Draft baseline and monitoring methodology AM00XX

"Avoidance of landfill gas emissions by in-situ aeration of landfills"

I. SOURCE, DEFINITIONS AND APPLICABILITY

Sources

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

- NM0294 "Avoidance of landfill gas emissions by in-situ aeration of landfills" prepared by Perspectives Climate Change GmbH, Gockhausen, Switzerland.

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;
- Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site.

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 definitions apply:

Air injection phase. Period of time during which the landfill is undergoing an active aeration, i.e., during which air blowers are operated (including downtime of air blowers due to maintenance or technical failures).

Post-injection phase. Period of time after stopping of the aeration, i.e., air blowers stop operating.

Air venting (Overdrawing). A method for aerating the landfill where ambient air is sucked into the landfilled **waste** through the installation of a negative pressure difference. Air venting methods are characterised by gas extraction rates that significantly exceed the LFG formation rates, thus leading to a gradual aeration starting from the landfill surface towards the inner areas. Due to the need for air intrusion via the surface, landfills that have already been finally covered are not suitable for this kind of aeration. The aeration process is relatively slow and it is difficult to ensure that the entire waste mass becomes homogenously aerated as flow directions are static. Therefore, the applicability of this aeration method under this methodology is limited to sites with waste depth is lower than 10m.

Low pressure aeration: Ambient air is continuously injected into the landfill body via aeration wells with **positive** pressures lower than 1000 mbar. Further distribution within the landfilled waste is realized by means of convection and diffusion processes as well as through application of controlled off-gas extraction. The off-gases are collected by a gas collection system which is operated in parallel to the aeration. The off-gases can be vented or finally purified by means of thermal or biological treatment in order to ensure emission reduction to the widest extent.

Applicability

This methodology applies to project activities where landfilled waste is treated aerobically on-site by means of **air venting (overdrawing)** or **low pressure aeration** with the objective of avoiding anaerobic degradation processes and achieving aerobic degradation. By aeration of the landfilled waste, landfill gas emissions are avoided.

The methodology is applicable under the following conditions:

- The aeration techniques used is either air venting (overdrawing) or low pressure aeration;[1]
- The project activity involves the treatment of landfilled waste in closed landfills or closed landfill cells aiming at the reduction of landfill gas emissions in cases where the baseline scenario is the partial or total atmospheric release of landfill gas;
- If mandatory environmental regulations require the collection and flaring of landfill gas, the corresponding compliance rate is below 50% in the host country. If monitored compliance with the regulations exceeds 50%, the project activity shall receive no further credits, since the assumption that the policy is not enforced is no longer tenable;
- Closed cells of operating or closed landfills might be eligible as long as they are physically distinct from the remaining parts of the landfill. This includes 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 cell covered under the project activity and other cells is allowed.

[1] Semi-aerobic aeration technique or other aeration techniques are not applicable under this methodology.

The project activity will comprise two project phases:

- During the air-injection phase, the landfilled waste will be actively aerated and, if required, moisture will be added or leachate will be recirculated. The aeration will lead to an enhanced aerobic degradation of the landfilled waste. After a certain treatment time, the degradation process slows down and the organic matter will have been degraded to a point where the methane gas potential has been significantly reduced. At that point, further aeration or addition of moisture may cease to be practical. The air-injection may be stopped if a threshold value for L_0 of 11 m^3/tonne dry matter, corresponding to 0,0077 Mg/Mg dry matter[2] is met. The treated waste is left on the landfill and the land can be reclaimed, if applicable;
- In the subsequent post-injection phase, actual methane emissions from the landfill will be further monitored. As a consequence of the treatment (air-injection and monitoring), an after-use of landfill site might be feasible and might lead to revenues. Project participants have to clearly identify the potential for after-use and corresponding land values, as described in the section "Additionality" of the methodology.

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

Finally, this methodology is only applicable if the application of the procedure to identify the baseline scenario results in that the partial or total atmospheric release of landfill gas from the closed landfill or the closed landfill cell is the most plausible baseline scenario.

II. BASELINE METHODOLOGY PROCEDURE

Identification of the baseline scenario

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

Step 1: Identification of 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.[3] 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.

[2] This default threshold values is based on the German Ordinance on the environmentally sound landfilling of waste (AbfAblV) that defines that wastes to be landfilled should have a maximum total gas generation rate of 20 Nl/kg dry matter, corresponding to 11 m^3 CH_4/tonne of dry matter, assuming a CH_4 content of 54%. The objective of this limit is to achieve "low-emission" landfills.

[3] Relevant clarifications on the treatment of national and/or sectoral policies and regulations in determining a baseline scenario should be taken into account as per Annex 3 to the Executive Board 22nd meeting and any other forthcoming guidance from the Board on this subject.

(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);
- Via the adjustment factor AF in the baseline emissions, project participants must take into account that some of the methane generated in the baseline must be captured and destroyed to comply with regulations or contractual requirements;
- 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 (in-situ aeration of landfills), i.e., the scenario relevant for estimating baseline methane emissions, to be analyzed should include, *inter alia*:

LFG1: The project activity (in-situ aeration of landfills) 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: The landfill is opened and all existent waste is recycled and/or composted.

Step 2: 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: Where more than one credible and plausible alternative remains, project participants shall, as a conservative assumption, 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 business-as-usual, 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.[4]

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

In case the land covered by the landfill can be used for activities generating economic value in the post-injection-phase, an investment analysis is mandatory. For the investment analysis, project proponents have to follow the steps as described below:

(a) Identification of possible after-uses: Project proponents have to identify all credible and feasible options for the after-use of the landfill site after the air-injection phase. 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 proponents 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 proponents should use 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;
(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 assessment and demonstration of additionality" has to be applied.

In the case the land covered by the landfill cannot be used in the post-injection phase, 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 cell, 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.
		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 vehicles used on-site etc.
		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.
		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 for aerobic landfill operation.

