Monitoring report form for CDM programme of activities
(Version 03.0)

Complete this form in accordance with the instructions attached at the end of this form.

MONITORING REPORT		
Title of the PoA	Landfills' gas capture, flaring and use program in Morocco	
UNFCCC reference number of the PoA	6568	
Version numbers of the PoA-DD applicable to this monitoring report	2	
Version number of this monitoring report	4.0	
Completion date of this monitoring report	15/12/2020	
Monitoring period number	Second monitoring period	
Duration of this monitoring period	01/08/2016 – 31/12/2018	
Monitoring report number for this monitoring period	1	
Coordinating/managing entity	Fonds d'Equipement Communal (FEC)	
Host Parties	Host Party of the PoA	Is this the host Party of a CPA covered in this monitoring report? (yes/no)
	Morocco	Yes
Applied methodologies and standardized baselines	ACM0001 version 12.0: Flaring or use of landfill gas No standardized baselines applied.	
Sectoral scopes	13 : Waste handling and disposal	
Amount of GHG emission reductions or net anthropogenic GHG removals achieved by all CPAs covered in this monitoring report in this monitoring period	Amount achieved before 1 January 2013	Amount achieved from 1 January 2013
	0	9,723 tCO_2e
Amount of GHG emission reductions or net anthropogenic GHG removals estimated ex ante for this monitoring period in the CPA-DDs for the CPAs covered in this monitoring report	321,922 tCO_2e	

PART I Monitoring of programme of activities (PoA)

SECTION A. Description of PoA

A.1. General description of PoA

The main objective of the PoA is to avoid methane emissions from municipal waste landfills in Morocco by promoting landfill gas (LFG) capture and flaring or utilization projects.

A.1.1. Corresponding generic component project activities (CPAs)

Title and reference number of the corresponding generic CPA	Version of the PoA-DD	Sectoral scopes	Applied methodologies and standardized baselines
Landfill's gas (LFG) capture, flaring [and/or] use at the [landfill name] landfill. Version [XX] [DD/MM/YYYY]	2	13: Waste handling and disposal	ACM0001 version 12.0: Flaring or use of landfill gas (https://cdm.unfccc.int/filestorage/Y/9/4/Y94STJCQP5FEIVL21HWKUBMRXAOND6.1/EB65_repan15_ACM0001_ver12.0.0.pdf?t=ckV8cWpvZzZtfDBAQuNTo2lg4RMEdfolIMhk) The other methodological tools referred in the methodology and used are: ▪ Combined tool to identify the baseline scenario and demonstrate additionality (version 04.0.0) ▪ Tool "Emissions from solid waste disposal sites" (version 6.0.1) ▪ Tool to calculate baseline, project and/or leakage emissions from electricity consumption (version 01.0) ▪ Tool to determine project emissions from flaring gases containing methane (version 01.0) ▪ Tool to determine the mass flow of a greenhouse gas in a gaseous stream (version 02.0.0) ▪ Tool to calculate the emission factor for an electricity system (version 02.2.1) ▪ Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion (version 02.0) The above are found on the UNFCCC CDM website at: http://cdm.unfccc.int/methodologies/DB/EYUD9R1ZAUZ2XNZXD3HQH18OK3VWIV

A.1.2. CPAs included in the PoA

Title and UNFCCC reference number of the CPA	Version of the PoA-DD	Title and reference number of the corresponding generic CPA	Crediting period type and duration	Covered in this monitoring report? (yes/no)
Landfill's gas (LFG) capture, flaring and use at the Oum Azza landfill (version 6) CPA 6568-P1-0001-CP1	2	Landfill's gas (LFG) capture, flaring [and/or] use at the [landfill name] landfill. Version [XX] [DD/MM/YYYY]	Renewable 28/02/2014-27/02/2021	Yes

Note: Initial CPA-DD with Ref. No. 6568-P1-0001-CP1 was included on 18 Dec 2012. Due to post-registration changes, the latest version 6 of CPA-DD was approved by UNFCCC on 24 November 2019 with the Ref. No. PRC-6568-001.

A.2. Coordinating/managing entity

Fonds d'Equipement Communal (FEC)

SECTION B. Implementation of PoA

B.1. Description of implemented PoA

The management system of the PoA has been implemented by the CME as described in the PoA-DD. The FEC:

- screened and validated the projects for inclusion in the PoA
- arranged training and capacity development for the CPA Implementer
- ensured that the CPA Implementer was aware and agreed to participate in the PoA
- maintained a record keeping system of the CPA
- benefited from grant to improve the PoA management system.

No sampling approach was applied for monitoring of this CPA covered in this monitoring report, all parameters were measured and recorded.

The installed technologies, technical processes and equipment for the included CPA is described below according to the the latest approved CPA-DD (version 6 of CPA-DD "Landfill's gas (LFG) capture, flaring and use at the Oum Azza landfill" and was approved by UNFCCC on 24 November 2019 with the Ref. No. PRC-6568-001).

The landfill gas project developed under this CPA falls under the sectoral scope 13 – waste handling and disposal and scope 1 – energy industries (renewable/non-renewable sources).

The generated biogas was not collected; therefore, the baseline scenario is the same as the scenario existing prior to the start of implementation of the project activity namely the atmospheric release of the LFG and the use of electricity supplied by the national grid.

According to the project's technical feasibility study[1], a brief description of the technology to be employed is provided below.

Landfill Gas Collection System

The project activity involves the installation of state-of-the-art LFG collection technology. This includes:

- Vertical gas wells drilled into the waste to extract the LFG.
  Wells specification[2]:
  - ✓ Well spacing of approximately 25 meters, with diameter of 500 mm;
  - ✓ Depth of about 20 meters or 90% of depth of waste;
  - ✓ In the eventuality of the presence of leachate, the well can be used as a combined gas and leachate well. This will require the installation of a combined gas and leachate extraction wellhead equipped with appropriate fittings for the extraction of leachate and the insertion of a compressed air pipe; and
  - ✓ All gas extraction equipment will be equipped with gas measuring ports that can be connected to either manual or automatic gas measuring equipment.
- A gas collection pipe network.
- Blower that will feed the LFG to gas engines and flares.

[1] Landfill Gas Capture, Flaring and use for power generation at the Oum Azza Landfill in Morocco – Detailed Feasibility Study – Energía Sur De Europa and MTERRA, 10/01/2011.

[2] Ibid

- Condensate collection units, installed at low points and before entry of pipeline into the gas flaring system.

Flaring

An enclosed flare with the following characteristics is to be used:

Table 1: Enclosed landfill gas flare technical specifications

Parameter	Value
Flare	
Maximum landfill gas flow @ 50% CH_4	1,500 Nm^3/h or thermal equivalent
Minimum landfill gas flow @ 50% CH_4	300 Nm^3/h or thermal equivalent

Electricity Generation Technology

The specifications of the electricity powering generators are as follows:

Table 2: Generation unit technical specifications[3]

Capacity	1,064 kW
Frequency	50 Hz
Factor of isolation	0.98
Rated efficiency	36.8% @ 50% load 38.9 @ 75% load 40.0% @ 100 load

Technology will be imported from Annex 1 country (Jenbacher or equivalent). Jenbacher is a General Electric gas engine division[4]. It is one of the world's leading manufacturers of gas-fuelled reciprocating engines, packaged generator sets and cogeneration units for power generation. It is one of the only companies in the world focusing exclusively on gas engine technology. GE's Jenbacher gas engines range in power from 0.25 MW to 4 MW and run on either natural gas or a variety of other gases (e.g., biogas, landfill gas, coal mine gas, sewage gas, combustible industrial waste gases).

The engines are equipped with the following protections:

- 3-ph for voltage excess: 110%UN
- Loss of voltage: 85%UN
- Frequency excess: 51HZ
- Loss of frequency: 49HZ

Closure is automatic and detected by a relay with a vector of 3 phases in 100 thousandths of a second.

A total of five (5) units of 1.064 MW are expected to be deployed progressively in the Oum Azza Landfill as the gas becomes available, according to the following schedule.

[3] Engine JGC 320 GS-L.L technical brochures – Jenbacher -2010

[4] https://information.jenbacher.com/index.php

Table 3: Engine deployment schedule[5]

Year	Additional engines	Total number of engines
2013	0	0
2020	2	2
2021	1	3
2023	1	4
2027	1	5

However, during this monitoring period there has been no electricity generation from the project.

B.2. Post-registration changes to PoA

B.2.1. Corrections

Not Applicable.

B.2.2. Inclusion of monitoring plan

Not Applicable.

B.2.3. Permanent changes to the registered monitoring plan, or permanent deviation of monitoring from the applied methodologies, standardized baselines, or other methodological regulatory documents

Not Applicable.

B.2.4. Changes to programme design

Not Applicable.

B.2.5. Changes specific to afforestation or reforestation activities

Not Applicable.

PART II Monitoring of CPAs

SECTION C. Implementation of CPAs

C.1. Description of implemented CPAs

The specific-case CPA described in this Monitoring Report consists in the implementation of a landfill gas capture and destruction on the landfill of Oum Azza, near Rabat. The purpose is to avoid GHG emission of methane from the decomposition of waste in the landfill.
The technology employed consists in:

- Vertical gas wells, including perforated HDPE pipes and well heads,
- and an enclosed flaring unit of 1500 Nm^3/h capacity manufactured by BFM HAASE (high combustion temperature flare, 300-1500 Nm^3/h, 20-100% CH_4, ≥0.3 s retention time).

