

CDM-MP77-A08

Draft Methodological tool

TOOL06: Project emissions from flaring

Version 03.0

DRAFT



United Nations
Framework Convention on
Climate Change

COVER NOTE

1. Procedural background

1. The Executive Board of the clean development mechanism (CDM) (hereinafter referred to as the Board), at its eighty-fifth meeting, requested the MP to recommend a revision to the "TOOL06: Project emissions from flaring" to include non-binding best practice examples.
2. In addition, the Board, at its at ninety-ninth meeting, requested the MP to revise TOOL06 to:
 - (a) Align with the latest version of "TOOL08: Tool to determine the mass flow of a greenhouse gas in a gaseous stream"
 - (b) Enhance the clarity of description of options B.1 and B.2 in TOOL06;
 - (c) Develop a spreadsheet for TOOL06 similar to the one developed for TOOL08.

2. Purpose

3. The purpose of the draft revision is to:
 - (a) To clarify methodological provisions that could trigger potential issues in requests for registration or issuance of CERs for CDM project activities applying the tool;
 - (b) Enhance the understanding of the tool and facilitate its application by project participants.

3. Key issues and proposed solutions

4. In order to identify methodological issues that could be addressed through best-practice examples, the secretariat analyzed:
 - (a) The current provisions of the methodology in order to identify methodological bottlenecks;
 - (b) The database of project submissions to identify methodological issues raised at information and report check stage, summary note stage and in requests for review.

4. Impacts

5. The revision will streamline the applicability of the tool and facilitate its usability by the project participants.

5. Subsequent work and timelines

6. The MP, at its 77th meeting, agreed on the draft revised methodological tool to seek public inputs. If inputs are received, the inputs will be taken into account when preparing the recommendation to the Board. If no inputs are received, the methodological tool is

recommended by the MP for consideration by the Board at its one-hundred-first meeting. No further work is envisaged.

6. Recommendations to the Board

7. If no inputs are received during the call for public input, the MP recommends that the Board adopt this final draft methodological tool, to be made effective at the time of the Board's approval. If inputs are received, this section is not applicable.

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1. Introduction

1. This tool provides procedures to calculate project emissions from flaring of a residual gas, where the component with the highest concentration is methane. The source of the residual gas is biogenic (e.g. landfill gas or biogas from wastewater treatment) or coal mine methane¹.

2. Scope, applicability, and entry into force

2.1. Scope and Applicability

2. This tool provides procedures to calculate project emissions from flaring of a residual gas. The tool is applicable to enclosed or open flares and project participants should document in the CDM-PDD the type of flare used in the project activity.
3. This tool is applicable to the flaring of flammable greenhouse gases where:
 - (a) Methane is the component with the highest concentration in the flammable residual gas; and
 - (b) The source of the residual gas is coal mine methane or a gas from a biogenic source (e.g. biogas, landfill gas or wastewater treatment gas).
4. The tool is not applicable to the use of auxiliary fuels and therefore the residual gas must have sufficient flammable gas present to sustain combustion. For the case of an enclosed flare, there shall be operating specifications provided by the manufacturer of the flare.

- ~~5. This methodology refers to the latest approved version of the "Tool to determine the mass flow of a greenhouse gas in a gaseous stream". The applicability conditions of this tool also apply.~~

2.2. Entry into force

6. The date of entry into force is the date of the publication of the EB XX meeting report on DD Month YYYY.

3. Parameters

7. This tool provides procedures to determine the following parameter:

Parameter	SI Unit	Description
$PE_{flare,y}$	t CO ₂ e	Project emissions from flaring of the residual gas in year y

4. Normative references

- (a) Fundamentals of Classical Thermodynamics; Gordon J. Van Wylen, Richard E. Sonntag and Claus Borgnakke; 4^o Edition, 1994, John Wiley & Sons, Inc.

¹ Emissions of CO₂ from the combustion of coal mine methane shall be accounted by the respective applicable methodology.

(b) Environment Agency Guidance for monitoring enclosed landfill gas flares. LFTGN05 v2 2010.

8. This methodology refers to the latest approved version of the following tools:

(a) "Tool to determine the mass flow of a greenhouse gas in a gaseous stream".