Project emissions

Project emissions are calculated as follows:

$$PE_y = PE_{EC,y} + PE_{FC,j,y} + PE_{ia,y} \quad (1)$$

Where:

PE_y = Project emissions in year y (t CO_2/yr)
$PE_{EC,y}$ = Project emissions from electricity consumption in year y (t CO_2/yr)
$PE_{FC,j,y}$ = Project emissions from fossil fuel combustion in year y (t CO_2/yr)
$PE_{ia,y}$ = Project emissions from in-situ aeration of the landfill in year y (t CO_2/yr)

Project participants shall apply the following steps to estimate project emissions:

Step 1: Determination of project emissions from electricity consumption ($PE_{EC,y}$)

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".

Step 2: Determination of project emissions from fossil fuel combustion ($PE_{FC,j,,y}$)

Project emissions from fossil fuel combustion ($PE_{FC,j,y}$) 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.

Step 3: Determination of project emissions from in-situ aeration of the landfill ($PE_{ia,y}$)

The project activity may lead to residual methane and nitrous oxide emissions, as e.g., due to incomplete aeration (including downtime of aeration equipment), incomplete degradation and as a consequence of the aerobic degradation process itself. Residual methane emissions are estimated as follows:

$$PE_{ia,y} = PE_{CH4,ia,y} + PE_{N2O,ia,y} \quad \textbf{(2)}$$

Where:

$PE_{CH4,ia,y}$	=	CH_4 emissions from in-situ aeration of the landfill in year *y* (t CO_2/yr)
$PE_{N2O,ia,y}$	=	N_2O emissions from in-situ aeration of the landfill in year *y* (t CO_2/yr)

<u>Methane emissions from in-situ aeration of landfills ($PE_{CH4,ia,y}$)</u>

CH_4 emissions from in-situ aeration of the landfill in year *y* are calculated as follows:

During air injection phase

$$PE_{CH4,ia,y} = PE_{CH4,emissions,y} \quad \textbf{(3)}$$

Where:

$PE_{CH4,emissions,y}$	=	Monitored CH_4 emissions from in-situ aeration of the landfill in year *y* (t CO_2/yr)

<u>Ex post determination of CH4 emissions from in-situ aeration during air injection phase</u>

$$PE_{CH4.emissions,y} = \sum_k (GWP_{CH4} * MC_{CH4,v,k,y} * SG_{v,k,y}) + \sum_i \sum_q (GWP_{CH4} * MC_{CH4.s,i,q} * SG_{s,i,q} * CF) \quad \textbf{(4)}$$

Where:

GWP_{CH4}	=	Global Warming Potential (GWP) of methane, valid for the relevant commitment period (t CO_2/t CH_4)
$MC_{CH4,v,k,y}$	=	Monitored methane content in venting well/header *k* during in-situ aeration in the year *y* (t CH_4/m^3)
$SG_{v,k,y}$	=	Volume of captured emissions in venting well/header *k* in year *y* (m^3/yr)
$MC_{CH4,s,i,q}$	=	Monitored methane content from surface emissions during in-situ aeration in zone *i* in the quarter *q* (t CH_4/m^3)

$SG_{s,i,,q}$ = Total volume of surface emissions in zone *i* in quarter *q* (m^3)
k = Number of venting wells/headers (monitoring of vented emissions might require measuring at different sampling points, e.g., several headers that are not interconnected)
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

During downtime of the aeration equipment during the air injection period, project emissions are assumed to be equal to baseline emissions. For these cases, a value of the methane generation rate (k_{CH4}) shall be estimated from the values given in the table in the data and parameters not monitored section which enables the estimation of the baseline emission during the downtime e.g., if the down time is in months, a monthly value shall be estimated. System Downtime (DT) is defined when less than the minimum number of blowers required to aerate the landfill is operational. The CDM-PDD has to specify the minimum number and specifications of blowers required for landfill aeration and this needs to be validated by the DOE. Moreover, the number and specifications of backup blowers that are normally not operational is to be specified in the CDM-PDD.

Ex ante estimation of methane emissions during air injection phase

Ex ante estimation of $PE_{CH4,emissions,y}$ during the **air-injection phase** may be done with the latest version of the approved “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site”. The same guidance given in the baseline section below may be used for waste classification and waste quantities. MCF value of 0.5 may be used for *ex ante* estimation during air injection phase.

During post-injection phase

Annual methane emissions are calculated as follows:

$$PE_{ia,y} = Max(PE_{CH4,emisions,y}, PE_{CH4,FOD,y}) \quad \textbf{(5)}$$

Where:
$PE_{CH4,emissions,y}$ = Monitored methane emissions of the landfill (t CO_2e/yr)
$PE_{CH4,FOD,y}$ = Methane emissions of the landfill, calculated based on an adjusted first order decay model (FOD), using analyzed waste quality and an adjusted methane correction factor (MCF_{adj})

$PE_{CH4,emissions,y}$ is estimated as follows:

$$PE_{CH4.emissions,y} = \sum_i (GWP_{CH4} * MC_{CH4.s,i,y} * SG_{s,i,y}) \quad \textbf{(6)}$$

Where:
GWP_{CH4} = Global Warming Potential (GWP) of methane, valid for the relevant commitment period (t CO_2/t CH_4)
$MC_{CH4,s,i,y}$ = Monitored methane content from surface emissions in zone *i* in the year *y* (t/m^3)
$SG_{,s,i,y}$ = Volume of surface emissions in zone *i* in year *y* (m^3)
i = Number of surface zones (see monitoring procedures below)

During the post-injection phase annual campaigns for estimating surface emissions will be conducted. Guidance given in the monitoring section for conducting surface measurement campaigns should be followed replacing *q* (quarter) with *a* (annual).

