ARTICLE 6.4 MECHANISM

A6.4-AMT-004

Methodological tool

Project emissions from flaring

Version 01.0

United Nations
Framework Convention on
Climate Change

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1. Introduction

1.1. Scope

1. This methodological tool establishes requirements, approaches and guidelines to determine project emissions (PE) from flaring of a residual gas for which 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).

2. The methodological tool is applicable to enclosed or open flares, and activity participants shall document in the project design document (PDD) the type of flare used in the Article 6.4 activity.

3. This methodological tool establishes requirements to determine the following parameter:

Table 1. Parameters determined

Parameter	SI Unit	Description
$PE_{flare,y}$	tCO_2e	Project emissions (PE) from flaring of the residual gas in year *y*

1.2. Entry into force and validity

4. This methodological tool enters into force on 30 October 2025.

5. This methodological tool remains valid for five years, until 29 October 2025, unless an earlier date applies if the methodological tool is revised or withdrawn in accordance with the "Procedure: Development, revision and clarification of methodologies and methodological tools" (A6.4-PROC-METH-001).[1]

2. Definitions

2.1. General terms

6. The following general terms are applied to the methodological tool:

   (a) "Shall" is used to indicate requirements that must be followed;

   (b) "Should" is used to indicate that, among several options, one course of action is recommended as particularly suitable;

   (c) "May" is used to indicate what is permitted.

2.2. Methodological terms and definitions

7. The following methodological tool terms and definitions are applied to the methodological tool:

   (a) **Activity participant:** A public or private entity that participates in an Article 6.4 activity;

[1] See https://unfccc.int/sites/default/files/resource/A6.4-PROC-METH-001.pdf.

(b) **Auxiliary fuel**: An 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 usually propane supplied from cylinders of gas or processed natural gas from a gas pipeline;

(c) **Enclosed flare**: A device where the residual gas is destroyed in a combustion chamber, where the length of chamber is more than two times the diameter or side of the enclosure. The device includes a burning system and an air intake system based on natural or forced draft, and it must be operated within the ranges specified by the manufacturer for an efficient combustion reaction;

(d) **Exhaust gas (EG):** The combustion gases emitted from the flaring of residual gas;

(e) **Methane destruction efficiency**: The 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 the residual gas to be flared (both referred to on a dry basis and under reference conditions);

(f) **Flare operating specifications**: The manufacturer's specification for operating the flare, which include: the minimum and maximum flow rate and heating value; other minimum and maximum operating conditions; and the details for the controlling devices;

(g) **Low-height flare**: An enclosed flare for which the combustion chamber has a height between two and ten times the diameter of the combustion enclosure;

(h) **Open flare**: A device where the residual gas is burned in an open-air tip, with or without auxiliary assistance, or a flare with a vertical cylindrical or rectilinear combustion chamber, for which the combustion chamber is less than two times the diameter of the enclosure;

(i) **Reference conditions:** Conditions defined as 0ºC (273.15 K, 32ºF) and 1 atm (101.325 kN/m^2, 101.325 kPa, 14.69 psia, 29.92 in Hg, 760 torr);

(j) **Residual gas:** A flammable gas containing methane that is to be flared as part of the Article 6.4 activity;

(k) **Residual gas component:** The chemical molecules composing the residual gas (CH_4, CO, CO_2, O_2, H_2, H_2S, NH_3, N_2).

8. Further definitions from the "Article 6.4 Glossary of Terms", once adopted by the Supervisory Body, shall also apply to this methodological tool.

3. Applicability

9. Mechanism methodologies intending to use this methodological tool shall include a reference to this tool within the mechanism methodology and shall specify for which residual gases it shall be applied.

10. This tool may be used by mechanism methodologies related to emission reductions.

11. This version of the methodological tool applies only to Article 6.4 projects and may be amended in the future to cover activities at other scales (e.g., programmes of activities, policies, sectoral approaches) once the adopted standards for the development of

mechanism methodologies (e.g., additionality standard, baseline-setting standard) are revised to incorporate other scales.