5. Definitions

9. The definitions contained in the Glossary of CDM terms shall apply.

10. For the purpose of this tool, the following definitions apply:

- (a) **Auxiliary fuel** - additional fuel added to the residual gas to increase the calorific value to the point where the mixture will sustain continuous combustion. Auxiliary fuel where needed is normally propane supplied from cylinders of gas or methane from a gas main;
- (b) **Enclosed flare** - devices where the residual gas is burned in a vertical cylindrical or rectilinear enclosure, where the flame enclosure is more than 2 times the diameter of the enclosure. The device includes a burning system and a damper where air intake system based on natural or forced draft for the combustion reaction is admitted;
- (c) **Exhaust gas (EG)** - combustion gases gas emitted from the flaring flare, following the flaring of residual gas as part of the project activity;
- (d) **Flare efficiency** - methane destruction efficiency of the flare, defined as one minus the ratio between the mass flow of methane in the exhaust gas and the mass flow of methane in residual gas to be flared (both referred to in dry basis and reference conditions);
- (e) **Flare specification** - the manufacturer's design specification of the flare, which includes: the minimum and maximum flow rate and/or heat flux; the other minimum and maximum operating conditions temperature; and the location(s) of temperature sensors details for the controlling devices;
- (f) **Low height flare** - an enclosed flare for which the flame enclosure has a height between 1.0 ten and two times the diameter of the combustion enclosure;
- ~~(g) **Maintenance schedule** - the flare manufacturer's specification for the schedule of routine maintenance that is required to maintain the flare in good working order. This is typically expressed as the desirable time between maintenance events;~~
- ~~(h) **Manufacturer** - the original manufacturer of the flare, or its authorized agent for undertaking the manufacture of the flare;~~
- (i) **Open flare** - device where the residual gas is burned in an open-air tip with or without any auxiliary fluid assistance or a flare with a vertical cylindrical or rectilinear enclosure, for which the flame enclosure is less than 2 times the diameter of the enclosure;
- (j) **Reference conditions** - reference conditions are defined as 0°C (273.15 K, 32°F) and 1 atm (101.325 kN/m², 101.325 kPa, 14.69 psia, 29.92 in Hg, 760 torr);

- (k) **Residual gas (RG)** - gas containing methane that is to be flared as part of the project activity;
- (l) **Residual gas component** - chemical molecules composing the residual gas (CH₄, CO, CO₂, O₂, H₂, H₂S, NH₃, N₂).

6. Methodological procedure

- 11. The calculation procedure in this tool determines the project emissions from flaring the residual gas ($PE_{flare,y}$) based on the flare efficiency ($\eta_{flare,m}$) and the mass flow of methane to the flare ($F_{CH_4,RG,m}$). The flare efficiency is determined for each minute m of year y based either on monitored data or default values.
- 12. The project emissions calculation procedure is given in the following steps:
 - (a) STEP 1: Determination of the methane mass flow of the residual gas;
 - (b) STEP 2: Determination of the flare efficiency;
 - (c) STEP 3: Calculation of project emissions from flaring.
- 13. An excel sheet that can be used to calculate the project emissions following this procedure (STEP 1, STEP 2 and STEP 3) is provided at the following weblink on the UNFCCC CDM website:
 < <https://cdm.unfccc.int/Reference/tools/index.html> >

6.1. Step 1: Determination of the methane mass flow in the residual gas

- 14. The “Tool to determine the mass flow of a greenhouse gas in a gaseous stream” shall be used to determine the following parameter:

Parameter	SI Unit	Description
$F_{CH_4,m}$	kg	Mass flow of methane in the residual gaseous stream in the minute m

- 15. The following requirements apply:
 - (a) The gaseous stream tool shall be applied to the residual gas;
 - (b) The flow of the gaseous stream shall be measured continuously;
 - (c) CH₄ is the greenhouse gas i for which the mass flow should be determined;
 - (d) The simplification offered for calculating the molecular mass of the gaseous stream is valid (equations 3 and 17 in the tool); and
 - (e) The time interval t for which mass flow should be **calculated-averaged** is every minute m .
- 16. $F_{CH_4,m}$, which is measured as the mass flow during minute m , shall then be used to determine the mass of methane in kilograms fed to the flare in minute m ($F_{CH_4,RG,m}$). $F_{CH_4,m}$ shall be determined on a dry basis.

6.2. Step 2: Determination of flare efficiency

17. The flare efficiency depends on the combustion efficiency of combustion in the flare and the time that the flare is operating. For determining the efficiency of combustion of enclosed flares project participants shall choose to determine the efficiency based on monitored data or the option to apply a default value there is the option to apply a default value or determine the efficiency based on monitored data. For open flares a default value must be applied. The time the flare is operating is determined by monitoring the flame operation using a flame detector and, for the case of enclosed flares, in addition the monitoring requirements provided by the manufacturer's specifications for operating conditions shall be met.

6.2.1. Open flare

18. In the case of open flares, the flare efficiency in the minute m ($\eta_{flare,m}$) is 50% when the flame is detected in the minute m ($Flame_m$), otherwise $\eta_{flare,m}$ is 0%.

6.2.2. Enclosed flare

19. In the case of enclosed flares, project participants may choose between the following two options to determine the flare efficiency for minute m ($\eta_{flare,m}$) and shall document in the CDM-PDD which option is selected:

- (a) Option A: Apply a default value for flare efficiency;
- (b) Option B: Measure the flare efficiency.

20. Project participants may also choose to follow the provisions of Option A above as a backup approach in case of missing data for parameters relevant to the measurement of the flare efficiency (Option B) and shall document this choice in the CDM-PDD.

21. For enclosed flares that are defined as low height flares, the flare efficiency in the minute m ($\eta_{flare,m}$) shall be adjusted, as a conservative approach, by subtracting 0.1 10 percentile points from the efficiency as determined in Options A or B. For example, the default value applied should be 80%, rather than 90%, and if for example the measured value was 99%, then the value to be used shall correspond to 89%.