$PE_{CH4,FOD,y}$ is estimated as follows:

$$PE_{CH4,FOD,y} = \varphi * (1-f) * GWP_{CH4} * (1-OX) * MCF_{adj} * \sum_{i} A_{lf,i} * L_{0,i} * e^{-k_{CH4}(y-x)} * (1-e^{-k_{CH4}}) \quad \textbf{(7)}$$

Where:

φ	=	Default model correction factor to account for model uncertainties (1.1)
f	=	Fraction of methane captured and flared. As no methane will be captured and flared during the project activity, *f* is set to 0 for project emission calculation
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); if the landfill cover is not changed due to project activity, the OX value chosen has to be equal for baseline and project emission calculation
MCF_{adj}	=	Adjusted methane correction factor. MCF values according to the latest version of the "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site" have to be applied
$A_{lf,i}$	=	Amount of landfilled waste in landfill zone *i* (t). Estimated as per equation (15) below
$L_{o,i}$	=	Potential methane generation capacity of the waste in landfill zone *i* as determined by sampling and lab analysis (Mg CH_4/Mg Waste) **once after the end** of the air-injection phase as per the monitoring methodology described below. Alternatively, the value of L_o determined before the start of the project activity can be used instead, since this is conservative
k_{CH4}	=	Methane generation rate. k_{CH4} value as per table in the data and parameters not monitored section below is used
y	=	Year for which the methane emissions are calculated since the stop of the air injection phase. In case L_o value determined since the start of the project activity, *y* is the year since start of air injection
x	=	The year of stopping of air injection (yr). In case L_o value determined before the start of the air injection is used, *x* is the year of start of air injection
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

Ex ante estimation of methane emissions during post injection phase

Ex ante estimation of emissions for **post injection phase** may be done with the latest version of the approved "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site". The same guidance given in the baseline section below may be used for waste classification and waste quantities MCF values according to the latest version of the same tool may be used.

Nitrous oxide emissions from in-situ aeration of landfills ($PE_{N2O,ia,y}$)

Emissions of N_2O may be estimated using either of the options given below:

Option 1:

$$PE_{N2O,ia,y} = \sum_k (GWP_{N2O} * MC_{N2O,v,k,y} * SG_{v,k,y}) + \sum_i (GWP_{N2O} * MC_{N2O,s,i,y} * SG_{s,i,y} * CF) \quad \textbf{(8)}$$

Where:

GWP_{N2O}	=	Global Warming Potential of nitrous oxide, valid for the relevant commitment period (t CO_2e /t N_2O)
$MC_{N2O,v,k,,y}$	=	Monitored nitrous oxide content at venting well/header *k* during in-situ aeration in the year *y* (t N_2O/m^3)
$SG_{v,k,y}$	=	Volume of captured emissions in venting well/header *k* in year *y* (m^3/yr)
$MC_{N2O,s,\ i,y}$	=	Monitored nitrous oxide content from surface emissions in zone *i* during in-situ aeration in the year *y* (t N_2O/m^3)
$SG_{s,i,,y}$	=	Volume of surface emissions in zone *i* in year *y* (m^3/yr)
k	=	Number of venting wells/headers (monitoring of vented emissions might require measuring at different sampling points, e.g. several headers that are not interconnected)
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

Option 2:

$$PE_{N2O,ia,y} = \frac{\sum_i A_{lf,i} * EF_{ia,N20} * GWP_{N2O}}{a} \quad \textbf{(9)}$$

Where:

$A_{lf,i}$	=	Amount of landfilled waste in landfill zone *i* (t)
i	=	Landfill zone category (index)
$EF_{ia,N2O}$	=	Emission factor for N_2O emissions from the in-situ aeration and stabilization (t N_2O/t treated waste). Based on the findings of Schenk and others[5] N_2O emissions of 0.027 kg N_2O per tonne of treated waste can be expected for the complete composting process. Accordingly, this emission factor might also be used for in-situ stabilization as the microbial process is similar to composting
a	=	Scheduled minimum duration of in-situ aeration and stabilization (years). The actual number of years used for stabilization shall be used for *ex post* determination of N_2O emissions

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[5] Manfred K. Schenk, Stefan Appel, Diemo Daum: "N_2O emissions during composting of organic waste", Institute of Plant Nutrition University of Hannover, 1997; according to that paper, total nitrous oxide emissions due to composting are 42 mg N_2O-N/kg composted dry matter, including emissions during storage and the application. During the composting process itself, 26.9 mg will be released.

Baseline emissions

Baseline emissions are calculated as follows:

$$BE_y = (MB_y - MD_{reg,y}) \quad \textbf{(10)}$$

Where:

BE_y	=	Baseline emissions in year *y* (t CO_2/yr)
MB_y	=	Methane that would be produced in the landfill in the absence of the project activity in year *y* (t CO_2/yr)
$MD_{reg,y}$	=	Methane that would be destroyed in the absence of the project activity in year *y* (t CO_2/yr)

Adjustment Factor (AF)

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. In doing so, the project participant should take into account that some of the methane generated by the landfill may be captured and destroyed to comply with other relevant regulations or contractual requirements, or to address safety and odour concerns.

$$MD_{reg,y} = MB_y * AF \quad \textbf{(11)}$$

Where:

AF	=	Adjustment Factor for MB_y (%)

The parameter AF shall be estimated as follows:

- In cases where a specific system for collection and destruction of methane is mandated by regulatory or contractual requirements, the ratio between the destruction efficiency of that system and the reduction efficiency of the system used in the project activity shall be used;
- In cases where a specific percentage of the "generated" amount of methane to be collected and destroyed is specified in the contract or mandated by the regulation, this percentage divided by an assumed efficiency for the reduction system used in the project activity shall be used.

The 'Adjustment Factor' shall be revised at the start of each new crediting period taking into account the amount of GHG flaring that occurs as part of common industry practice and/or regulation at that point in the future.

Rate of compliance

In cases where there is a regulation which mandates the collection and treatment of landfill gas from closed landfills or closed landfill cells and which is not being enforced, the baseline scenario is identified as a gradual improvement of waste management practices to the acceptable technical options expected over a period of time to comply with the regulation. The adjusted baseline emissions ($BE_{y,a}$) are calculated as follows:

$$BE_{y,a} = BE_y * (1 - RATE^{Compliance}{}_y) \quad \textbf{(12)}$$

Where:

$RATE^{Compliance}_{y}$	=	State-level compliance rate with the regulation in that year *y*. The compliance rate shall be lower than 50%; if it exceeds 50%, the project activity shall receive no further credits

In such cases $BE_{y,a}$ should replace BE_y in Equation 19 to estimate emission reductions.