No gas engine has been installed yet as the level of LFG is not sufficient.

[5] Calendar is based on prevision on LFG flow. Quality and quantity of LFG to be extracted is still to be tested. Therefore this calendar is provisional and subject to change/revisions depending on gas quality and flow.

The law authorizing independent power producers to deliver medium voltage electricity to the grid is still pending to be ratified. Thus, grid connection is currently not permitted.

In parallel, actions have been taken to improve the LFG production such as connection of inclined and horizontal wells on another cell of the landfill, leachate pumping, balancing of the wells and improvement of the network, etc.

Relevant dates:

- -Installation of the gas collection network (45 vertical wells): February-March 2015
- -Commissioning of the flare system: 30-31 July 2015
- -During the month of August 2015, the flare was in testing phase and was shut down most of the time (availability 16%).
- -Additional installation of 2 horizontal wells: May 2016 (installed, not yet connected to the network).
- -Frequent flare stops occured during the monitoring period due to a low pressure of gas flow.

The total GHG emission reductions achieved during the monitoring period are **9,723 tCO_2e**.

This landfill is not CDM registered in another PoA neither as an individual project activity, therefore there is no double counting of GHG emission reductions.

C.2. Location of CPAs

Host Party: Morocco
The landfill of Oum Azza is located near the city of Rabat in the commune of Oum Azza.
Geocoordinates: +33.8727, -6.8089

C.3. Post-registration changes to CPAs

C.3.1. Temporary deviations from the monitoring plans in the included CPA-DDs, applied methodologies, standardized baselines or other methodological regulatory documents

Not applicable.

C.3.2 Corrections

There are corrections to project information or parameters fixed at the inclusion of this CPA covered in this monitoring report. The correrctions have been updated in the latest version 6 of CPA-DD “Landfill’s gas (LFG) capture, flaring and use at the Oum Azza landfill” and was approved by UNFCCC on 24 November 2019 with the Ref. No. PRC-6568-001.

All changes have been approved by the Board prior to the submission of this monitoring report and are listed below according to the approved Validation report form for post-registration changes for component project activities:

Description of post registration change			
Start Date: Please provide the start date of the change	28/02/2014	**End Date:** Please provide the end date of the change, if applicable	
Description: Please give a detailed description of the change(s)	Several editorial corrections have been applied during the course of this PRC. 1. The GWP_{CH4} has been specified for the first (21 tCO2e/tCH4) and second commitment period (25 tCO2e/tCH4) 2. Start date of the crediting period has been corrected w.r.t. previous PRC of delay in start date of CP.		

C.3.3. Changes to the start date of the crediting period

The start date of the crediting period has been changed from 01/03/2013 to 28/02/2014.

Due to the commissioning of the project on 30-31/07/2015 the start date of the crediting period has been postponed from 01/03/2013 to 28/02/2014 by one year. A related notification has been forwarded by the PP to the UNFCCC during the first monitoring period (28 Feb 2014 - 31 Jul 2016) as indicated during interviews conducted during site inspection. A related CL 2 has been raised and resolved in the first monitoring period PoA Verification Report page 19, section I.2.3. Changes to the start date of the crediting period.

The start date has been changed and related project webpage has been revised accordingly and is now in line with the documents provided. Pls see related project page: http://cdm.unfccc.int/ProgrammeOfActivities/cpa_db/S173W8HI9MNUPREYKQOT6VJ5LFB4DX/view

C.3.4. Inclusion of monitoring plan

Not applicable.

C.3.5. Permanent changes to the included monitoring plans, or permanent deviation of monitoring from the applied methodologies, standardized baselines, or other methodological regulatory documents

There are permanent changes to the monitoring plan in the included CPA-DD. The changes have been updated in the latest version 6 of CPA-DD "Landfill's gas (LFG) capture, flaring and use at the Oum Azza landfill" and was approved by UNFCCC on 24 November 2019 with the Ref. No. PRC-6568-001.

All changes have been approved by the Board prior to the submission of this monitoring report and are listed below according to the approved Validation report form for post-registration changes for component project activities:

Description of post registration change			
Start Date: Please provide the start date of the change	28/02/2014	**End Date:** Please provide the end date of the change, if applicable	
Description: Please give a detailed description of the change(s)	1. Removal of calculated parameters in the monitoring plan section, as they are irrelevant as identified during the first verification. 2. Removal of monitoring parameters for monitoring of LFG on a dry basis, as for this CPA LFG is monitored on a wet basis, as identified during the first verification.		

C.3.6. Changes to project design

There are changes to the project design the CPA covered in this monitoring report.. The changes have been updated in the latest version 6 of CPA-DD "Landfill's gas (LFG) capture, flaring and use at the Oum Azza landfill" and was approved by UNFCCC on 24 November 2019 with the Ref. No. PRC-6568-001.

All changes have been approved by the Board prior to the submission of this monitoring report and are listed below according to the approved Validation report form for post-registration changes for component project activities:

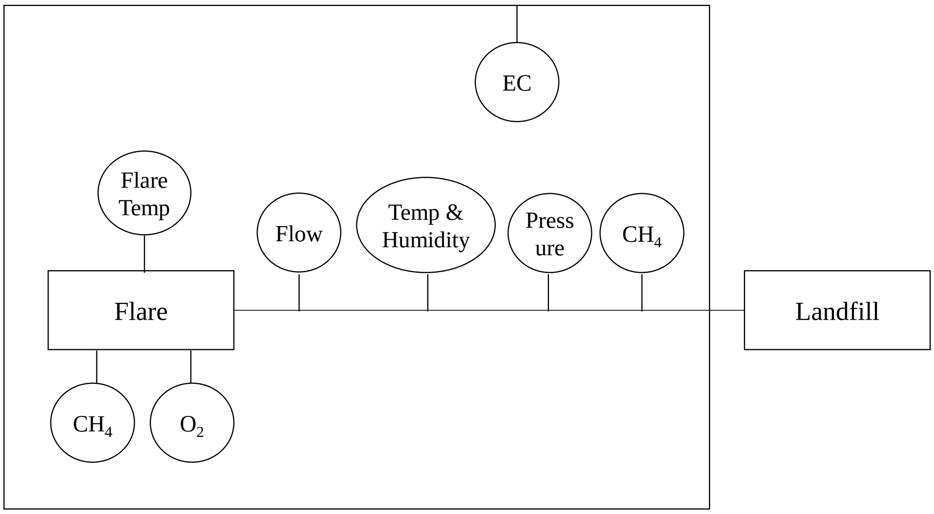
Description of post registration change			
Start Date: Please provide the start date of the change	28/02/2014	**End Date:** Please provide the end date of the change, if applicable	
Description: Please give a detailed description of the change(s)	There is a delay of the energy generation component of the project to the last year of the first crediting period. Subsequently the number of installed units has been reduced from 6 to 5. Therefore the total installed capacity is reduced from 6.384 MW (= 6 x 1.064 MW) to 5.320 MW.		

C.3.7. Changes specific to afforestation or reforestation CPA

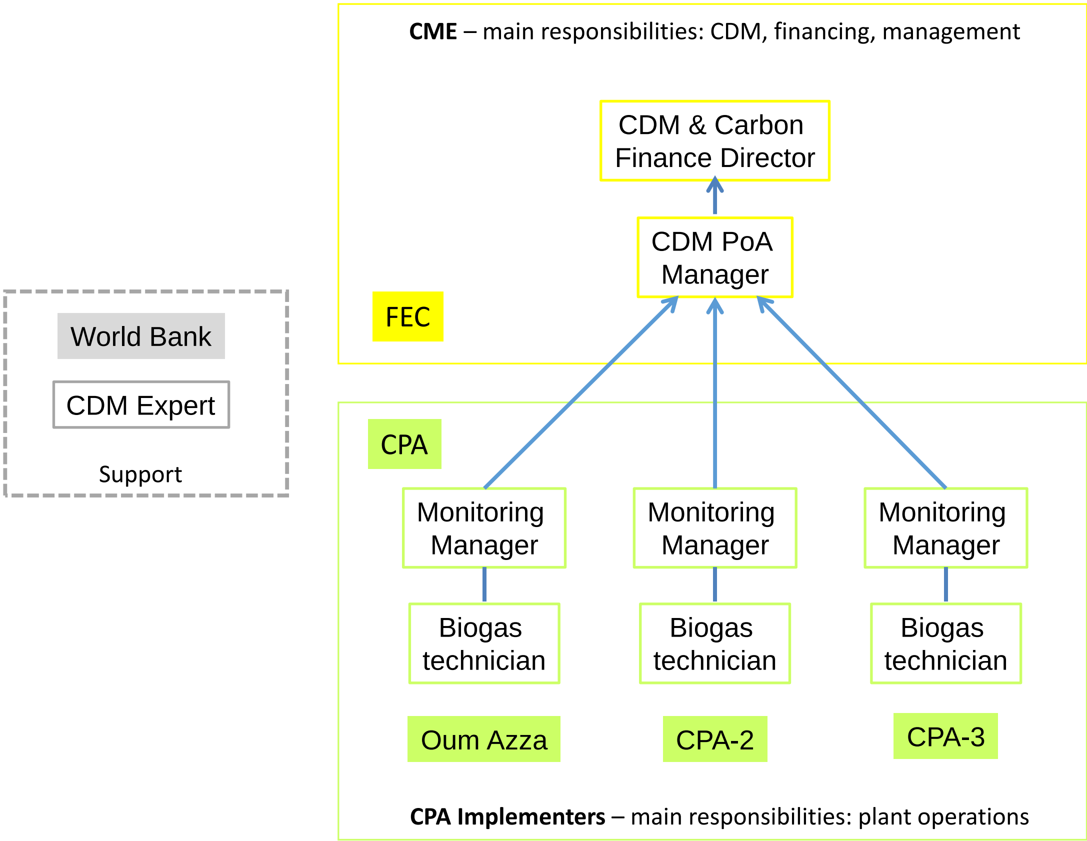
Not applicable.