6.2.2.1. Option A: Default value

22. The flare efficiency for the minute m ($\eta_{flare,m}$) is 90% when the following two conditions are met to demonstrate that the flare is operating:

- (a) The temperature of the flare ($T_{EG,m}$) and the flow rate of the residual gas to the flare ($F_{RG,m}$) is within the manufacturer's specification for the flare ($SPEC_{flare}$) in minute m ; and
- (b) The flame is detected in minute m ($Flame_m$).

23. Otherwise $\eta_{flare,m}$ is 0%.

24. For enclosed flares that are defined as low height flares, the flare efficiency shall be adjusted, as a conservative approach, by subtracting 10 percentile points. For example, the default value applied should be 80%, rather than 90%.

6.2.2.2. Option B: Measured flare efficiency

25. The flare efficiency in the minute m is a measured value ($\eta_{flare,m} = \eta_{flare,calc,m}$) when the following **three** conditions are met to demonstrate that the flare is operating:
- The temperature of the flare ($T_{EG,m}$) and the flow rate of the residual gas to the flare ($F_{RG,m}$) is within the manufacturer's specification for the flare ($SPEC_{flare}$) in minute m ;
 - The flame is detected in minute m ($Flame_m$); and
26. Otherwise $\eta_{flare,m}$ is 0%.
27. **For the measurement of the flare efficiency in applying (Option B), the project participants may choose to determine $\eta_{flare,calc,m}$ using one of the options below: either Option B.1 or Option B.2. Under Option B.1 the measurement is conducted by an accredited entity on a biannual basis and under Option B.2 the flare efficiency is measured in each minute.**
- Option B.1: the measurement is conducted by an accredited entity on a biannual basis;**
 - Option B.2 the flare efficiency is measured in each minute.**

Box 1. Non-binding best practice example 1: Flame detection (option B)

Project participants may choose the flame detector that is appropriate and cost-effective for the project activity, ensuring that the emission reductions are not over-estimated.

Example 1 - A project activity involves the installation and operation of a landfill gas recovery and flaring system.

In order to monitor the operation of the flare, project participants have installed a fixed UV/IR detector, which are sensitive to both Ultra Violet and InfraRed wavelengths, and detects flame by comparing signals of both ranges. This detector operates continuously.

Example 2 - A project activity involves the installation and operation of a biogas recovery and flaring system in an existing industrial facility.

In order to monitor the operation of the flare, project participants have installed a set of thermocouples, which continuously measure temperature, and therefore allow the detection of the presence and absence of flame.

6.2.2.2.1. Option B.1: Biannual measurement of the flare efficiency

28. The calculated flare efficiency $\eta_{flare,calc,m}$ is determined as the average of two measurements of the flare efficiency made in year y ($\eta_{flare,calc,y}$), **adjusted by an uncertainty factor of 5 percentile points** as follows:

$$\eta_{flare,calc,y} = 1 - \frac{1}{2} \sum_{t=1}^2 \left(\frac{F_{CH4,EG,t}}{F_{CH4,RG,t}} \right) - 0.05 \quad \text{Equation (1)}$$

Where:

$\eta_{flare,calc,y}$ = Flare efficiency in the year y

$F_{CH_4,EG,t}$	=	Mass flow of methane in the exhaust gas of the flare on a dry basis at reference conditions in the time period t (kg)
$F_{CH_4,RG,t}$	=	Mass flow of methane in the residual gas on a dry basis at reference conditions in the time period t (kg)
t	=	The two-time periods in year y during which the flare efficiency is measured, each a minimum of one hour and separated by at least six months

29. $F_{CH_4,EG,t}$ is measured according to an appropriate national or international standard. $F_{CH_4,RG,t}$ is calculated according to Step 1, and consists of the sum of methane flow in the minutes m that make up the time period t .

Box 2. Non-binding best practice example 2: Biannual measurement of the flare efficiency (option B.1)

Project participants may choose the approach for the measurement of the flare efficiency that is appropriate and cost-effective for the project activity, ensuring that the emission reductions are not over-estimated.

Example - A project activity involves the installation and operation of a small-scale biogas recovery and flaring system.

The project participants opted to conduct the measurement of the flare efficiency by an accredited entity on biannual basis. This accredited entity conducts two measurements per year of the mass flow of methane in the residual gas (kg) and the mass flow of methane in the exhaust gas of the flare (kg). The two measurements for each parameter are taken during at least one hour.

The flare efficiency for year y is calculated based on the average of the two measurements on a dry basis at reference conditions, subtracting an uncertainty factor of 5 percentile points.

6.2.2.2.2. Option B.2: Measurement of flare efficiency in each minute

30. The flare efficiency ($\eta_{flare,calc,m}$) is determined based on monitoring the methane content in the exhaust gas, the residual gas, and the air used in the combustion process during the minute m in year y , as follows:

$$\eta_{flare,calc,m} = 1 - \frac{F_{CH_4,EG,m}}{F_{CH_4,RG,m}} \quad \text{Equation (2)}$$

Where:

$\eta_{flare,calc,m}$	=	Flare efficiency in the minute m
$F_{CH_4,EG,m}$	=	Mass flow of methane in the exhaust gas of the flare on a dry basis at reference conditions in the minute m (kg)
$F_{CH_4,RG,m}$	=	Mass flow of methane in the residual gas on a dry basis at reference conditions in the minute m (kg)

31. $F_{CH_4,RG,m}$ is calculated according to Step 1.