The compliance ratio $RATE^{Compliance}_{y}$ shall be monitored *ex post* based on official reports, for instance annual reports provided by municipal bodies.

Methane generation from the landfill in the absence of the in-situ alternative treatment (in-situ aeration of landfills) (MB_y)

Ex ante estimation of the amount of the methane generation in absence of the project activity ($MB_{y,ea}$)

The *ex ante* estimation of the methane generation from the landfill in the absence of the project activity (in-situ aeration of landfills) may be done with the latest version of the approved "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site". In this case, the following additional equation shall be used:

$$MB_{y,ea} = BE_{CH4,SWDS,y} \qquad \textbf{(13)}$$

Where:

$BE_{CH4,SWDS,y}$	=	Methane generation from the landfill in the absence of the project activity at year *y*, calculated as per the "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site". The tool estimates methane generation adjusted for, using adjustment factor (f), 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 "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site" is to be replaced by a variable $A_{lf,exante,j,x}$, which is the amount of organic waste disposed in the landfill in the year *x* (tonnes/year)

Furthermore the following guidance should be taken into account:

- In the tool, *x* will refer to the year since the landfill started receiving wastes [*x* runs from the first year of landfill operation (x=1) to the year for which emissions are calculated (x=y)];
- The estimate of $A_{lf,exante,j,,x}$, should be done by one of the following procedures:

  (a) Assessment of the different waste types j through sampling at the landfill site;
  (b) Utilization of data from previous studies on the waste types j in the landfill;
  (c) 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. In case data for different types of waste is not available, the value of k_j for the share of biodegradable waste is the one specified for "bulk waste" in Table 3.3 of the IPCC national greenhouse gas inventories (2006), volume 5, chapter 3 may be used.

<u>*Adjustment to the estimation of the methane generation in absence of the in-situ project activity at the project start ($MB_{y,ad}$)*</u>

At the project start, project proponents have to do a statistically significant 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:

$$MB_{y,ad} = \varphi * (1-f) * GWP_{CH4} * (1-OX) * MCF_{adj} * \sum_i A_{lf,i} * L_{0,i} * e^{-k_{CH4}(y-x)} * (1-e^{-k_{CH4}}) \quad \textbf{(14)}$$

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_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_{adj}	= Adjusted methane correction factor. MCF values according to the latest version of the "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site" have to be applied
$A_{lf,i}$	= Amount of landfilled waste in landfill zone *i* (t). Estimated as per equation (15) below.
$L_{o,i}$	= Potential methane generation capacity of the waste in landfill zone *i* as determined by sampling and lab analysis (Mg CH_4/Mg 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 air injection phase. (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

<u>*Estimation of the amount of landfilled waste in landfill zone i ($A_{lf,i}$)*</u>

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 degradable 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 $A_{lf,i}$:

$$A_{lf,i} = f_{dg,i} \cdot A_{T,i} \quad \textbf{(15)}$$

Where:

$A_{lf,i}$	= Amount of landfilled waste in landfill zone *i* (t)
$f_{dg,i}$	= Fraction of degradable waste in landfill zone *i*
$A_{T,i}$	= Total waste quantities in landfill zone *i* (t)

<u>*Baseline Campaign*</u>

Methane emissions shall be measured prior the start of the aeration of the landfill to check the validity of the FOD model. This baseline campaign will last for at least 3 months. Measurements shall only start a week after the wells have been installed. 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:

$$R = \frac{ME_{CH4,bl\_campaign}}{MB_{bl\_campaign,ad}} \quad \textbf{(16)}$$

Where:

R	=	Ratio between the actual methane measured and the methane estimated using the FOD model. If R is greater than 1, a value of 1 shall be used
$ME_{CH4,bl\_campaign}$	=	Methane produced in the landfill in the baseline campaign measured and calculated as per equation 17 below. (t CO_2/bl_campaign)
$MB_{bl\_campaign,ad}$	=	Methane produced in the landfill in the baseline campaign estimated as per equation 18 below. (t CO_2/bl_campaign)

$$ME_{CH4,bl\_campaign} = \sum_k (GWP_{CH4} * MC_{CH4,v,k,bl\_campaign} * SG_{v,k,bl\_campaign}) + \sum_i (GWP_{CH4} * MC_{CH4.s,i,bl\_campaign} * SG_{s,i,bl\_campaign}) \quad \textbf{(17)}$$

Where:

GWP_{CH4}	=	Global Warming Potential (GWP) of methane, valid for the relevant commitment period (t CO_2/t CH_4)
$MC_{CH4,v,k,bl\_campaign}$	=	Monitored methane content in venting well/header k during the baseline campaign (t CH_4/m^3)
$SG_{v,k,bl\_campaign}$	=	Volume of emissions in venting well/header k in the baseline campaign (m^3/bl_campaign)
$MC_{CH4,s,i,bl\_campaign}$	=	Monitored methane content from surface emissions in zone i during the baseline campaign (t CH_4/m^3)
$SG_{s,i,,bl\_campaign}$	=	Volume of surface emissions in zone i in the baseline campaign (m^3/yr)
k	=	Number of venting wells/headers (monitoring of vented emissions might require measuring at different sampling points, e.g. several headers that are not interconnected)
i	=	Number of surface zones (see monitoring procedures below)

$$MB_{bl\_campaign,ad} = \varphi * (1-f) * GWP_{CH4} * (1-OX) * MCF_{adj} * \sum_i A_{lf,i} * L_{0,i} * e^{-k_{CH4}(m-x)} * (1-e^{-k_{CH4}}) \quad \textbf{(18)}$$

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_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_{adj}	=	Adjusted methane correction factor. MCF values according to the latest version of the “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site” have to be applied
$A_{lf,i}$	=	Amount of landfilled waste in landfill zone *i* (t). Estimated as per equation 15 above.
$L_{o,i}$	=	Potential methane generation capacity of the waste in landfill zone *i* as determined by sampling and lab analysis (Mg CH_4/Mg Waste) once before start of the project activity as per the monitoring methodology described below
k_{CH4}	=	Monthly methane generation rate. k_{CH4} value as per table in the data and parameters not monitored section below is used after adjusting to monthly values (by dividing the values in the table by 12)
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

Monthly campaigns for measuring surface emissions during the baseline campaign are required. Guidance given in the monitoring methodology for conducting surface measurement campaigns should be followed replacing *q* (quarter) with *m* (month).