SECTION D. Description of monitoring system of CPAs

The data acquisition system is AEMS, managed by Geotech.
All the parameters described in section E.2. are automatically recorded in the data logger every 5 minutes.
Data is kept on the remote server for 3 months and a copy of monitored data is kept on site.
Raw data is extracted from the remote server every week and every month and sent by email to the CME and the World Bank, together with weekly / monthly operations reports.
Project data and documentation is uploaded on Dropbox and information is shared between the CPA Implementer, the CME and the World Bank.
The monitoring system is illustrated in the figure below:



Organizational structure, roles and responsibilities of personnel for the monitoring system:



The CME is responsible for managing the PoA, and thus the CDM. Though the FEC is the intermediary between the World Bank funds and the project development, it is not responsible for financing of the projects.

The CPA Implementers are responsible for the construction and operations of the LFG plants, including maintenance and monitoring.
The Monitoring Manager is responsible for the monitoring plan and reporting to the CME.
The Biogas Technician is responsible for the daily operations of the project, including balancing of the gas network, maintenance of the LFG plant, data extraction, etc.

The World Bank will give support on CDM expertise, such as training, technical review of documents, validation and verification with the objective of building capacity so that in the future all activities can be undertaken by the CME.

QA/QC procedures:

- Internal audits carried out by the CME and the World Bank
- Trainings
- Regular maintenance
- Calibration planning
- Restricted access to raw data
- Shared access to project documentation between the three parties

Emergency procedures:

- Technical failure of a device: rapid identification of the damage, availability of spare parts, pool of suppliers identified for rapid replacement, regular maintenance to prevent technical failure
- Loss of data: back up of the data, manual records
- Calibration delays: use of a calibration planning, identification of a pool of laboratories or accredited agent for rapid calibration

SECTION E. Data and parameters

E.1. Data and parameters fixed ex ante

Data/parameter:	**GWP_{CH4}**
Unit	tCO_2e/tCH_4
Description	Global warming potential of CH_4
Source of data	IPCC Fourth Assessment Report, Section 2.10.3.1 Methane (https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter2-1.pdf)
Value(s) applied)	25
Choice of data or measurement methods and procedures	The value is taken from the table used for Annex I Parties on the UNFCCC website: https://unfccc.int/process-and-meetings/transparency-and-reporting/greenhouse-gas-data/frequently-asked-questions/global-warming-potentials-ipcc-fourth-assessment-report
Purpose of data/parameter	Calculation of baseline emissions or baseline net GHG removals.
Additional comments	None

Data/parameter:	**OX_{top_layer}**
Unit	Dimensionless
Description	Fraction of methane that would be oxidized in the top layer of the SWDS in the baseline
Source of data	Tool “Emissions from solid waste disposal sites” Version 6.0.1 (https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-04-v6.0.1.pdf/history_view)
Value(s) applied)	0.1
Choice of data or measurement methods and procedures	Default value taken from page 9 of the Tool “Emissions from solid waste disposal sites” Version 6.0.1.
Purpose of data/parameter	Calculation of baseline emissions or baseline net GHG removals.
Additional comments	None

Data/parameter:	**$EF_{grid,CM,y}$**
Unit	tCO_2 / MWh
Description	Emission factor for an electricity system
Source of data	Fixed ex-ante in the PoA-DD, page 49 (https://cdm.unfccc.int/filestorage/p/7/EJD8ZSOTV43Y7L2H9IW610NGQ5PRBK.pdf/PoA-DD%20LFG%20Morocco_v.2?t=MVp8cW0yZmphfDDdXme38A0z9VggQvvoE1Kw)
Value(s) applied)	0.6639

Choice of data or measurement methods and procedures	$EF_{grid,CM,y}$ is calculated as a weighted sum of the OM and BM emission factors, according to the "Tool to calculate the emission factor for an electricity system", version 02.2.1 (https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v2.pdf/history_view)
Purpose of data/parameter	Calculation of project emissions
Additional comments	Set ex-ante and fixed for the first crediting period.

Data/parameter:	$TDL_{j,y}$ and $TDL_{k,y}$
Unit	-
Description	Average technical transmission and distribution losses for providing electricity to source j or k in year y
Source of data	Default values according to the Tool to calculate baseline, project and/or leakage emissions from electricity consumption. Version 1.0. (https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-05-v1.pdf/history_view) Fixed ex-ante in the PoA-DD
Value(s) applied)	$TDL_{j,y}$ = 20% or 0 $TDL_{k,y}$ = 3%
Choice of data or measurement methods and procedures	For project emissions $TDL_{j,y}$ Apply 20% in case of scenario A (use of electricity imported from the grid) or 0 in case of scenario B (use of a fossil fuel backup generator). For baseline emissions $TDL_{k,y}$ Under the option A1, a default value of 3% shall be applied. In both cases, default values as per the tool will be applied.
Purpose of data/parameter	Calculation of project emissions
Additional comments	Ex-ante option is chosen: the Average technical transmission and distribution losses are not monitored during the crediting period.

Other ex-ante parameters η_{PJ}, $\varphi_{default}$, F, $DOC_{f,default}$, $MCF_{default}$, DOC_j, k_j, f, W_x, $p_{n,i,x}$ listed under section B.4.2 of the the latest CPA-DD (version 6.0) are not presented here as they are not relevant for this monitoring period.

E.2. Data and parameters monitored

As Option C of the "Tool to determine the mass flow of a greenhouse gas in a gaseous stream" (version 2.0) is chosen to calculate the mass flow of CH4, following parameters are monitored accordingly.

Data/Parameter	**$V_{t,wb}$ (same as $FV_{RG,h}$)**
Unit	Nm^3/h
Description	Volumetric flow of the gaseous stream (LFG) in time interval t on a wet basis
Measured/calculated/ default	Measured
Source of data	Flow meter
Value(s) of monitored parameter	The complete list of values of this monitored parameter is included in the electronic spreadsheets for exhaustive measures during the monitoring period.

<table>
<tr><td>Monitoring equipment</td><td>
<table>
<tr><th>Monitoring equipment</th><th>Manufacturer
Type
Accuracy</th><th>Serial number</th><th>Calibration frequency</th><th>Date of last calibration</th><th>Validity of the calibration</th></tr>
<tr><td>Thermal mass flow meter</td><td>Endress+Hauser
Proline Prowirl R200
Accuracy ± 0.75%</td><td>K3262219 000</td><td>Not necessary (“lifelong calibration”)</td><td>Initial calibration: 15/04/2015</td><td>Lifelong calibration</td></tr>
</table>
</td></tr>
<tr><td>Measuring/reading/recording frequency</td><td>Measured continuously; recorded every 5 minutes</td></tr>
<tr><td>Calculation method (if applicable)</td><td>Not calculated</td></tr>
<tr><td>QA/QC procedures</td><td>According to the manual, the flowmeter “offers lifelong calibration”. It does not need to be recalibrated.</td></tr>
<tr><td>Purpose of data/parameter</td><td>Calculation of baseline emissions or baseline net GHG removals</td></tr>
<tr><td>Additional comments</td><td>Two flow meters are installed in the plant. One is located before the blower “FT1” and the other one is located after the blower in the pipe, close to the flare stack “FT2”. Values from FT1 are used for the calculations.
The measures of the moisture content analyser show that the flow is in wet conditions. Option C of the Tool to determine the mass flow of a greenhouse gas in a gaseous stream will be applied.
As indicated from the section No. 3 on page 18 of the equipment UCG manual: “Biogas flow rate in the suction pipe in Nm3 / h (Biogas from landfill flowrate in Nm3 / h)”, the measured values are normalized flows and thus is equal to $\mathbf{V}_{t,wb,n}$, and no need to use values from Pt and Tt to convert. Therefore, parameters Pt, and Tt are not irrelevant for the monitoring and thus not listed here.</td></tr>
</table>