32. Determine $F_{CH_4,EG,m}$ according to Steps 2.1 - 2.4 below:

6.2.3. Step 2.1: Determine the methane mass flow in the exhaust gas on a dry basis

33. The mass flow of methane in the exhaust gas is determined based on the volumetric flow of the exhaust gas and the measured concentration of methane in the exhaust gas, as follows:

$$F_{CH_4,EG,m} = V_{EG,m} \times f_{c_{CH_4,EG,m}} \times 10^{-6} \quad \text{Equation (3)}$$

Where:

$F_{CH_4,EG,m}$	=	Mass flow of methane in the exhaust gas of the flare on a dry basis at reference conditions in the minute m (kg)
$V_{EG,m}$	=	Volumetric flow of the exhaust gas of the flare on a dry basis at reference conditions in minute m (m ³)
$f_{c_{CH_4,EG,m}}$	=	Concentration of methane in the exhaust gas of the flare on a dry basis at reference conditions in minute m (mg/m ³)

6.2.4. Step 2.2: Determine the volumetric flow of the exhaust gas ($V_{EG,m}$)

34. Determine the average volume flow of the exhaust gas in minute m based on a stoichiometric calculation of the combustion process. This depends on the chemical composition of the residual gas, the amount of air supplied to combust it and the composition of the exhaust gas. It is calculated as follows:

$$V_{EG,m} = Q_{EG,m} \times M_{RG,m} \quad \text{Equation (4)}$$

Where:

$V_{EG,m}$	=	Volumetric flow of the exhaust gas on a dry basis at reference conditions in minute m (m ³)
$Q_{EG,m}$	=	Volume of the exhaust gas on a dry basis at reference conditions per kilogram of residual gas on a dry basis at reference conditions in minute m (m ³ exhaust gas/kg residual gas)
$M_{RG,m}$	=	Mass flow of the residual gas on a dry basis at reference conditions in the minute m (kg)

6.2.5. Step 2.3: Determine the mass flow of the residual gas ($M_{RG,m}$)

35. Project participants may select to monitor the mass flow of the residual gas in minute m directly (see monitored parameter $M_{RG,m}$) or, according to the procedure given in this step, calculate $M_{RG,m}$ based on the volumetric flow and the density of the residual gas. The density of the residual gas is determined based on the volumetric fraction of all components in the gas.

$$M_{RG,m} = \rho_{RG,ref,m} \times V_{RG,m} \quad \text{Equation (5)}$$

Where:

- $M_{RG,m}$ = Mass flow of the residual gas on a dry basis at reference conditions in minute m (kg)
- $\rho_{RG,ref,m}$ = Density of the residual gas at reference conditions in minute m (kg/m³)
- $V_{RG,m}$ = Volumetric flow of the residual gas on a dry basis at reference conditions in the minute m (m³)

and

$$\rho_{RG,ref,m} = \frac{P_{ref}}{\frac{R_u}{MM_{RG,m}} \times T_{ref}} \quad \text{Equation (6)}$$

Where:

- $\rho_{RG,ref,m}$ = Density of the residual gas at reference conditions in minute m (kg/m³)
- P_{ref} = Atmospheric pressure at reference conditions (Pa)
- R_u = Universal ideal gas constant (Pa.m³/kmol.K)
- $MM_{RG,m}$ = Molecular mass of the residual gas in minute m (kg/kmol)
- T_{ref} = Temperature at reference conditions (K)

36. Use the equation below to calculate $MM_{RG,m}$. When applying this equation, project participants may choose to either a) use the measured volumetric fraction of each component i of the residual gas, or b) as a simplification, measure the volumetric fraction of methane and consider the difference to 100% as being nitrogen (N₂). The same equation applies, irrespective of which option is selected.

$$MM_{RG,m} = \sum_i (v_{i,RG,m} \times MM_i) \quad \text{Equation (7)}$$

Where:

- $MM_{RG,m}$ = Molecular mass of the residual gas in minute m (kg/kmol)
- MM_i = Molecular mass of residual gas component i (kg/kmol)
- $v_{i,RG,m}$ = Volumetric fraction of component i in the residual gas on a dry basis at reference conditions in the hour h
- i = Components of the residual gas. If Option (a) is selected to measure the volumetric fraction, then $i = \text{CH}_4, \text{CO}, \text{CO}_2, \text{O}_2, \text{H}_2, \text{H}_2\text{S}, \text{NH}_3, \text{N}_2$ or if Option (b) is selected then $i = \text{CH}_4$ and N_2

6.2.6. Step 2.4: Determine the volume of the exhaust gas on a dry basis at reference conditions per kilogram of residual gas ($Q_{EG,m}$)