12. This methodological tool is applicable to the flaring of flammable greenhouse gases in the project scenario where:

    (a) Methane is the component with the highest concentration in the flammable residual gas;

    (b) The source of the residual gas is biogenic (e.g., biogas, landfill gas, or wastewater treatment gas); and

    (c) Electric igniters in the flare are only used for start-up or flame recovery in case of flame quenching.

13. This methodological tool is not applicable to the use of auxiliary fuels; therefore, the residual gas must contain sufficient flammable gas to sustain combustion.

14. In the case of an enclosed flare, this methodological tool is applicable only if the flare is operated in line with the operating instructions specified by the manufacturer.

15. The provisions in paragraphs 12 to 14 above shall be demonstrated in the PDD and assessed at the validation. Moreover, the same provisions shall be demonstrated in each monitoring report and be assessed at each verification.

16. The provisions in paragraph 14 above shall be demonstrated in each monitoring report and assessed at each verification.

17. Mechanism methodologies may specify additional provisions for the application of this tool in relation to the mitigation activity types they cover. Where the mechanism methodology referring to this tool specifies approaches that differ from those described in this tool, the requirements contained in the mechanism methodology shall take precedence.

4. Normative and informative references

18. The following normative document is indispensable for the application of this methodological tool. The most recent version of the documents listed shall apply:

    (a) "Methodological tool: Mass flow of a greenhouse gas in a gaseous stream" (hereinafter referred to as "mass flow tool").

19. The following informative documents provide supporting information that may assist in the application of this methodological tool:

    (a) G. J. Van Wylen, R. E. Sonntag, and C. Borgnakke, *Fundamentals of Classical Thermodynamics*, 4th ed. New York: John Wiley & Sons, 1994;

    (b) UK Environment Agency, *Guidance for Monitoring Enclosed Landfill Gas Flares (LFTGN05 v2)*. Bristol: UK Environment Agency, 2010;[2]

[2] See https://www.gov.uk/government/publications/monitoring-enclosed-landfill-gas-flares-lftgn-05.

(c) IPCC, *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 1: General guidance and reporting.* Chapter 3: Uncertainties.[3]

5. Methodological approaches

20. The calculation procedure in this methodological tool determines the PE from flaring the residual gas ($PE_{flare,y}$) based on the methane destruction efficiency ($\eta_{flare,m}$) and the mass flow of methane to the flare ($F_{CH4,RG,m}$). The methane destruction efficiency is determined for each minute *m* of year *y* based either on monitored data or default values.

21. Activity participants shall apply the following steps to determine the PE from flaring:

    (a) Step 1: Determination of the methane mass flow of the residual gas;

    (b) Step 2: Determination of the methane destruction efficiency;

    (c) Step 3: Calculation of PE from flaring.

22. Activity participants may use the “Workbook: Project emissions from flaring”, made available on the UNFCCC website,[4] to calculate project emissions in accordance with Steps 1–3 of this tool. The workbook is provided as a supporting resource to assist in the calculation, but its use is not mandatory.

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

23. Activity participants shall determine the methane mass flow in the residual gas ($F_{CH4,m}$) using the mass flow tool as follows:

    (a) The flow of the gaseous stream sent to the flares shall be measured continuously;

    (b) CH_4 is the greenhouse gas *i* for which the mass flow shall be determined;

    (c) The simplification offered for calculating the molecular mass of the gaseous stream is valid (Equations (3) and (17) in the mass flow tool); and

    (d) The time interval *t* for which mass flow shall be averaged is every minute *m*.

24. $F_{CH4,m}$, 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 the minute m ($F_{CH4,RG,m}$). $F_{CH4,m}$ shall be determined on a dry basis. In cases where the determination is made under different conditions (any of the conditions covered by the mass flow methodological tool), the values shall be corrected to dry basis as per the guidance in the mass flow tool.

5.2. Step 2: Determination of methane destruction efficiency

25. The methane destruction efficiency depends on the type of flare, its combustion efficiency, and the time that the flare is operating. To determine the methane destruction efficiency of enclosed flares, activity participants shall choose to determine the efficiency based on monitored data or apply a default value. For open flares, a default value shall be applied.

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[3] See https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/1_Volume1/19R_V1_Ch03_Uncertainties.pdf.

[4] Currently published together with this methodological tool. However, once the tool is approved by the Supervisory Body the workbook will be published separately.