<table>
<tr><th>Data/Parameter</th><th>$v_{CH4,t,wb}$ (same as $fv_{CH4,h}$)</th></tr>
<tr><td>Unit</td><td>m^3 CH_4 / m^3 LFG (wet)</td></tr>
<tr><td>Description</td><td>Volumetric fraction of CH_4 in time interval t on a wet basis</td></tr>
<tr><td>Measured/calculated/ default</td><td>Measured</td></tr>
<tr><td>Source of data</td><td>Gas analyser</td></tr>
<tr><td>Value(s) of monitored parameter</td><td>The complete list of values of this monitored parameter is included in the electronic spreadsheets for exhaustive measures during the monitoring period.</td></tr>
<tr><td>Monitoring equipment</td><td>
<table>
<tr><th>Monitoring equipment</th><th>Manufacturer
Type
Accuracy</th><th>Serial number</th><th>Calibration frequency</th><th>Date of last calibration</th><th>Validity of the calibration</th></tr>
<tr><td rowspan="2">Gas analyser</td><td rowspan="2">Geotech
FAU
2%
0.2% with autocalibration</td><td>GA14465</td><td rowspan="2">Auto-calibration</td><td>Calibrated by the manufacturer on 08/04/2016
Start of use 23/04/2016
Then Calibrated on 14/03/2017
Then Calibrated on 29/06/2018</td><td rowspan="2">Valid during the entire monitoring period</td></tr>
<tr><td>GA14466</td><td>Calibrated by the manufacturer on 18/04/2015
Start of use 01/08/2015
Then Calibrated on 31/05/2016
Then Calibrated on 09/06/2017
Then Calibrated on 23/02/2018</td></tr>
</table>
</td></tr>
<tr><td>Measuring/reading/recording frequency</td><td>Measured and recorded every 5 minutes</td></tr>
</table>

Calculation method (if applicable)	Not applicable
QA/QC procedures	The calibration is done every year and auto calibration occurs when triggered in case of deviation. This module ensures a high accuracy. The measures of the gas analyser are checked every day (“calcheck”), if a deviation is found, a calibration is automatically triggered. A zero check (verified with air) and a typical value check are performed by comparison with standard certified gas (49.99% CH_4 and 50.01% CO_2 and is valid until 12/04/2019 composed on 13/04/2016 cylinder #438508, certificate S095880)
Purpose of data/parameter	Calculation of baseline emissions or baseline net GHG removals
Additional comments	GA14466 was replaced by GA14465 on 23/04/2016, which was duly calibrated by the manufacturer before installation in the plant. GA14465 was replaced by GA14466 on 27/12/2016 which was duly calibrated by the manufacturer on 31/05/2016 before installation in the plant. GA14466 was replaced by GA14465 on 18/04/2017 which was duly calibrated by the manufacturer on 14/03/2017 before installation in the plant. GA14465 was replaced by GA14466 on 13/03/2018 which was duly calibrated by the manufacturer on 09/06/2017 and on 23/02/2018 before installation in the plant. GA14466 was replaced by GA14465 on 27/08/2018 which was duly calibrated by the manufacturer on 29/06/2018 before installation in the plant. The measures of the moisture content analyser show that the volumetric fraction of methane is in wet conditions. Option C of the *Tool to determine the mass flow of a greenhouse gas in a gaseous stream* will be applied.

The CPA includes LFG flaring (Step A), thus the following parameters will be monitored:

In case of enclosed flares (flare options B and C):

Data/Parameter	T_{flare}
Unit	°C
Description	Temperature in the exhaust gas of the flare
Measured/calculated/ default	Measured
Source of data	Thermocouple
Value(s) of monitored parameter	The complete list of values of this monitored parameter is included in the electronic spreadsheets for exhaustive measures during the monitoring period.

<table>
<tr><td>Monitoring equipment</td><td>
<table>
<tr><th>Monitoring equipment</th><th>FManufacturer
Type
Accuracy</th><th>Batch number</th><th>Calibration / replacement frequency</th><th>Date of last calibration / replacement</th><th>Validity</th></tr>
<tr><td>Thermocouple</td><td>Günther
Type S
±1.0°C</td><td>05-20387210-0500</td><td>Every year</td><td>Factory calibration 02/09/2016</td><td>02/09/2016 to 01/09/2017</td></tr>
<tr><td>Thermocouple</td><td>Günther
Type S
±1.0°C</td><td>05-2038721 0-0500</td><td>Every year</td><td>Factory calibration 18/05/2017</td><td>18/05/2017 to 17/05/2018</td></tr>
<tr><td>Thermocouple</td><td>Günther
Type S
±1.0°C</td><td>05-2038721 0-0500</td><td>Every year</td><td>Factory calibration 29/03/2018</td><td>29/03/2018 to 28/03/2019</td></tr>
</table>
</td></tr>
<tr><td>Measuring/reading/recording frequency</td><td>Measured continuously; recorded every 5 minutes</td></tr>
<tr><td>Calculation method (if applicable)</td><td>Not applicable</td></tr>
<tr><td>QA/QC procedures</td><td>Calibration or replacement every year</td></tr>
<tr><td>Purpose of data/parameter</td><td>Calculation of baseline emissions or baseline net GHG removals (determining $\eta_{flare,h}$).</td></tr>
<tr><td>Additional comments</td><td>TC 05-2038721 0-0500 has been exchanged on 02/09/2016, 18/05/2017 and 29/03/2018. The same batch number had three devices. A spare part is available on site.</td></tr>
</table>

<table>
<tr><td>Data/Parameter</td><td>$fv_{CH4,FG,h}$</td></tr>
<tr><td>Unit</td><td>mg/m^3</td></tr>
<tr><td>Description</td><td>Concentration of CH_4 in the exhaust gas of the flare in dry basis at normal conditions in the hour h</td></tr>
<tr><td>Measured/calculated/ default</td><td>Measured</td></tr>
<tr><td>Source of data</td><td>Gas analyser</td></tr>
<tr><td>Value(s) of monitored parameter</td><td>The complete list of values of this monitored parameter is included in the electronic spreadsheets for exhaustive measures during the monitoring period.</td></tr>
<tr><td>Monitoring equipment</td><td>
<table>
<tr><th>Monitoring equipment</th><th>Manufacturer
Type
Accuracy</th><th>Serial number</th><th>Calibration frequency</th><th>Date of last calibration</th><th>Validity of the calibration</th></tr>
<tr><td>Gas analyser</td><td>Servomex
Servopro 4900
1% of reading or 0.5 ppm</td><td>653383</td><td>Auto calibration</td><td>Factory calibration 15/06/2015 Start of use 01/08/2015 Recalibrated by a third party on 16/03/2016</td><td>Valid during the entire monitoring period</td></tr>
</table>
</td></tr>
<tr><td>Measuring/reading/recording frequency</td><td>Measured continuously; recorded every 5 minutes</td></tr>
<tr><td>Calculation method (if applicable)</td><td>Not applicable</td></tr>
</table>

QA/QC procedures	The exhaust gas analyser for CH4 in exhaust gas is set on automatic calibration mode: The equipment conducts therefore regular, automatic calibrations against standard gas after zero check by use of inert gas (N2). This module ensures a high accuracy. A zero check (verified with N_2, certificate S107685, valid until 14/01/2019) and a typical value check are performed by comparison with standard certified gas (0.69% CH_4 / 10% O_2, certificate S107684, valid until 14/01/2019).
Purpose of data/parameter	Calculation of baseline emissions or baseline net GHG removals (determining $\eta_{flare,h}$).
Additional comments	The point of measurement is located in the upper section of the flare stack.

Data/Parameter	$t_{O2,h}$
Unit	-
Description	Volumetric fraction of O_2 in the exhaust gas of the flare in the hour *h*
Measured/calculated/ default	Measured
Source of data	Gas analyser
Value(s) of monitored parameter	*As the O2 measurement device was missing calibration since 28th February 2017 till now, we are taking the most conservative method from 1st March 2017 till the end of this monitoring period on 31st December 2018 using default value of 0 and 50% as per Step 6 on page 10 of the “Tool to determine project emissions from flaring gases containing methane”:* *“In case of enclosed flares and use of the default value for the flare efficiency, the flare efficiency in the hour h (ηflare,h) is:* *• 0% if the temperature in the exhaust gas of the flare (T_{flare}) is below 500 °C for more than 20 minutes during the hour h.* *• 50%, if the temperature in the exhaust gas of the flare (T_{flare}) is above 500 °C for more than 40 minutes during the hour h, but the manufacturer’s specifications on proper operation of the flare are not met at any point in time during the hour h.* *• 90%, if the temperature in the exhaust gas of the flare (T_{flare}) is above 500 °C for more than 40 minutes during the hour h and the manufacturer’s specifications on proper operation of the flare are met continuously during the hour h.”* *ER Calculations for the period during August 2016 till February 2017 remain qualified and thus still use equation 14 of the tool.*
Monitoring equipment	(see table below)
Measuring/reading/recording frequency	Measured continuously; recorded every 5 minutes
Calculation method (if applicable)	Not applicable
QA/QC procedures	The exhaust gas analyser for O_2 in exhaust gas is set on automatic calibration mode: The equipment conducts therefore regular, automatic calibrations against standard gas after zero check by use of inert gas (N_2). This module ensures a high accuracy. A zero check (verified with N_2, certificate S107685, valid until 14/01/2019) and a typical value check are performed by comparison with standard certified gas (0.69% CH_4 / 10% O_2, certificate S107684, valid until 14/01/2019).
Purpose of data/parameter	Calculation of baseline emissions or baseline net GHG removals (determining $\eta_{flare,h}$).