37. $Q_{ECO2,EG,m}$ shall be determined as follows:

$$Q_{EG,m} = Q_{CO2,EG,m} + Q_{O2,EG,m} + Q_{N2,EG,m} \quad \text{Equation (8)}$$

Where:

- $Q_{EG,m}$ = Volume of the exhaust gas on a dry basis per kg of residual gas on a dry basis at reference conditions in the minute m (m^3/kg residual gas)
- $Q_{CO2,EG,m}$ = Quantity of CO_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m^3/kg residual gas)
- $Q_{N2,EG,m}$ = Quantity of N_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m^3/kg residual gas)
- $Q_{O2,EG,m}$ = Quantity of O_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m^3/kg residual gas)

with

$$Q_{O2,EG,m} = n_{O2,EG,m} \times VM_{ref} \quad \text{Equation (9)}$$

Where:

- $Q_{O2,EG,m}$ = Quantity of O_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m^3/kg residual gas)
- $n_{O2,EG,m}$ = Quantity of O_2 (moles) in the exhaust gas per kg of residual gas flared on a dry basis at reference conditions in minute m (kmol/kg residual gas)
- VM_{ref} = Volume of one mole of any ideal gas at reference temperature and pressure ($m^3/kmol$)

$$Q_{N2,EG,m} = VM_{ref} \times \left\{ \frac{MF_{N,RG,m}}{2 \times AM_N} + \left(\frac{1 - v_{O2,air}}{v_{O2,air}} \right) \times [F_{O2,RG,m} + n_{O2,EG,m}] \right\} \quad \text{Equation (10)}$$

Where:

- $Q_{N2,EG,m}$ = Quantity of N_2 (volume) in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m^3/kg residual gas)
- VM_{ref} = Volume of one mole of any ideal gas at reference temperature and pressure ($m^3/kmol$)

$MF_{N,RG,m}$	=	Mass fraction of nitrogen in the residual gas in the minute m
AM_N	=	Atomic mass of nitrogen (kg/kmol)
$v_{O_2,air}$	=	Volumetric fraction of O ₂ in air
$F_{O_2,RG,m}$	=	Stoichiometric quantity of moles of O ₂ required for a complete oxidation of one kg residual gas in minute m (kmol/kg residual gas)
$n_{O_2,EG,m}$	=	Quantity of O ₂ (moles) in the exhaust gas per kg of residual gas flared on a dry basis at reference conditions in minute m (kmol/kg residual gas)

$$Q_{CO_2,EG,m} = \frac{MF_{C,RG,m}}{AM_C} \times VM_{ref} \quad \text{Equation (11)}$$

Where:

$Q_{CO_2,EG,m}$	=	Quantity of CO ₂ volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m ³ /kg residual gas)
$MF_{C,RG,m}$	=	Mass fraction of carbon in the residual gas in the minute m
AM_C	=	Atomic mass of carbon (kg/kmol)
VM_{ref}	=	Volume of one mole of any ideal gas at reference temperature and pressure (m ³ /kmol)

$$n_{O_2,EG,m} = \frac{v_{O_2,EG,m}}{\left(1 - (v_{O_2,EG,m}/v_{O_2,air})\right)} \times \left[\frac{MF_{C,RG,m}}{AM_C} + \frac{MF_{N,RG,m}}{2 \times AM_N} + \left(\frac{1 - v_{O_2,air}}{v_{O_2,air}} \right) \times F_{O_2,RG,m} \right] \quad \text{Equation (12)}$$

Where:

$n_{O_2,EG,m}$	=	Quantity of O ₂ (moles) in the exhaust gas per kg of residual gas flared on a dry basis at reference conditions in minute m (kmol/kg residual gas)
$v_{O_2,EG,m}$	=	Volumetric fraction of O ₂ in the exhaust gas on a dry basis at reference conditions in the minute m
$v_{O_2,air}$	=	Volumetric fraction of O ₂ in the air
$MF_{C,RG,m}$	=	Mass fraction of carbon in the residual gas in the minute m
AM_C	=	Atomic mass of carbon (kg/kmol)
$MF_{N,RG,m}$	=	Mass fraction of nitrogen in the residual gas in the minute m
AM_N	=	Atomic mass of nitrogen (kg/kmol)

$F_{O_2,RG,m}$ = Stoichiometric quantity of moles of O₂ required for a complete oxidation of one kg residual gas in minute m (kmol/kg residual gas)

$$F_{O_2,RG,m} = \frac{MF_{C,RG,m}}{AM_C} + \frac{MF_{H,RG,m}}{4AM_H} - \frac{MF_{O,RG,m}}{2AM_O} \quad \text{Equation (13)}$$

Where:

$F_{O_2,RG,m}$ = Stoichiometric quantity of moles of O₂ required for a complete oxidation of one kg residual gas in minute m (kmol/kg residual gas)

$MF_{C,RG,m}$ = Mass fraction of carbon in the residual gas in the minute m

AM_C = Atomic mass of carbon (kg/kmol)

$MF_{O,RG,m}$ = Mass fraction of oxygen in the residual gas in the minute m

AM_O = Atomic mass of oxygen (kg/kmol)