Leakage

No leakage will occur due to the project activity.

Emission reductions

Emission reductions are calculated as follows:

$$ER_y = (R \cdot BE_y) - PE_y \qquad \textbf{(19)}$$

Where:

ER_y	=	Emission reductions in year *y* (t CO_2e/yr)
BE_y	=	Baseline emissions in year *y* (t CO_2e/yr)
R	=	Ratio between the actual methane measured and the methane estimated using the FOD model
PE_y	=	Project emissions in year *y* (t CO_2/yr)

If PE_y is smaller than 1% of BE_y in the first year after air-injection stops, the project participants may assume a fixed percentage of 1% for PE_y combined for the remaining years of the crediting period.

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.

<table>
<tr><td>Data / parameter:</td><td>k_{CH4}</td></tr>
<tr><td>Data unit:</td><td>-</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. Therefore, the same samples taken to determine L_o shall be classified into degradable and non degradable materials (by mass). Subsequently the decay constant “k” for the degradable 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>≤ 2a</td><td>0.045</td><td>0.100</td><td>0.055</td><td>0.170</td></tr>
<tr><td>>2a ≤ 10a</td><td>0.035</td><td>0.060</td><td>0.045</td><td>0.100</td></tr>
<tr><td>> 10a</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 “Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site”). From two to ten years, the moderately degrading components became bio-converted (i.e., k = mean value of moderately and slowly degrading material according to the classification made in the “Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site”). For waste ages > 10 years, only the values for the slowly degradable components</td></tr>
<tr><td>Any comment:</td><td></td></tr>
</table>

Data / parameter:	n_c
Data unit:	-
Description:	Number of monitoring locations *c* per zone *i*
Source of data:	Guidance from the UK environment agency
Measurement procedures (if any):	-
Any comment:	Function of the zone size

Data / parameter:	$A_{lf,exante,j,x}$
Data unit:	Tons
Description:	Amount of degradable waste disposed in the landfill in the year *x*
Source of data:	Project participants
Measurement procedures (if any):	Based on historical data of waste disposed at the landfill site. Measured with calibrated scales/load cells
Any comment:	

Data / parameter:	$EF_{ia,N20}$
Data unit:	t N_2O/t treated waste
Description:	Emission factor for N_2O emissions from the in-situ aeration and stabilization
Source of data:	Research literature
Measurement procedures (if any):	-
Any comment:	Default value of **0.027 kg-N_2O/t-compost**, after Schenk et al, 1997

III. MONITORING METHODOLOGY

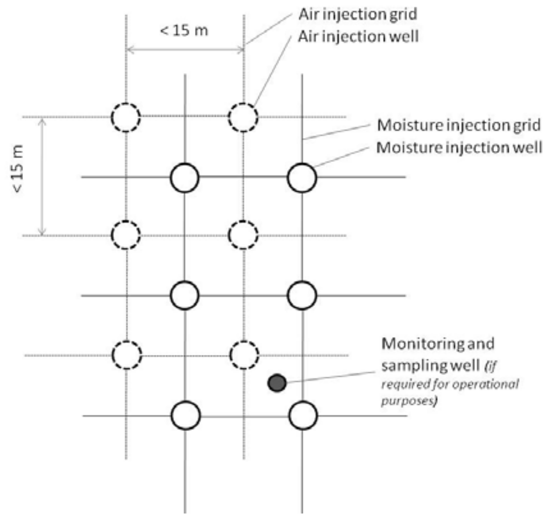
All data collected as part of monitoring should be archived electronically and be kept for at least 2 years after the end of the last crediting period. All measurements should be conducted with calibrated measurement equipment according to relevant industry standards.

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

The in-situ aeration process includes the installation of injection wells for injecting air and moisture in form of a grid. According to up-to-date experiences with in-situ aeration,[6] it is recommended that the mesh size of the grid should be lower than 15 m in order to assure a sufficient distribution of air and moisture within the landfill body. The exact mesh size has to be defined based on landfill characteristics (permeability, depth etc.).

[6] Reinhart, D.; Berge, N., Hudgins, M.: *"The* Status of Aerobic Bioreactor Landfills in the US"; Annual Spring Technical Conference: Solid Waste Association of North America – North Carolina Chapter, Asheville, NC - May 15-18 2006; *N.D. Berge, D.R. Reinhart, M. Hudgins: „*The status of aerobic landfills in the United States" in: R. Stegmann, M. Ritzkowski (editor): Landfill aeration; iwwg monograph series *CISA Publisher Padova , 2007;* Yazdani R, Kieffer J, Akau H, (2002), Full scale landfill bioreactor project at the Yolo county central landfill., Final Report, Yolo County, Planning and Public Works Department, 292 West Beamer Street Woodland, CA 95695; Presentation/Paper "*Use of Aerobic Landfill Bioreactor as a Greenhouse Gas Control and Sustainable Waste Management Strategy"* Landfill 2005 Conference, , Waste Management Association of Australia (WMAA), 7-9 September, 2005 Brisbane <http://www.aerobiclandfill.com/techpapers.htm>.