Monitoring equipment:

Monitoring equipment	Manufacturer Type Accuracy	Serial number	Calibration frequency	Date of last calibration	Validity of the calibration
Gas analyser	Servomex Servopro 4900 0.05%	653383	Auto calibration	Factory calibration 15/06/2015 Start of use 01/08/2015 Recalibrated by a third party on 16/03/2016	Valid during the entire monitoring period

Additional comments	The point of measurement is located in the upper section of the flare stack. As the O_2 measurement device was missing calibration since 28th February 2017 till now, we are taking the most conservative method from 1st March 2017 till the end of this monitoring period on 31st December 2018 using default value of 0 and 50% for flare efficiency as per Step 6 on page 10 of the "Tool to determine project emissions from flaring gases containing methane".

Data/Parameter	**$EC_{PJ,y}$**
Unit	MWh
Description	Quantity of electricity consumed by the CPA in the year *y*
Measured/calculated/ default	Measured and calculated
Source of data	1. Electricity meter measurement for consumption from LFG collection and flaring $EC_{PJ,e}$ 2. Electricity consumption calculated using capacities and operation hours due to the leachate pumping (2 compressors and 10 pumps)
Value(s) of monitored parameter	357.915
Monitoring equipment	1. For Electricity meter measurement for consumption from LFG collection and flaring: Manufacturer / type / model: Siemens Sentron PAC3200 Serial number: LQN1315 Accuracy: 0.5% Calibration: calibrated by the manufacturer. Recalibration not required $EC_{PJ,e}$ = 66.617 MWh 2. Electricity consumption calculated using capcities and operation hours due to the leachate pumping (2 compressors and 10 pumps) (a) Each compressor has a nominal capacity of 4 kW. To be conservative, we will assume that the compressors have been functioning at full capacity every hours of the monitoring period + 10%, since installation of the pumps. $EC_{PJ,com}$ = 2 *4kW * 24d/h * (365d *2+153d) * 110% = 186,490kWh = 186.490MWh (b) Each electric pump has a nominal capacity of 1.1 kW. The pumps have been functioning at full capacity, starting from 30/11/2017 until the end of monitoring period 31/12/2018. To be conservative, we assume full operation of 24 hours per day. $EC_{PJ,pump}$=10 * 1.1kw *24h/d * (365d+32d)=104,808kWh = 104.808MWh $EC_{PJ,y} = EC_{PJ,e} + EC_{PJ,com} + EC_{PJ,pump}$ = 66.617 MWh +186.490MWh + 104.808MWh = 357.915MWh
Measuring/reading/recording frequency	Measured continuously; recorded every 5 minutes.
Calculation method (if applicable)	Aggregated according to the monitoring period
QA/QC procedures	According to the manual, the electricity meter has been calibrated by the manufacturer and recalibration is not required.
Purpose of data/parameter	Project emissions calculations

Additional comments	All electricity consumptions have been accounted, including consumptions during the installation and testing phase prior to the flare comissioning. The monthly electricity consumption was measured consistently using the meter reading at the end of month deducting the reading at the beginning of month. Data will be kept for 2 years after end of crediting period or last issuance of CERs for the project activity.

Data/Parameter	**Other flare operation parameter**
Unit	-
Description	Data and parameters required to monitor whether the flare operates within the range of operating conditions according to the manufacturer specifications
Measured/calculated/ default	Measured
Source of data	Flow meter and gas analyser
Value(s) of monitored parameter	The complete list of values of this monitored parameter is included in the electronic spreadsheets for exhaustive measures during the monitoring period.
Monitoring equipment	Flow meter and gas analyser
Measuring/reading/recording frequency	Measured continuously; recorded every 5 minutes
Calculation method (if applicable)	Not calculated
QA/QC procedures	Refer to parameters $V_{t,wb}$ and $v_{CH4,t,wb}$
Purpose of data/parameter	Calculation of baseline emissions or baseline net GHG removals
Additional comments	The range of operating conditions of the flare are: minimum flow of 300 Nm^3/h and a minimum methane concentration of 20%.

Other parameters such as $M_{t,wb}$, Tt, Pt, $p_{H2O,t,sat}$, $EC_{BL,k,y}$, and Operation hours of the energy plant listed under section B.5.1 of the the latest CPA-DD (version 6.0) are not presented here as they are not relevant for this monitoring period.

Values of the monitored parameters for the monitoring period can be verified in the ER calculations spreadsheets and related formulas are presented in section F below.

E.3. Implementation of sampling plan

>>
Not applicable.

SECTION F. Calculation of emission reductions or net anthropogenic removals

F.1. Calculation of baseline emissions or baseline net removals

>>
The baseline emission are calculated as follows:

$$BE_y = BE_{CH4,y} + BE_{EC,y} \quad (1)$$

Where:

BE_y Baseline emissions in year y (tCO_2e)
$BE_{CH4,y}$ Baseline emissions of methane from the SWDS in year *y* (t CO_2e/yr)
$BE_{EC,y}$ Baseline emissions associated with electricity generation in year *y* (t CO_2/yr), equal to zero as electricity generation is not implemented during this monitoring period

$$BE_y = BE_{CH4,y} = (1-OX_{top\_layer}) * F_{CH4,PJ} * GWP_{CH4} \quad (2)$$

Where:
$F_{CH4,PJ,y} = F_{CH4,flared} + F_{CH4,EL}$ *(3)*

$F_{CH4,PJ,y}$ Amount of methane in the LFG which is flared and/or used in the project activity in year *y* (t CH_4/yr)
$F_{CH4,flared,y}$ Amount of methane in the LFG which is destroyed by flaring in year *y* (t CH_4/yr)
$F_{CH4,EL,y}$ Amount of methane in the LFG which is used for electricity generation in year *y* (t CH_4/yr), equal to zero as electricity generation is not implemented during this monitoring period

And where $F_{CH4,flared}$ is calculared as follows:

$F_{CH4,flared} = F_{CH4,sent\text{-}flare} - PE_{flare} / GWP_{CH4}$ *(4)*

Where:
$F_{CH4,sent\text{-}flare}$ is the mass flow of methane in the LFG sent to the flare and is calculared based on the following parameters:

$F_{CH4,sent\_flare} = V_{t,wb} * v_{CH4,t,wb} * \rho_{CH4}$ *(5)*

Where:
$V_{t,wb}$ Volumetric flow of the LFG in time interval *t* on a wet basis
$v_{CH4,t,wb}$ Volumetric fraction of CH_4 in time interval *t* on a wet basis
ρ_{CH4} Density of methane (kg CH_4/m^3 CH_4)

A humidity sensor has been installed to determine whether the measurements of LFG are in dry or wet conditions and the records show that the measurements of the volumetric flow and fraction of methane are taken in wet basis.
Option C of the “Tool to determine the mass flow of a greenhouse gas in a gaseous stream (version 2.0)” is applied to calculate the density of methane, and the resulting mass flow of methane:

The density of methane is calculated according to the following equation:

$\rho_{CH4} = P_n * MM_{CH4} / R_u * T_n$ *(6)*

Where:
P_n Absolute pressure at normal conditions (Pa)
MM_{CH4} Molecular mass CH_4 (kg/kmol)
R_u Universal ideal gas constant (Pa.m^3 / kmol.K)
T_n Temperature at normal conditions (K)

As per the given excel tool “Table to determine the mass flow of a greenhouse gas in a gaseous stream” attached to the “Tool to determine the mass flow of a greenhouse gas in a gaseous stream (version 2.0)”, once Option C is chosen, all four parameters above are set to be default values as follows:

Parameter	**Value**	**Units**	**Description**
MMi	16.04	kg / kmol	Molecular mass of gas k
Ru	8,314	Pa.m^3/kmol.K	Universal ideal gases constant
Pn	101,325	Pa	Absolute pressure at normal conditions
Tn	273.15	K	Temperature at normal conditions

Therefore, $\rho_{CH4} = P_n * MM_{CH4} / R_u * T_n$ = 101,325 * 16.04/ (8,314* 273.15) = 0.71566 kg/m3

PE_{flare} is calculated as per the "Tool to determine project emissions from flaring gases containing methane" (version 1.0) as described in the PoA-DD.