$MF_{H,RG,m}$ = Mass fraction of hydrogen in the residual gas in the minute m

AM_H = Atomic mass of hydrogen (kg/kmol)

38. Determine the mass fractions of carbon, hydrogen, oxygen and nitrogen in the residual gas, using the volumetric fraction of component i in the residual gas and applying the equation below. In applying this equation, the project participants may choose to either a) use the measured volumetric fraction of each component i of the residual gas, or (b) as a simplification, measure the volumetric fraction of methane and consider the difference to 100% as being nitrogen (N₂). The same equation applies, irrespective of which option is selected.

$$MF_{j,RG,m} = \frac{\sum_i v_{i,RG,m} \times AM_j \times NA_{j,i}}{MM_{RG,m}} \quad \text{Equation (14)}$$

Where:

$MF_{j,RG,m}$ = Mass fraction of element j in the residual gas in the minute m

$v_{j,RG,m}$ = Volumetric fraction of component i in the residual gas on a dry basis in the minute m

AM_j = Atomic mass of element j (kg/kmol)

$NA_{j,i}$ = Number of atoms of element j in component i

$MM_{RG,m}$ = Molecular mass of the residual gas in minute m (kg/kmol)

j = elements C, O, H and N

i = Component of residual gas. If Option (a) is selected to measure the volumetric fraction, then $i = \text{CH}_4, \text{CO}, \text{CO}_2, \text{O}_2, \text{H}_2, \text{H}_2\text{S}, \text{NH}_3, \text{N}_2$ or if Option (b) is selected then $i = \text{CH}_4$ and N_2

39. For enclosed flares that are defined as low height flares, the flare efficiency in the minute m ($\eta_{flare,m}$) shall be adjusted, as a conservative approach, by subtracting 10 percentile points from the efficiency. For example, if the measured value was 99%, then the value to be used shall correspond to 89%.

6.3. Step 3: Calculation of project emissions from flaring

40. Project emissions from flaring are calculated as the sum of emissions for each minute m in year y , based on the methane mass flow in the residual gas ($F_{CH4,RG,m}$) and the flare efficiency ($\eta_{flare,m}$), as follows:

$$PE_{flare,y} = GWP_{CH4} \times \sum_{m=1}^{525600} F_{CH4,RG,m} \times (1 - \eta_{flare,m}) \times 10^{-3} \quad \text{Equation (15)}$$

Where:

- $PE_{flare,y}$ = Project emissions from flaring of the residual gas in year y (tCO₂e)
- GWP_{CH4} = Global warming potential of methane valid for the commitment period (tCO₂e/tCH₄)
- $F_{CH4,RG,m}$ = Mass flow of methane in the residual gas in the minute m (kg)
- $\eta_{flare,m}$ = Flare efficiency in minute m

6.4. Data and parameters not monitored

41. Parameters and data that are not monitored include the constants used in equations, as listed in Table 1 below.

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 _{ref}	Pa	Atmospheric pressure at reference conditions	101 325
R _u	Pa.m ³ /kmol.K	Universal ideal gas constant	0.008314472

Parameter	SI Unit	Description	Value
T_{ref}	K	Temperature at reference conditions	273.15
$VO_{2,air}$	Dimensionless	O ₂ volumetric fraction of air	0.21
GWP_{CH_4}	tCO ₂ /tCH ₄	Global warming potential of methane valid for the commitment period	21 (for the first commitment period)
MV_n	m ³ /Kmol	Volume of one mole of any ideal gas at reference conditions	22.414
$\rho_{CH_4, n}$	kg/m ³	Density of methane gas at reference conditions	0.716
$NA_{i,j}$	Dimensionless	Number of atoms of element j in component i, depending on molecular structure	
VM_{ref}	m ³ / kmol	Volume of one mole of any ideal gas at reference temperature and pressure	22.4

Data / Parameter table 1.

Data / Parameter:	GWP_{CH_4}
Data unit:	tCO ₂ e/tCH ₄
Description:	Global warming potential of methane valid for the commitment period
Source of data:	IPCC
Value to be applied:	21 for the first commitment period. Default value of 25 from IPCC. Shall be updated for future commitment periods according to any future COP/MOP decisions
Any comment:	-

Data / Parameter table 2.

Data / Parameter:	$SPEC_{flare}$
Data unit:	Temperature - °C Flow rate or heat flux - kg/h or m ³ /h Maintenance schedule - number of days
Description:	Manufacturer's flare specifications for temperature, flow rate and maintenance schedule
Source of data:	Flare manufacturer
Value to be applied:	Document in the CDM-PDD the flare specifications set by the manufacturer for the correct operation of the flare for the following parameters: (a) Minimum and maximum inlet flow rate, if necessary converted to flow rate at reference conditions or heat flux; (b) Minimum and maximum operating temperature; and (c) Maximum duration in days between maintenance events

Any comment:	Only applicable in case of enclosed flares. The maintenance schedule is not required if Option A is selected to determine flare efficiency of an enclosed flare
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7. Monitoring methodology procedure

7.1. Data and parameters to be monitored

42. All monitored data must be linked in time, i.e. calculations shall be performed considering only a set of data acquired in the same time interval in case of continuous monitoring. Project participants shall use one minute or a smaller discrete time interval for reporting purposes.

