Regulatory **Document Type**: Standard **Business Function**: Methodology		