$PE_{flare} = \sum TM_{RG,h} \times (1 - \eta_{flare,h}) \times GWP_{CH4}/1000$ *(7)*

Where:

$TM_{RG,h}$	Mass flow of methane in the residual gas stream, which is the same as $F_{CH4,sent\_flare}$
$\eta_{flare,h}$	Flare efficiency (fraction) when LFG is flared
GWP_{CH4}	Global Warming Potential of methane (t CH_4/t CO_2)

And:

$\eta_{flare,h} = 1 - (TM_{FG,h} / TM_{RG,h})$ *(8)*

Where:

$TM_{FG,h}$ is the mass flow of methane in the exhaust gas of the flare (kg/h)

And:

$TM_{FG,h} = TV_{n,FG,h} * fv_{CH4,FG,h} / 1000000$ (9)

Where:

Variable	**SI Unit**	**Description**
$TM_{FG,h}$	kg/h	Mass flow rate of methane in the exhaust gas of the flare in dry basis at normal conditions in the hour *h*
$TV_{n,FG,h}$	m^3/h exhaust gas	Volumetric flow rate of the exhaust gas in dry basis at normal conditions in hour *h*
$fv_{CH4,FG,h}$	mg/m^3	Concentration of methane in the exhaust gas of the flare in dry basis at normal conditions in hour *h*

And:

$TV_{n,FG,h} = V_{n,FG,h} * FM_{RG,h}$ (10)

Where:

Variable	**SI Unit**	**Description**
$TV_{n,FG,h}$	m^3/h	Volumetric flow rate of the exhaust gas in dry basis at normal conditions in hour *h*
$V_{n,FG,h}$	m^3/kg residual gas	Volume of the exhaust gas of the flare in dry basis at normal conditions per kg of residual gas in hour *h*
$FM_{RG,h}$	kg residual gas/h	Mass flow rate of the residual gas in the hour *h*

And:

$V_{n,FG,h} = V_{n,CO2,h} + V_{n,O2,h} + V_{n,N2,h}$ (11)

Where:

Variable	**SI Unit**	**Description**
$V_{n,FG,h}$	m^3/kg residual gas	Volume of the exhaust gas of the flare in dry basis at normal conditions per kg of residual gas in the hour *h*
$V_{n,CO2,h}$	m^3/kg residual gas	Quantity of CO_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour *h*
$V_{n,N2,h}$	m^3/kg residual gas	Quantity of N_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour *h*
$V_{n,O2,h}$	m^3/kg residual gas	Quantity of O_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour h

And:

$V_{n,O2,h} = n_{O2,h} * MV_n$ (12)

Where:

Variable	SI Unit	Description
$V_{n,O2,h}$	m^3/kg residual gas	Quantity of O_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour *h*
$n_{O2,h}$	kmol/kg residual gas	Quantity of moles O_2 in the exhaust gas of the flare per kg residual gas flared in hour *h*
MV_n	m^3/kmol	Volume of one mole of any ideal gas at normal temperature and pressure (22.4 L/mol)

And:

$$V_{n,N_2,h} = MV_n * \left\{ \frac{fm_{N,h}}{200AM_N} + \left(\frac{1 - MF_{O_2}}{MF_{O_2}} \right) * \left[F_h + n_{O_2,h} \right] \right\}$$

(13)

Where:

Variable	SI Unit	Description
$V_{n,N2,h}$	m^3/kg residual gas	Quantity of N_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour *h*
MV_n	m^3/kmol	Volume of one mole of any ideal gas at normal temperature and pressure (22.4 m^3/Kmol)
$fm_{N,h}$	-	Mass fraction of nitrogen in the residual gas in the hour *h*
AM_n	kg/kmol	Atomic mass of nitrogen
MF_{O2}	-	O_2 volumetric fraction of air
F_h	kmol/kg residual gas	Stochiometric quantity of moles of O_2 required for a complete oxidation of one kg residual gas in hour *h*
$n_{O2,h}$	kmol/kg residual gas	Quantity of moles O_2 in the exhaust gas of the flare per kg residual gas flared in hour *h*

And:

$V_{n,CO2,h} = fm_{C,h} * MV_n / AM_C$ (14)

Where:

Variable	SI Unit	Description
$V_{n,CO2,h}$	m^3/kg residual gas	Quantity of CO_2 volume free in the exhaust gas of the flare at normal conditions per kg of residual gas in the hour *h*
$fm_{C,h}$	-	Mass fraction of carbon in the residual gas in the hour *h*
AM_C	kg/kmol	Atomic mass of carbon
MV_n	m^3/kmol	Volume of one mole of any ideal gas at normal temperature and pressure (22.4 m^3/Kmol)

And:

$$n_{O_2,h} = \frac{t_{O_2,h}}{\left(1 - (t_{O_2,h} / MF_{O_2})\right)} \times \left[\frac{fm_{C,h}}{AM_C} + \frac{fm_{N,h}}{2AM_N} + \left(\frac{1 - MF_{O_2}}{MF_{O_2}} \right) \times F_h \right]$$

(15)

Where:

Variable	SI Unit	Description
$n_{O2,h}$	kmol/kg residual gas	Quantity of moles O_2 in the exhaust gas of the flare per kg residual gas flared in hour *h*
$t_{O2,h}$	-	Volumetric fraction of O_2 in the exhaust gas in the hour *h*
MF_{O2}	-	Volumetric fraction of O_2 in the air (0.21)
F_h	kmol/kg residual gas	Stochiometric quantity of moles of O_2 required for a complete oxidation of one kg residual gas in hour *h*
$fm_{j,h}$	-	Mass fraction of element *j* in the residual gas in hour *h* (from equation 4)
AM_j	kg/kmol	Atomic mass of element *j*
j		The elements carbon (index C) and nitrogen (index N)

And:

$$F_h = \frac{fm_{C,h}}{AM_C} + \frac{fm_{H,h}}{4AM_H} - \frac{fm_{O,h}}{2AM_O} \qquad (16)$$

Where:

Variable	SI Unit	Description
F_h	kmol O_2/kg residual gas	Stoichiometric quantity of moles of O_2 required for a complete oxidation of one kg residual gas in hour *h*
$fm_{j,h}$	-	Mass fraction of element *j* in the residual gas in hour *h* (from equation 4)
AM_j	kg/kmol	Atomic mass of element *j*
j		The elements carbon (index C), hydrogen (index H) and oxygen (index O)

$$fm_{j,h} = \frac{\sum_i fv_{i,h} \cdot AM_j \cdot NA_{j,i}}{MM_{RG,h}} \qquad (17)$$

Where:

Variable	SI Unit	Description
$fm_{j,h}$	-	Mass fraction of element *j* in the residual gas in hour *h*
$fv_{i,h}$	-	Volumetric fraction of component *i* in the residual gas in the hour *h*
AM_j	kg/kmol	Atomic mass of element *j*
$NA_{j,i}$	-	Number of atoms of element *j* in component *i*
$MM_{RG,h}$	kg/kmol	Molecular mass of the residual gas in hour *h*
j		The elements carbon, hydrogen, oxygen and nitrogen
i		The components CH_4, CO, CO_2, O_2,H_2, N_2

Table 1. Constants used in equations

Parameter	SI Unit	Description	Value
MM_{CH4}	kg/kmol	Molecular mass of methane	16.04
MM_{CO}	kg/kmol	Molecular mass of carbon monoxide	28.01
MM_{CO2}	kg/kmol	Molecular mass of carbon dioxide	44.01
MM_{O2}	kg/kmol	Molecular mass of oxygen	32.00
MM_{H2}	kg/kmol	Molecular mass of hydrogen	2.02
MM_{N2}	kg/kmol	Molecular mass of nitrogen	28.02
AM_c	kg/kmol (g/mol)	Atomic mass of carbon	12.00
AM_h	kg/kmol (g/mol)	Atomic mass of hydrogen	1.01
AM_o	kg/kmol (g/mol)	Atomic mass of oxygen	16.00
AM_n	kg/kmol (g/mol)	Atomic mass of nitrogen	14.01
P_n	Pa	Atmospheric pressure at normal conditions	101 325
R_u	$Pa.m^3/kmol.K$	Universal ideal gas constant	8 314.472
T_n	K	Temperature at normal conditions	273.15
MF_{O2}	Dimensionless	O_2 volumetric fraction of air	0.21
GWP_{CH4}	tCO_2/tCH_4	Global warming potential of methane	21
MV_n	$m^3/Kmol$	Volume of one mole of any ideal gas at normal	22.414

$$FM_{RG,h} = \rho_{RG,n,h} * FV_{RG,h} \quad (18)$$

Where:

Variable	SI Unit	Description
$FM_{RG,h}$	kg/h	Mass flow rate of the residual gas in hour *h*
$\rho_{RG,n,h}$	kg/m^3	Density of the residual gas at normal conditions in hour *h*
$FV_{RG,h}$	m^3/h	Volumetric flow rate of the residual gas in dry basis at normal conditions in the hour *h*

And:

$$\rho_{RG,n,h} = \frac{P_n}{\frac{R_u}{MM_{RG,h}} \times T_n} \quad (19)$$

Where:

Variable	SI Unit	Description
$\rho_{RG,n,h}$	kg/m^3	Density of the residual gas at normal conditions in hour *h*
P_n	Pa	Atmospheric pressure at normal conditions (101 325)
R_u	$Pa.m^3/kmol.K$	Universal ideal gas constant (8 314)
$MM_{RG,h}$	kg/kmol	Molecular mass of the residual gas in hour *h*
T_n	K	Temperature at normal conditions (273.15)

$$MM_{RG,h} = \sum_i (fv_{i,h} * MM_i) \quad (20)$$

Where:

Variable	SI Unit	Description
$MM_{RG,h}$	kg/kmol	Molecular mass of the residual gas in hour *h*
$fv_{i,h}$	-	Volumetric fraction of component *i* in the residual gas in the hour *h*
MM_i	kg/kmol	Molecular mass of residual gas component *i*
I		The components CH_4, CO, CO_2, O_2,H_2, N_2

As a simplified approach, project participants may only measure the volumetric fraction of methane and consider the difference to 100% as being nitrogen (N_2).

Calculation Sample 1:

This method is applicable for the period during August 2016 until February 2017.

Below is an example calculation using data outputs aggreagated during 8:00-8:59 and 9:00-9:59 on October 1st, 2016, taken directly from the excel spreadsheet of ER calculation for 2016.