Figure 1: Grid of injection wells



The project activity is implemented in two phases (air-injection phase and post-injection phase). Different monitoring plans apply for each of these phases:

- During the air injection phase, the air injection 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;
- In the post-injection phase, air injection will be stopped. Injection and venting wells will not be operational any longer. Hence, all residual emissions will come through the surface where these emissions will be estimated as per equation 6 above. Vented emissions will be assigned a value of 0. However, special attention should be given to locations of the vents when conducting surface measurements for post injection phase since emissions at these locations are expected to be higher (i.e., these locations should be treated as features according to the UK guidelines). The further decrease of L_o in the post-injection phase is assumed to be slow, as the L_o has already been significantly reduced in the prior air injection phase and as environmental conditions after air-injection will only allow slow anaerobic degradation. In any case, L_o will not increase in the post-injection phase. Thus, it is conservative to assume L_0 as fixed value during the post-injection phase. L_o may either be estimated again after air injection stops or the value of L_o determined before the start of the project activity may be used, which is conservative.

Table 2: Overview of monitored parameters in both project phases

Parameter	Monitored?	
	Air-injection phase	Post-injection phase
Potential methane generation capacity of the landfilled waste (L_0)	Yes	No
Vented emissions – volume, methane and nitrous oxide emissions.	Yes	No
Surface emissions - volume, methane and nitrous oxide emissions.	Yes	Yes

Procedure for monitoring of methane and nitrous oxide emissions

To monitor actual methane emissions from the aerated landfill, both, surface and vented emissions have to be measured.

Monitoring these emissions will comprise metering the flow rate of the corresponding emission source and analyzing methane and nitrous oxide concentrations in this flow. Both samplings – for methane and nitrous oxide- are to be realized at the same time. Both concentrations will then refer to the same flow rate.

Monitoring Vented Emissions

To monitor the vented emissions, concentration and gas volume flow are to be measured on the same basis i.e., wet or dry, the "Tool to determine the mass flow of a greenhouse gas in a gaseous stream" should be used. The monitoring system is to be installed according to German VDI Guideline 3860, part 2.[7] In contrast to the regulations in the VDI guideline, continuous measurement of the flow rate is required. Then, error readings (e.g., downtime or malfunction) are to be eliminated from the output data series. CH_4 concentrations and N_2O concentrations should be measured continuously.

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 guidance from the UK environment agency,[9] whereby both, passive and active flux boxes are admissible. Project proponents should realize at least 4 measurement campaigns per year, i.e., quarterly during the air-injection phase. For post injection phase, a minimum of one campaign per year is required. The maximum value of emissions determined from monitoring surface emissions in the post injection phase and that determined from the FOD model shall be used for project emissions as described above.

7 VDI Guideline 3860 Measurement of landfill gases; Part 1 Fundamentals; Part 2 - Measurements in the gas collection system, February 2008, available in English at <www.beuth.de>.

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>.

9 Environment Agency: UK: Guidance on monitoring landfill gas surface emissions, September 2004, available at <http://www.environment-agency.gov.uk/static/documents/Business/lftgn07_surface_936575.pdf>.

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. 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. For the further data processing, the upper bound of the 95% confidence interval obtained from the periodical measurements should be used to ensure conservativeness.

Determination of the monitored methane content from surface emissions during in-situ aeration in zone i in the year y ($MC_{CH4,s,I,y}$)

(1) Calculate sample mean (μ) for each zone *i* and quarter *q*.

$$\mu_{MCCH4,s,i,q} = \frac{\sum_{c=1}^{n_c} MC_{CH4,s,i,c,q}}{n_c} \qquad \textbf{(20)}$$

Where:

$\mu_{MCCH4,s,i,q}$	=	Mean of monitored methane content from surface emissions during in-situ aeration in zone *i* in quarter *q* ($t\ CH_4/m^3$)
$MC_{CH4,s,i,c,q}$	=	Monitored methane content from surface emissions during in-situ aeration in zone *i* in location *c* in quarter *q* ($t\ CH_4/m^3$)
n_c	=	Number of monitoring locations per zone as per guidance from the UK environment agency (function of the zone size)
q	=	Quarters. Project proponents should realize at least 4 measurement campaigns per year. If more measurements are made then this will be the number of campaigns during the year

(2) Calculate the sample standard deviation (σ).

$$\sigma_{MCCH4,s,i,q} = \sqrt{\frac{\sum_{c=1}^{n_c} (MC_{ch4,s,i,c,q} - \mu_{MCCH4,s,i,q})^2}{n_C - 1}} \qquad \textbf{(21)}$$

Where:

$\sigma_{MCCH4,s,i,q}$	=	Standard deviation of monitored methane content from surface emissions during in-situ aeration in zone *i* in quarter *q* ($t\ CH_4/m^3$)

(3) Calculate the 95% confidence interval.

$$\mu_{MCCH4,s,l,q} - t \cdot \frac{\sigma_{MCCH4,s,i,q}}{\sqrt{n_c}} \leq MC_{CH4,s,l,q} \leq \mu_{MCCH4,s,i,q} + t \cdot \frac{\sigma_{MCCH4,s,i,q}}{\sqrt{n_c}} \qquad \textbf{(22)}$$

Where:

t	=	t statistic from the student t distribution table for a confidence level of 95% with degrees of freedom n-1

(4) Use the upper bound of the 95% confidence interval obtained from the above to ensure conservativeness.

Determination of total volume of surface emissions in zone i in quarter q ($SG_{s,l,,q}$)

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

$$\mu_{FLs,i,q} = \frac{\sum_{c=1}^{n_c} FL_{s,i,c,q}}{n_c} \quad \textbf{(23)}$$

Where:

$\mu_{FLs,i,q}$	=	Mean of flux of surface emissions in zone i in quarter q ($m^3/s\ m^2$)
$FL_{s,i,,c,q}$	=	Flux of surface emissions in zone i in location c in quarter q ($m^3/s\ m^2$)
n_c	=	Number of monitoring locations as per guidance from the UK environment agency (function of the zone size)
q	=	Quarters. Project proponents should realize at least 4 measurement campaigns per year

(2) Calculate the sample standard deviation (σ).

$$\sigma_{FL,s,i,q} = \sqrt{\frac{\sum_{c=1}^{n_c} (FL_{s,i,c,q} - \mu_{FLs,i,q})^2}{n_C - 1}} \quad \textbf{(24)}$$

Where:

$\sigma_{FLs,i,q}$	=	Standard deviation of flux of surface emissions in zone i in quarter q ($m^3/s\ m^2$)

(3) Calculate the 95% confidence interval.

$$\mu_{FLs,l,q} - t \cdot \frac{\sigma_{FLs,i,q}}{\sqrt{n_c}} \leq FL_{s,l,q} \leq \mu_{FLs,l,q} + t \cdot \frac{\sigma_{FLs,i,q}}{\sqrt{n_c}} \quad \textbf{(25)}$$

Where:

t	=	t statistic from the student t distribution table for a confidence level of 95% with degrees of freedom n-1
$FL_{s,l,q}$	=	Flux rate surface emissions in zone i in quarter q ($m^3/s\ m^2$)

(4) Use the upper bound of the 95% confidence interval obtained above to ensure conservativeness.

$$SG_{s,i,q} = FL_{s,i,q} \cdot s \cdot A_l \quad \textbf{(26)}$$

Where:

$SG_{s,i,q,t}$	=	Total volume of surface emissions in zone *i* in quarter *q* (m^3)
S	=	Seconds in a quarter (s)
A_i	=	Area of zone *i* (m^2)

During all periodic measurements (vented emissions and surface emissions, if applicable), 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, as different seasons and weather conditions etc. and cover typical operating conditions of the air-injection system (in terms of e.g., typical flow rates and operating times);
- At least one measurement for surface emissions is done during the three coldest months of the year (where maximum methane emissions are expected).

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

Procedure for sampling and analyzing the landfilled waste to estimate L*o*

The landfilled waste has to be sampled at the following points in time:

- Directly before the start of the project activity to determine the initial L_o for baseline emission calculation;
- Directly after the end of the air injection phase to determine the final L_o for the project emissions calculation for post injection phase.

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 5 m (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,[10] EN TR 15310-3 and -4.[11] 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;

[10] 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>.

[11] 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.

- 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 L_o, 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 proponents 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.

Procedure for monitoring system downtime (DT)

Blower operation will be monitored and recorded by a Programmable Logic Controller (PLC) that will record duration of operation (hour meter) and the time and date of operation. DT is determined by checking the run time meter records. If at any period, less than the minimum number of blowers specified in the CDM-PDD is shown as operational in the runtime records, it will be counted as DT.

Data and parameters monitored

Data / Parameter:	$PE_{EC,y}$
Data unit:	tCO_2
Description:	Project emissions from electricity consumption by the project activity during the year *y*
Source of data:	Calculated as per the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”
Measurement procedures (if any):	As per the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”
Monitoring frequency:	As per the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”
QA/QC procedures:	As per the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”
Any comment:	-

Data / Parameter:	$PE_{FC,j,y}$
Data unit:	tCO_2e
Description:	Project emissions from fossil fuel combustion in process *j* during the year *y*
Source of data:	Calculated as per the "Tool to calculate project or leakage CO2 emissions from fossil fuel combustion"
Measurement procedures (if any):	As per the "Tool to calculate project or leakage CO2 emissions from fossil fuel combustion"
Monitoring frequency:	As per the "Tool to calculate project or leakage CO2 emissions from fossil fuel combustion"
QA/QC procedures:	As per the "Tool to calculate project or leakage CO2 emissions from fossil fuel combustion"
Any comment:	-

Data / Parameter:	AF
Data unit:	%
Description:	Methane destroyed due to regulatory or other requirements
Source of data:	Local and/or national authorities
Measurement procedures (if any):	
Monitoring frequency:	At renewal of crediting period
QA/QC procedures:	Data are derived from or based upon local or national guidelines, so QA/QC-procedures for these data are not applicable
Any comment:	Changes in regulatory requirements, relating to the baseline landfill(s) need to be monitored in order to update the adjustment factor (AF) or directly $MD_{reg.}$. This is done at the beginning of each crediting period

Data / Parameter:	$RATE^{Compliance}_{y}$
Data unit:	Number
Description:	Rate of compliance with landfill regulation
Source of data:	Municipal bodies
Measurement procedures (if any):	The compliance rate is based on the annual reporting of the municipal bodies issuing these reports. The state-level aggregation involves all landfill sites in the country. If the rate exceeds 50%, no CERs can be claimed
Monitoring frequency:	Annual
QA/QC procedures:	
Any comment:	

Data / Parameter:	L_o
Data unit:	Mg methane/Mg waste
Description:	Potential methane generation capacity; depending on type and composition of the waste placed in the landfill
Source of data:	Laboratory analysis
Measurement procedures (if any):	L_o should be analyzed as Biochemical Methane Potential (BMP) according to the methods described by Kelly et al. (2006)[12], Owens & Chenowyth (1993)[13], Hansen et al. (2004)[14] or alternative appropriate standards
Monitoring frequency:	At least at project start and at the end of the air-injection phase (value determined at the start of the project may be used for post injection phase, since this is conservative)
QA/QC procedures:	See procedures description above
Any comment:	More frequent sampling is encouraged

Data / Parameter:	$f_{dg,i}$
Data unit:	-
Description:	Fraction of degradable waste in landfill zone *i*
Source of data:	Project
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 and optionally after stopping aeration of the landfill
QA/QC procedures:	To be compared to data for waste classification per type of waste, if available
Any comment:	

Data / Parameter:	$A_{T,i}$
Data unit:	Tons
Description:	Total waste quantities in landfill zone *i*
Source of data:	Project
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

[12] 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>.

[13] 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.

[14] 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:	A_i
Data unit:	m^2
Description:	Area of 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:	$SG_{s,i,c,q}$
Data unit:	m^3/s
Description:	Flow rate of surface emissions in zone *i* in location *c* in quarter *q* at Normal Temperature and Pressure
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the surface emissions will be carried out according to VDI guideline 3790[15] or the UK guidance mentioned above
Monitoring frequency:	Periodic (in the middle of each quarter during air-injection phase, annually during the post-injection phase)
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:	More frequent sampling is encouraged

Data / Parameter:	$SG_{s,i,bl\ campaign}$
Data unit:	m^3
Description:	Volume of surface emissions in zone *i* in the baseline campaign at Normal Temperature and Pressure
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the surface emissions will be carried out according to VDI guideline 3790[16] or the UK guidance mentioned above
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:	

[15] VDI guideline VDI 3790 "Emissions of gases, odours and dusts from diffuse sources", January 2005, <www.vdi.de>.
[16] VDI guideline VDI 3790 "Emissions of gases, odours and dusts from diffuse sources", January 2005, <www.vdi.de>.