Data / Parameter table 3.

Data / Parameter:	$F_{CH_4,EG,t}$
Data unit:	kg
Description:	Mass flow of methane in the exhaust gas of the flare on a dry basis at reference conditions in the time period t
Source of data:	Measurements undertaken by a third party accredited entity
Measurement procedures (if any):	<p>Measure the mass flow of methane in the exhaust gas according to an appropriate national or international standard e.g. UKs Technical Guidance LFTGN05.</p> <p>The time period t over which the mass flow is measured must be at least one hour.</p> <p>The average flow rate to the flare during the time period t must be greater than the average flow rate observed for the previous six months</p>
Monitoring frequency:	Biannual
QA/QC procedures:	According to the standard applied
Any comment:	Monitoring of this parameter is required in the case of enclosed flares and if the project participants select Option B.1 to determine flare efficiency

Data / Parameter table 4.

Data / Parameter:	$T_{EG,m}$
Data unit:	°C
Description:	Temperature in the exhaust gas of the enclosed flare in minute m
Source of data:	Project participants
Measurement procedures (if any):	<p>Measure the temperature of the exhaust gas in the flare by an appropriate temperature measurement equipment. Measurements outside the operational temperature specified by the manufacturer may indicate that the flare is not functioning correctly and may require maintenance.</p> <p>Flare manufacturers must provide suitable monitoring ports for the monitoring of the temperature of the flare. These would normally be expected to be in the middle third of the flare.</p> <p>Where more than one temperature port is fitted to the flare, the flare manufacturer must provide written instructions detailing the conditions under which each location shall be used and the port most suitable for monitoring the operation of the flare according to manufacturers specifications for temperature</p>
Monitoring frequency:	Once per minute
QA/QC procedures:	Temperature measurement equipment should be replaced or calibrated in accordance with their maintenance schedule
Any comment:	<p>Unexpected changes such as a sudden increase/drop in temperature can occur for different reasons. These events should be noted in the site records along with any corrective action that was implemented to correct the issue.</p> <p>Monitoring of this parameter is applicable in case of enclosed flares. Measurements are required to determine if manufacturer's flare specifications for operating temperature are met</p>

Data / Parameter table 5.

Data / Parameter:	$V_{i,RG,m}$
Data unit:	-
Description:	Volumetric fraction of component i in the residual gas on a dry basis in the minute m where $i = \text{CH}_4, \text{CO}, \text{CO}_2, \text{O}_2, \text{H}_2, \text{H}_2\text{S}, \text{NH}_4, \text{N}_2$
Source of data:	Measurements by project participants using a continuous gas analyser
Measurement procedures (if any):	Measurement may be made on either dry or wet basis. If value is made on a wet basis, then it shall be converted to dry basis for reporting
Monitoring frequency:	Continuously. Values to be averaged on a minute basis
QA/QC procedures:	Analysers must be periodically calibrated according to the manufacturer's recommendation. A zero check and a typical value check should be performed by comparison with a standard certified gas

Any comment:	As a simplified approach, project participants may only measure the content CH ₄ , CO and CO ₂ of the residual gas and consider the remaining part as N ₂ . Monitoring of this parameter is only applicable in case of enclosed flares and continuous monitoring of the flare efficiency
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Data / Parameter table 6.

Data / Parameter:	$V_{RG,m}$
Data unit:	m ³
Description:	Volumetric flow of the residual gas on a dry basis at reference conditions in the minute m
Source of data:	Measurements by project participants using a flow meter
Measurement procedures (if any):	Instruments with recordable electronic signal (analogical or digital)
Monitoring frequency:	Continuously. Values to be averaged on a minute basis
QA/QC procedures:	Flow meters are to be periodically calibrated according to the manufacturer's recommendation
Any comment:	Monitoring of this parameter is applicable in case of enclosed flares and continuous monitoring of the flare efficiency and if project participant selects to calculate $V_{RG,m}$ instead of monitoring directly. Monitoring of this parameter may also be necessary for confirming that the manufacturer's specifications for flow rate/heat flux are met. In this case the flow rate should be measured in a m ³ /h basis

Data / Parameter table 7.

Data / Parameter:	$M_{RG,m}$
Data unit:	kg
Description:	Mass flow of the residual gas on a dry basis at reference conditions in the minute m
Source of data:	-
Measurement procedures (if any):	Instruments with recordable electronic signal (analogical or digital)
Monitoring frequency:	Continuous, values to be averaged on a minute basis
QA/QC procedures:	Periodic calibration against a primary device provided by an independent accredited laboratory is mandatory. Calibration and frequency of calibration is according to manufacturer's specifications
Any comment:	Monitoring of this parameter is applicable in case of enclosed flares and continuous monitoring of the flare efficiency and if project participant selects to monitor $M_{RG,m}$ directly, instead of calculating. Monitoring of this parameter may also be necessary for confirming that the manufacturer's specifications for flow rate/heat flux are met. In this case the flow rate should be measured in a kg/h basis

Data / Parameter table 8.