Table A: Meter outputs aggregated for hourly average on October 1st, 2016 to calculate $F_{CH4,sent-flare}$

YYYY_MM	YYYY_MM_DD_HH	CH4 (%)	Flow (Nm3h	Pressure (mbara	Temp (°C)	Humidity (%)	Tflare (°C)	CH4e (vpm)	O2e (%)		ρ_{CH4} ($kgCH_4/m^3CH$	$F_{CH4,sent\_flare}$ ($kgCH_4/h$)
2016_10	2016_10_01_08	25.90	133.21	1,003.25	27.98	12.70	266.65	1,074.42	18.56		0.71566	24.69
2016_10	2016_10_01_09	32.09	332.83	1,002.17	37.73	4.87	967.03	10.75	11.63		0.71566	76.44

For the time 9:00-9:59:

$F_{CH4,sent\_flare} = V_{t,wb} * v_{CH4,t,wb} * \rho_{CH4} = 332.83Nm^3/h *32.09\%*0.71566kg/m^3= 76.44$ kg/h

Table B: Calculated parameters using meter outputs from Table 1 to determing $\eta_{flare,h}$ and PE_{flare}

YYYY_MM	YYYY_MM_DD_HH	$MM_{RG,h}$ (kg/kmol)	$\rho_{RG,n,h}$ (kg/m^3)	$FM_{RG,h}$ (kg/h)	$fm_{C,h}$	$fm_{H,h}$	$fm_{N,h}$	F_h (kmol O_2/kg LFG)	$n_{O2,h}$ (kmol/kg LFG)	$V_{n,CO2,h}$ (m^3/kg LFG)	$V_{n,N2,h}$ (m^3/kg LFG)	$V_{n,O2,h}$ (m^3/kg LFG)	$V_{n,FG,h}$ (m^3/kg LFG)	$TV_{n,FG,h}$ (m^3/h)	$TM_{FG,h}$ (kg/h)	$TM_{RG,h}$ (kg/h)	$\eta_{flare,h}$	PE_{flare}
2016_10	2016_10_01_08	24.90	1.11	148.01	0.12	0.04	0.83	0.02	0.21	0.23	19.70	4.77	24.70	3,655	2.8118	24.69	0.00%	0.61728
2016_10	2016_10_01_09	24.16	1.08	358.81	0.16	0.05	0.79	0.03	0.07	0.30	7.82	1.48	9.61	3,447	0.0265	76.44	99.97%	0.00066

For the time 8:00-8:59:

As the average Tflare < 500 °C, $\eta_{flare,h} = 0$.

For the time 9:00-9:59, as the average Tflare > 500 °C:

$TM_{RG,h} = F_{CH4,sent\_flare} = 76.44$ kg/h

$n_{O2,h} = [t_{O2,h}/(1-(t_{O2,h}/MF_{O2})] * [fm_{C,h}/AM_C + fm_{N,h}/2AM_N + (1-MF_{O2}) * F_h/MF_{O2}]$

$= 0.07$ kmol/kg

$F_h= fm_{C,h}/AM_C + fm_{H,h}/4AM_H – fm_{O,h}/2AM_O$

$=0.16/(12kg/kmol) +0.05/(4*1.01kg/kmol) - 0$

$= 0.03kmol\ O_2/kg$ residual gas

$MM_{RG,h} = \sum(fv_{i,h} * MM_i) = \sum(fv_{CH4,h} * MM_{CH4}) + \sum(fv_{N2,h} * MM_{N2})$

$= \sum(v_{CH4,t,wb} * MM_{CH4}) + \sum(1- v_{CH4,t,wb}) * MM_{N2})$

$= 32.09\% * 16.04kg/mol + (1-32.09\%) * 28.01kg/mol = 24.16$ kg/mol

$fm_{C,h} = \sum fv_{CH4,h} * AM_C * NA_{C,CH4}/MM_{RG,h} = 32.09\% * 12kg/kmol * 1/ 24.16kg/kmol = 0.16$

$fm_{H,h} = \sum fv_{CH4,h} * AM_H * NA_{H,CH4}/MM_{RG,h} = 32.09\% * 1.01 kg/kmol * 4/ 24.16kg/kmol = 0.05$

$fm_{N,h} = \sum fv_{N2,h} * AM_N * NA_{N,N2}/MM_{RG,h} = (1-32.09\% * 14.01 kg/kmol * 2/ 24.16kg/kmol = 0.79$

$fm_{O,h} = \sum fv_{O2,h} * AM_O * NA_{O,O2}/MM_{RG,h} = 0\% * 16 kg/kmol * 2/ 24.16kg/kmol = 0$

$V_{n,O2,h}$ = $n_{O2,h}$ * MV_n = 0.07kmol/kg * 22.4L/mol = 1.48 m^3/kg
$V_{n,CO2,h}$ = $fm_{C,h}$ * MV_n / AM_C = 0.16 * 22.4L/mol / 12kg/kmol = 0.3 m^3/kg
$V_{n,N2,h}$ = MV_n * {$fm_{N,h}$ /200AM_N + [(1-MF_{O2})/MF_{O2}] * (F_h + $n_{O2,h}$) }
= 22.4L/mol * {0.79/(200*14.01 kg/kmol) +[(1-0.21)/0.21] * (0.03kmol/kg + 0.07 kmol/kg)
= 7.82 m^3/kg

$V_{n,FG,h}$ = $V_{n,CO2,h}$ + $V_{n,O2,h}$ + $V_{n,N2,h}$ = 0.3 + 1.48 + 7.82 = 9.61 m^3/kg

$\rho_{RG,n,h}$ = P_n * $MM_{RG,h}$ / (R_u * T_n)
= 101,325 Pa * 24.16 kg/mol / (8,314Pam3/kmol. K * 273.15K)
= 1.08kg/m^3

$FV_{RG,h}$ = $V_{t,wb}$ = 332.83Nm^3/h

$FM_{RG,h}$ = $\rho_{RG,n,h}$ * $FV_{RG,h}$ = 1.08kg/m^3 * 332.83m^3/h = 358.81kg/h

$TV_{n,FG,h}$ = $V_{n,FG,h}$ * $FM_{RG,h}$ = 9.61 m^3/kg * 358.81kg/h = 3,447 m^3/h

$TM_{FG,h}$ = $TV_{n,FG,h}$ * $fv_{CH4,FG,h}$ / 1000000 = (3,447m^3/h * 10.75*0.716 mg/m^3) / 1000000 = 0.0265 kg/h

$\eta_{flare,h}$ = 1 – ($TM_{FG,h}$ / $TM_{RG,h}$) = 1 – (0.0265/76.48) = 0.99965 = 99.97%

PE_{flare1} = ∑$TM_{RG,h}$ x (1 – $\eta_{flare,h}$) x GWP_{CH4}/1000 = 76.48 * (1-99.97%) * 25/1000 = 0.00066

$F_{CH4,flared}$ = $F_{CH4,sent-flare}$ - PE_{flare}/ GWP_{CH4} = 76.44 – 0.00066/25 = 76.44 kg/h

As the value of $F_{CH4,flared}$ here is calculated based on the hourly average interval output; therefore, the total month value of for October 2016:

∑$F_{CH4,flared}$ = the sum of all hourly interval values = 29.54 tCH4

BEy = $BE_{CH4,y}$ = (1-OX_{top_layer}) * ∑$F_{CH4,flared}$ * GWP_{CH4}
= (1-0.1) * 29.54 *25 = 664.68 tCO_{2e}

Calculation Sample 2:

This method is applicable for the period during March 2017 until December 2018.

As the O_2 measurement device was missing calibration since 28th February 2017 till now, we are taking the most conservative method from 1st March 2017 till the end of this monitoring period on 31st December 2018 using default value of 0 and 50% as per Step 6 of the "Tool to determine project emissions from flaring gases containing methane":

"In case of enclosed flares and use of the default value for the flare efficiency, the flare efficiency in the hour h ($\eta_{flare,h}$) is:

• 0% if the temperature in the exhaust gas of the flare (T_{flare}) is below 500 °C for more than 20 minutes during the hour h .

• 50%, if the temperature in the exhaust gas of the flare (T_{flare}) is above 500 °C for more than 40 minutes during the hour h, but the manufacturer's specifications on proper operation of the flare are not met at any point in time during the hour h.

• 90%, if the temperature in the exhaust gas of the flare (T_{flare}) is above 500 °C for more than 40 minutes during the hour h and the manufacturer's specifications on proper operation of the flare are met continuously during the hour h."

ER Calculations for the period during August 2016 till February 2017 remain qualified and thus still use equation 14 on page 10 of the tool.

Therefore, for the period during March 2017 till December 2018, $\eta_{flare,h}$ is not determined by parameters $TM_{FG,h}$ and $TM_{RG,h}$ any more, but by parameter T_{flare} as follows:

$\eta_{flare,h}$ = 0, if T_{flare} is below 500 °C,
$\eta_{flare,h}$ = 0.5 if T_{flare} is above 500 °C.