The time the flare is operating is determined by using a flame detector and, in the case of enclosed flares, by additionally meeting the monitoring requirements provided in the manufacturer's operating specifications for operating conditions.

5.2.1. Open flare

26. In the case of open flares, the methane destruction efficiency in the minute *m* ($\eta_{flare,m}$) is 50 per cent when the flame is detected in the minute *m* ($Flame_m$); otherwise, $\eta_{flare,m}$ is 0 per cent. Additional discount factors to the methane destruction efficiency shall be applied if prescribed in the applicable mechanism methodology.

5.2.2. Enclosed flare

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

    (a) Option A: Apply a default value for methane destruction efficiency;

    (b) Option B: Measure the methane destruction efficiency.

28. In case of missing data for parameters relevant to the measurement of the methane destruction efficiency under Option B above, activity participants may follow the provisions of Option A as a backup approach. The choice shall be documented in the PDD.

29. Additional discount factors to the methane destruction efficiency shall be applied if prescribed in the applied mechanism methodology.

5.2.2.1. Option A: Default value

30. The methane destruction efficiency for minute *m* ($\eta_{flare,m}$) is 90 per cent 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 ($F_{RG,m}$) are within the manufacturer's operating specification for the flare ($SPEC_{flare}$) in minute *m*; and

    (b) The flame is detected in minute *m* ($Flame_m$).

31. Otherwise $\eta_{flare,m}$ is 0 per cent.

32. For enclosed flares that are defined as low-height flares, the methane destruction efficiency shall be adjusted, as a conservative approach, by subtracting 10 percentage points.[5]

[5] For example, the default value applied shall be 80 per cent rather than 90 per cent.

5.2.2.2. Option B: Measured methane destruction efficiency

33. The methane destruction efficiency in minute *m* is a measured value ($\eta_{flare,m} = \eta_{flare,calc,m}$) when the following conditions are met to demonstrate that the flare is operating according to the manufacturer's operating specifications:

    (a) The temperature of the flare ($T_{EG,m}$) and the flow rate of the residual gas to the flare ($F_{RG,m}$) are within the manufacturer's operating specification for the flare ($SPEC_{flare}$) in minute *m*; and

    (b) The flame is detected in minute *m* ($Flame_m$).

34. Otherwise $\eta_{flare,m}$ is 0 per cent.

35. For the measurement of the methane destruction efficiency, activity participants may choose one of the following options:

    (a) Option B.1: The measurement is conducted by an accredited entity at least on a biannual basis;[6]

    (b) Option B.2: The methane destruction efficiency is measured in each minute.

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

> Activity participants may choose a flame detector that is appropriate and cost-effective for the Article 6.4 activity, ensuring that emission reductions are not overestimated.
>
> **Example 1 -** An Article 6.4 activity involves the installation and operation of a landfill gas recovery and flaring system.
>
> To monitor the operation of the flare, activity participants installed a fixed UV/IR detector, which is sensitive to both ultraviolet and infrared wavelengths and detects flame by comparing signals across both ranges. This detector operates continuously.
>
> **Example 2 -** An Article 6.4 activity involves the installation and operation of a biogas recovery and flaring system in an existing industrial facility.
>
> To monitor the operation of the flare, activity participants installed a set of thermocouples, which continuously measure temperature and therefore allow the detection of the presence or absence of flame

5.2.2.2.1. Option B.1: Biannual measurement of the methane destruction efficiency

36. The calculated methane destruction efficiency $\eta_{flare,calc,m}$ shall be determined as the average of at least two measurements of the methane destruction efficiency made in year *y* ($\eta_{flare,calc,y}$), adjusted by an uncertainty factor of 5 percentage points as follows:

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

[6] If the monitoring period is shorter than one year, measurements shall be taken at least twice during the monitoring period, with a maximum interval of six months between each measurement.