Data / Parameter:	$V_{O_2,EG,m}$
Data unit:	-
Description:	Volumetric fraction of O ₂ in the exhaust gas on a dry basis at reference conditions in the minute <i>m</i>
Source of data:	Measurements by project participants using a continuous gas analyser
Measurement procedures (if any):	Extractive sampling analysers with water and particulates removal devices or in situ analysers for wet basis determination. The point of measurement (sampling point) shall be in the upper section of the flare (80% of total flare height). Sampling shall be conducted with appropriate sampling probes adequate to high temperatures level (e.g. inconel probes)
Monitoring frequency:	Continuously. Values to be averaged on a minute basis
QA/QC procedures:	Analysers must be periodically calibrated according to the manufacturer's recommendation. A zero check and a typical value check should be performed by comparison with a standard gas
Any comment:	Monitoring of this parameter is only applicable in case of enclosed flares and continuous monitoring of the flare efficiency

Data / Parameter table 9.

Data / Parameter:	$f_{CH_4,EG,m}$
Data unit:	mg/m ³
Description:	Concentration of methane in the exhaust gas of the flare on a dry basis at reference conditions in the minute <i>m</i>
Source of data:	Measurements by project participants using a continuous gas analyser
Measurement procedures (if any):	Extractive sampling analysers with water and particulates removal devices or in situ analyser for wet basis determination. The point of measurement (sampling point) shall be in the upper section of the flare in order that the sampling is of the gas after consumption has taken place (80% of total flare height). Sampling shall be conducted with appropriate sampling probes adequate to high temperatures level (e.g. inconel probes)
Monitoring frequency:	Continuously. Values to be averaged on a minute basis
QA/QC procedures:	Analysers must be periodically calibrated according to manufacturer's recommendation. A zero check and a typical value check should be performed by comparison with a standard gas
Any comment:	Monitoring of this parameter is only applicable in case of enclosed flares and continuous monitoring of the flare efficiency. Measurement instruments may read ppmv or % values. To convert from ppmv to mg/m ³ simply multiply by 0.716. 1% equals 10 000 ppmv

Data / Parameter table 10.

Data / Parameter:	<i>Flame_m</i>
Data unit:	Flame on or Flame off
Description:	Flame detection of flare in the minute <i>m</i>
Source of data:	Project participants
Measurement procedures (if any):	Measure using a fixed installation optical flame detector: Ultra Violet detector or Infra-Red or both
Monitoring frequency:	Once per minute. Detection of flame recorded as a minute that the flame was on, otherwise recorded as a minute that the flame was off
QA/QC procedures:	Equipment shall be maintained and calibrated in accordance with manufacturer's recommendations
Any comment:	Applicable to all flares

Data / Parameter table 11.

Data / Parameter:	<i>Maintenance_y</i>
Data unit:	Calendar dates
Description:	Maintenance events completed in year <i>y</i>
Source of data:	Project participants
Measurement procedures (if any):	Record the date that maintenance events were completed in year <i>y</i> . Records of maintenance logs must include all aspects of the maintenance including the details of the person(s) undertaking the work, parts replaced, or needing to be replaced, source of replacement parts, serial numbers and calibration certificates
Monitoring frequency:	Annual
QA/QC procedures:	Records must be kept in a maintenance log for two years beyond the life of the flare
Any comment:	Monitoring of this parameter is required for the case of enclosed flares and the project participant selects Option B to determine flare efficiency. These dates are required so that they can be compared to the maintenance schedule to check that maintenance events were completed within the minimum time between maintenance events specified by the manufacturer (<i>SPEC_{flare}</i>)

IV REFERENCES

Fundamentals of Classical Thermodynamics; Gordon J. Van Wylen, Richard E. Sonntag and Claus Borgnakke; 4^o Edition, 1994, John Wiley & Sons, Inc.

Environment Agency Guidance for monitoring enclosed landfill gas flares. LFTGN05 v2 2010.

Document information

<i>Version</i>	<i>Date</i>	<i>Description</i>
03.0	18 October 2018	<p>MP 77, Annex 8</p> <p>A call for input will be issued for this draft document.</p> <p>If no public inputs are received, this draft document will be considered by the Board at EB 101.</p> <p>The revision includes non-binding best practice examples.</p>
02.0.0	20 July 2012	<p>EB 68, Annex 15</p> <p>The revision:</p> <ul style="list-style-type: none"> • Provides an additional option for determining the methane destruction efficiency of an enclosed flare, using biannual measurements of the efficiency of the flare; • Expands the applicability of the tool to flaring gases that also contain ammonium and hydrogen sulfide; • Defines low height flares and specifies how the methane destruction efficiency shall be determined for this type of flares; • Changes the title from methodological “Tool to determine project emissions from flaring gases containing methane” to “Project emissions from flaring”; • Improves the structure and other editorial aspects.
01.0.0	15 December 2006	<p>EB 28, Annex 13</p> <p>Initial adoption.</p>

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