An example from October 2017 is taken below to demonstrate the calculation:

Table C: Data during 8:00-8:59 and 9:00-9:59 on March 29th, 2017 to calculate $F_{CH4,sent\text{-}flare}$

YYYY_MM	YYYY_MM_DD_HH	CH4 (%)	Flow (Nm3h	Pressure (mbara	Temp (°C)	Humidity (%)	Tflare (°C)	CH4e (vpm)	O2e (%)		ρ_{CH4} ($kgCH_4/m^3CH$	$F_{CH4,sent\_flare}$ ($kgCH_4/h$)
2017_03	2017_03_29_08	33.49	170.08	1,012.00	56.68	16.23	292.40	28.83	21.13		0.71607	40.79
2017_03	2017_03_29_09	39.01	365.38	1,009.92	45.97	35.45	1,011.33	19.83	20.35		0.71607	102.06

YYYY_MM	YYYY_MM_DD_HH	CH4 (%)	Flow (Nm3h	Pressure (mbara	Temp (°C)	Humidity (%)	Tflare (°C)	CH4e (vpm)	O2e (%)		ρ_{CH4} ($kgCH_4/m^3CH$	$F_{CH4,sent\_flare}$ ($kgCH_4/h$)
2017_03	2017_03_29_08	33.49	170.08	1,012.00	56.68	16.23	292.40	28.83	21.13		0.71566	40.77
2017_03	2017_03_29_09	39.01	365.38	1,009.92	45.97	35.45	1,011.33	19.83	20.35		0.71566	102.00

Notes: During 8:00-8:59, hourly average T_{flare} = 292.40 °C
During 9:00-9:59, hourly average T_{flare} = 1,011.33 °C

Table D: Calculated parameters using meter outputs from Table C to determing $\eta_{flare,h}$ and PE_{flare}

YYYY_MM	YYYY_MM_DD_HH	$MM_{RG,h}$ (kg/kmol)	$\rho_{RG,n,h}$ (kg/m^3)	$FM_{RG,h}$ (kg/h)	$fm_{C,h}$	$fm_{H,h}$	$fm_{N,h}$	F_h (kmol O_2/kg LFG)	$n_{O2,h}$ (kmol/kg LFG)	$V_{n,CO2,h}$ (m^3/kg LFG)	$V_{n,N2,h}$ (m^3/kg LFG)	$V_{n,O2,h}$ (m^3/kg LFG)	$V_{n,FG,h}$ (m^3/kg LFG)	$TV_{n,FG,h}$ (m^3/h)	$TM_{FG,h}$ (kg/h)	$TM_{RG,h}$ (kg/h)	$\eta_{flare,h}$	PE_{flare}
2017_03	2017_03_29_08	23.99	1.07	182.09	0.17	0.06	0.78	0.03	6.44	0.31	544.90	144.22	689.44	125,537	2.5917	40.77	0.00%	1.01917
2017_03	2017_03_29_09	23.33	1.04	380.40	0.20	0.07	0.73	0.03	1.14	0.37	98.77	25.51	124.65	47,418	0.6734	102.00	50.00%	1.27502

Therefore, during 8:00-8:59, as hourly average T_{flare} = 292.40 °C < 500 °C, $\eta_{flare,h}$ = 0.

$PE_{flare2} = \sum TM_{RG,h} \times (1 - \eta_{flare,h}) \times GWP_{CH4}/1000$ = 40.77 * (1-0) * 25/1000 = 1.01917 tCO_2e.

During 9:00-9:59, hourly average T_{flare} = 1,011.33 °C > 500 °C,

$PE_{flare3} = \sum TM_{RG,h} \times (1 - \eta_{flare,h}) \times GWP_{CH4}/1000$ = 102.00 * (1-0.5) * 25/1000 = 1.27502 tCO_2e.

Other calculations follow the same formulae throughout the whole crediting period.

Besides, due to the delay in calibration for the parameter Tflare, the project owner has taken the most conservative approach to remove the total baseline emission for August 2016.

Full detailed calculations of baseline emissions are provided in electronic spreadsheets attached to the monitoring report.

Baseline emissions calculated during the monitoring period: **10,008 tCO_2e**

F.2. Calculation of project emissions or actual net removals

Project emission due to electricity consumption $PE_{EC,y}$:

$PE_{EC,y} = EC_{PJ,j,y} \times EF_{EL,y} \times (1 + TDL_{j,y})$ *(9)*

Where

$EC_{PJ,j,y}$	Net quantity of electricity consumed from the grid (MWh)
$EF_{EL,y}$	Emission factor of the grid used for CPA's electric consumption (tCO_2/MWh)
$TDL_{j,y}$	Average technical transmission and distribution losses in the grid in the year *y*

For Electricity meter measurement for consumption from LFG collection and flaring:
$EC_{PJ,e}$ = 66.617 MWh

Electricity consumption calculated using capacities and operation hours due to the leachate pumping (2 compressors and 10 pumps)

Each compressor has a nominal capacity of 4 kW. To be conservative, we will assume that the compressors have been functioning at full capacity every hours of the monitoring period + 10%, since installation of the pumps.

$EC_{PJ,com}$ = 2 *4kW * 24d/h * (365d *2+153d) * 110% = 186,490kWh = 186.490MWh

Each electric pump has a nominal capacity of 1.1 kW. The pumps have been functioning at full capacity, starting from 30/11/2017 until the end of monitoring period 31/12/2018. To be conservative, we assume full operation of 24 hours per day.

$EC_{PJ,pump}$=10 * 1.1kw *24h/d * (365d+32d)=104,808 kWh = 104.808 MWh

$\mathbf{EC_{PJ,y}}$ **=** $EC_{PJ,e}$ +$EC_{PJ,com}$ +$EC_{PJ,pump}$
= 66.617 MWh +186.490 MWh + 104.808 MWh
= 357.915 MWh

$PE_{EC,y} = EC_{PJ,j,y} \times EF_{EL,y} \times (1 + TDL_{j,y})$
= 357.915 MWh * 0.6639 tCO_2/MWh * 1.2 = 285 tCO_2e

Monitored values of Project Emissions from electricity consumed by the CPA during the monitoring period are: **285 tCO_2e**.

Fulll detailed calculations of project emissions are provided in electronic spreadsheets attached to the monitoring report.

F.3. Calculation of leakage emissions

No leakage is considered for the PoA.

F.4. Calculation of emission reductions or net anthropogenic removals

ER = BE - PE

CPA UNFCCC reference number	Baseline GHG emissions or baseline net GHG removals (t CO_2e)	Project GHG emissions or actual net GHG removals (t CO_2e)	Leakage GHG emissions (t CO_2e)	GHG emission reductions or net anthropogenic GHG removals (t CO_2e)		
				Before 01/01/2013	From 01/01/2013	Total amount
CPA 6568-P1-0001-CP1	**10,008**	285	0	0	9,723	9,723
Total	**10,008**	285	0	0	9,723	9,723

F.5. Comparison of emission reductions or net anthropogenic removals achieved with estimates in the included CPA-DDs

(1) The monitoring period started on 01/08/2016, so we compare the CPA-DD value at this date.

CPA UNFCCC reference number	Amount achieved during this monitoring period (t CO_2e)	Amount estimated ex ante for this monitoring period in the CPA-DD (t CO_2e)
CPA 6568-P1-0001-CP1	9,723	321,922
Total	9,723	321,922

F.5.1. Explanation of calculation of "amount estimated ex ante for this monitoring period in the CPA-DD"

The amount estimated ex ante for this monitoring period in this CPA is calculated as follows:

321,922 tCO_2e = 5/12(1) months in 2016 * 121,836 tCO_2e + 131,122 tCO_2e in 2017 + 140,035 tCO_2e in 2018.

The Values for 2016, 2017 ad 2018 are based on the latest approved version 6.0 of CPA-DD page 37 Section B4.4 Summary of ex ante estimates of emission reductions (https://cdm.unfccc.int/filestorage/E/M/8/EM8K5XBO10IYL7J9NZV6D2WF43SHUP/OumAzza%20CPA_DD_21Aug2019_Clean.pdf?t=RWV8cWpvZmtzfDCeNSoXq0gH2GDUSp4ss85o):

Year	Baseline emissions ($t\ CO_2e$)	Project emissions ($t\ CO_2e$)	Leakage ($t\ CO_2e$)	Emission reductions ($t\ CO_2e$)
01/03/2013-31/12/2013	75,781	152	0	75,629
2014	101,949	182	0	101,767
2015	112,268	182	0	112,086
2016	122,018	182	0	121,836
2017	131,304	182	0	131,122
2018	140,217	182	0	140,035
2019	148,833	182	0	148,651

F.6. Remarks on increase in achieved emission reductions

There was no increase in achieved emimssion reductions but a decrease. The difference between the values estimated in ex-ante calculation and the values actually achieved is due to a lower amount of landfill gas generated in the landfill due to the presence of leachate and no power generation.

F.7. Remarks on scale of small-scale CPAs

Not applicable. The section is left blank intentionally.

Document information

Version	*Date*	*Description*
03.0	31 May 2019	Revision to: • Ensure consistency with version 02.0 of the “CDM project standard for programmes of activities” (CDM-EB93-A07-STAN); • Add a section on remarks on the observance of the scale limit of small-scale CPAs during the crediting periods; • Add "changes specific to afforestation or reforestation activities/CPA" as a possible post-registration changes; • Clarify the reporting of net anthropogenic GHG removals for A/R PoAs between two commitment periods; • Make structural and editorial improvements.
02.0	7 June 2017	Revision to: • Ensure consistency with version 01.0 of the “CDM project standard for programmes of activities (CDM-EB93-A07-STAN); • Make editorial improvements.
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