Data / Parameter:	$MC_{N2O,s,i,y}$
Data unit:	$t\ N_2O/m^3$
Description:	Monitored content of nitrous oxide in the surface emissions from the in-situ aeration of landfill in year *y*
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the content of nitrous oxide will be carried out according to internationally recognized standards, using gas chromatography or non-dispersion infrared absorption analyzer
Monitoring frequency:	Periodic (in the middle of each quarter during air-injection phase, annually during the post-injection phase)
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:	More frequent sampling is encouraged

Data / Parameter:	$MC_{CH4,s,i,c,q}$
Data unit:	tCH_4/m^3
Description:	Monitored methane content from surface emissions during in-situ aeration in zone *i* in location *c* in quarter *q*
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the methane content will be carried out according to internationally recognized standards, using flame ionization detector, infrared sensors or similar
Monitoring frequency:	Periodic (in the middle of each quarter during air-injection phase, annually during the post-injection phase)
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:	More frequent sampling is encouraged

Data / Parameter:	$MC_{CH4,s,i,bl\ campaign}$
Data unit:	tCH_4/m^3
Description:	Monitored methane content from surface emissions 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 internationally recognized standards, 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:	Periodic (in the middle of each quarter during air-injection phase, annually during the post-injection phase)
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:	More frequent sampling is encouraged

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:	Periodic (in the middle of each quarter during air-injection phase, annually during the post-injection phase)
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:	More frequent sampling is encouraged

Data / Parameter:	$SG_{v,k,y}$
Data unit:	m^3
Description:	Total volume of vented emissions in year *y* at Normal Temperature and Pressure
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the emissions will be carried out according to internationally recognized standards. The monitoring system shall comply with the VDI Guideline 3860 (Blatt 1 and 2)[17]
Monitoring frequency:	Continuous
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:	$SG_{v,k,bl\_campaign}$
Data unit:	m^3
Description:	Volume of emissions in venting well/header *k* in the baseline campaign at Normal Temperature and Pressure
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the emissions will be carried out according to internationally recognized standards. The monitoring system shall comply with the VDI Guideline 3860 (Blatt 1 and 2)[18]
Monitoring frequency:	Continuous
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:	

[17] VDI Guideline 3860: Measurement of landfill gas - Measurements in the gas collection system (Blatt 1 and 2); February 2008; <www.vdi.de>.

[18] VDI Guideline 3860: Measurement of landfill gas - Measurements in the gas collection system (Blatt 1 and 2); February 2008; <www.vdi.de>.

Data / Parameter:	$MC_{N2O,s,k,y}$
Data unit:	tN_2O/m^3
Description:	Monitored content of nitrous oxide in vented emissions in year *y*
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the content of nitrous oxide will be carried out according to internationally recognized standards, using gas chromatography or non-dispersion infrared absorption analyzer
Monitoring frequency:	Continuous
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:	$MC_{CH4,v,k,y}$
Data unit:	tCH_4/m^3
Description:	Monitored content of methane in venting well/header *k* in year *y*
Source of data:	Project participants
Measurement procedures (if any):	The measurements of the methane content will be carried out according to internationally recognized standards, using flame ionization detector, infrared sensors or similar
Monitoring frequency:	Continuous
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:	$MC_{CH4,v,k,bl\ campaign}$
Data unit:	tCH_4/m^3
Description:	Monitored methane content in venting well/header *k* 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 internationally recognized standards, using flame ionization detector, infrared sensors or similar
Monitoring frequency:	Continuous
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 thatautomatically 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:	DT
Data unit:	Hours
Description:	Injection Blower System Downtime
Source of data:	Project participants
Measurement procedures (if any):	Blower operation will be monitored and recorded by a Programmable Logic Controller (PLC) that will record duration of operation (hour meter) and the time and date of operation
Monitoring frequency:	Continuously
QA/QC procedures:	Measuring instruments, these should be subject to a regular maintenance and testing regime in accordance to appropriate national/international standards
Any comment:	Record used to determine date, time and duration of any period when air injection is not being performed

IV. REFERENCES AND ANY OTHER INFORMATION

Template: Waste sampling protocol

Reason for sampling
Name of the landfill/landfill cell/ landfill zone
Location of the sampling point (indicate on map, if applicable)
Depth of the sampling drilling (m)
Date of sampling / time
Name of sampling staff
Sampling method (grab samples, collective samples)
Source of the collective sample (how many grab samples were taken from the core)
Volume/weight of the sample (entire core, grab sample, collective sample, lab sample)
Description of the waste at sampling (colour, odor, homogeneity, grain size)
Ambient conditions at sampling (rainfall, ambient temperature)
Other observations during sampling (gas release etc.)
Labeling of collective/lab sample
Packaging of the sample
Storage of sample (duration and storage conditions)
Laboratory
Place, date, signature

Template: Measurement protocol for emissions

Reason for measurement		
Name of the landfill/landfill cell/ sampled header / sampled zone / sampled location		
Location of the measurement point (indicate on map, if applicable)		
Date of measurement / time		
Name of measurement staff		
Measurement parameters		
Measurement method (measurement devices used)		
QA/QC (regular maintenance, testing?)		
Measurement results		
Time	Parameter 1 (Unit)	Parameter 2 (Unit)
Ambient conditions at measurement (rainfall, ambient temperature)		
Other observations during sampling (gas release etc.)		
Lab samples/retain samples?		
Place, date, signature		

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History of the document

Version	Date	Nature of revision(s)
01	EB 48, Annex # 17 July 2009	To be considered at EB 48.