Where:

$\eta_{flare,calc,y}$	=	Methane destruction efficiency in the year *y*
$F_{CH4,EG,t}$	=	Mass flow of methane in the exhaust gas of the flare, on a dry basis at reference conditions, in period *t* (kg)
$F_{CH4,RG,t}$	=	Mass flow of methane in the residual gas, on a dry or wet basis at reference conditions, in period *t* (kg), determined based on Step 1
t	=	The two periods in year *y* during which the methane destruction efficiency is measured, each lasting a minimum of one hour and separated by at least six months

37. $F_{CH4,EG,t}$ shall be measured in accordance with an appropriate national or international standard. $F_{CH4,RG,t}$ shall be calculated according to Step 1 and shall consist of the sum of the methane flow in the minutes *m* that make up period *t*.

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

Activity participants may choose the approach for the measurement of the methane destruction efficiency that is appropriate and cost-effective for the Article 6.4 activity, ensuring that the emission reductions are not overestimated.

Example - An Article 6.4 activity involves the installation and operation of a small-scale biogas recovery and flaring system.

The activity participants opted to conduct the measurement of the methane destruction 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). Each measurement is conducted for a minimum of one hour.

The methane destruction efficiency for year *y* is calculated based on the average of the two measurements on a dry basis at reference conditions, with an uncertainty factor of 5 percentage points subtracted

5.2.2.2.2. Option B.2: Measurement of methane destruction efficiency in each minute

38. The methane destruction 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 minute *m* in year *y,* as follows:

$$\eta_{flare,calc,m} = 1 - \frac{F_{CH4,EG,m}}{F_{CH4,RG,m}} \quad \text{Equation (2)}$$

Where:

$\eta_{flare,calc,m}$	=	Methane destruction efficiency in minute *m*
$F_{CH4,EG,m}$	=	Mass flow of methane in the exhaust gas of the flare on a dry basis at reference conditions in minute *m* (kg)
$F_{CH4,RG,m}$	=	Mass flow of methane in the residual gas on a dry or wet basis at reference conditions in minute *m* (kg), determined based on Step 1

39. $F_{CH4,RG,m}$ is calculated according to Step 1, and $F_{CH4,EG,m}$ is determined according to Steps 2.1 - 2.4 below.

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

40. 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:

$$F_{CH4,EG,m} = V_{EG,m} \times fc_{CH4,EG,m} \times 10^{-6} \quad \text{Equation (3)}$$

Where:

$F_{CH4,EG,m}$	=	Mass flow of methane in the exhaust gas of the flare on a dry basis at reference conditions in 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), determined based on Equation (4) below
$fc_{CH4,EG,m}$	=	Concentration of methane in the exhaust gas of the flare on a dry basis at reference conditions in minute *m* (mg/m^3)

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

41. 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 for combustion, 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), determined based on Equation (5) below
$M_{RG,m}$	=	Mass flow of the residual gas on a dry basis at reference conditions in minute *m* (kg), determined based on Step 1

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

42. Activity participants shall determine this parameter using the mass flow tool, applying the following requirements:

(a) CH_4 is the greenhouse gas for which the mass flow shall be determined;

(b) The simplification for an ideal gas is offered for calculating the molecular mass of the gaseous stream (Equations (3) or (17) in the mass flow tool), otherwise *i* = CH_4, CO, CO_2, O_2, H_2, H_2S, NH_3, N_2;

(c) The mass flow should be calculated on a minute basis for each minute *m* in year *y*.

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

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

$$Q_{EG,m} = Q_{O2,EG,m} + Q_{N2,EG,m} + Q_{CO2,EG,m} \quad \text{Equation (5)}$$

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 minute *m* (m^3/kg residual gas)
$Q_{O2,EG,m}$	=	O_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in minute *m* (m^3/kg residual gas), determined based on Equation (6) below
$Q_{N2,EG,m}$	=	N_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in minute *m* (m^3/kg residual gas), determined based on Equation (7) below
$Q_{CO2,EG,m}$	=	CO_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in minute *m* (m^3/kg residual gas), determined based on Equation (8) below

with

$$Q_{O2,EG,m} = n_{O2,EG,m} \times VM_{ref} \quad \text{Equation (6)}$$

Where:

$Q_{O2,EG,m}$	=	O_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in minute *m* (m^3/kg residual gas)
$n_{O2,EG,m}$	=	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), determined based on Equation (9) below
VM_{ref}	=	Volume of one mole of any ideal gas at reference temperature and pressure (m^3/kmol)

$$Q_{N2,EG,m} = VM_{ref} \times \left\{ \frac{MF_{N,RG,m}}{2 \times AM_N} + \left(\frac{1 - v_{O2,air}}{v_{O2,air}} \right) \times \left[F_{O2,RG,m} + n_{O2,EG,m} \right] \right\} \quad \text{Equation (7)}$$

Where:

$Q_{N2,EG,m}$	=	N_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in 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 minute *m*, determined based on Equation (11) below
AM_N	=	Atomic mass of nitrogen (kg/kmol)

$v_{O2,air}$	=	Volumetric fraction of O_2 in air
$F_{O2,RG,m}$	=	Stochiometric quantity of moles of O_2 required for complete oxidation of one kg residual gas in minute *m* (kmol/kg residual gas), determined based on Equation (10) below
$n_{O2,EG,m}$	=	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)

$$Q_{CO2,EG,m} = \frac{MF_{C,RG,m}}{AM_C} \times VM_{ref} \quad \text{Equation (8)}$$

Where:

$Q_{CO2,EG,m}$	=	CO_2 volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in minute *m* (m^3/kg residual gas)
$MF_{C,RG,m}$	=	Mass fraction of carbon in the residual gas in minute *m*, determined based on Equation (11) below
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)

$$n_{O2,EG,m} = \frac{v_{O2,EG,m}}{\left(1 - \left(v_{O2,EG,m}/v_{O2,air}\right)\right)} \times \left[\frac{MF_{C,RG,m}}{AM_C} + \frac{MF_{N,RG,m}}{2 \times AM_N} + \left(\frac{1 - v_{O2,air}}{v_{O2,air}}\right) \times F_{O2,RG,m}\right] \quad \text{Equation (9)}$$

Where:

$n_{O2,EG,m}$	=	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)
$v_{O2,EG,m}$	=	Volumetric fraction of O_2 in the exhaust gas on a dry basis at reference conditions in minute *m*
$v_{O2,air}$	=	Volumetric fraction of O_2 in air
$MF_{C,RG,m}$	=	Mass fraction of carbon in the residual gas in minute *m*, determined based on Equation (11) below
AM_C	=	Atomic mass of carbon (kg/kmol)
$MF_{N,RG,m}$	=	Mass fraction of nitrogen in the residual gas in minute *m*, determined based on Equation (11) below
AM_N	=	Atomic mass of nitrogen (kg/kmol)
$F_{O2,RG,m}$	=	Stochiometric quantity of moles of O_2 required for complete oxidation of one kg residual gas in minute *m* (kmol/kg residual gas)

$$F_{O2,RG,m} = \frac{MF_{C,RG,m}}{AM_C} + \frac{MF_{H,RG,m}}{4AM_H} - \frac{MF_{O,RG,m}}{2AM_O} \quad \text{Equation (10)}$$

Where:

$F_{O2,RG,m}$	=	Stochiometric quantity of moles of O_2 required for 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 minute *m*, determined based on Equation (11) below
AM_C	=	Atomic mass of carbon (kg/kmol)
$MF_{O,RG,m}$	=	Mass fraction of oxygen in the residual gas in minute *m*, determined based on Equation (11) below
AM_O	=	Atomic mass of oxygen (kg/kmol)
$MF_{H,RG,m}$	=	Mass fraction of hydrogen in the residual gas in minute *m*, determined based on Equation (11) below
AM_H	=	Atomic mass of hydrogen (kg/kmol)

44. 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. Activity 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 per cent as being nitrogen (N_2).

The same equation applies in both cases:

$$MF_{j,RG,m} = \frac{\sum_i v_{i,RG,m} \times AM_j \times NA_{j,i}}{MM_{RG,m}}$$ Equation (11)

Where:

$MF_{j,RG,m}$	=	Mass fraction of element *j* in the residual gas in minute *m*
$v_{j,RG,m}$	=	Volumetric fraction of component *i* in the residual gas on a dry basis in 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* = CH_4, CO, CO_2, O_2, H_2, H_2S, NH_3, N_2. If Option (b) is selected, then *i* = CH_4 and N_2.

5.3. Step 3: Calculation of project emissions from flaring

45. PE 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 methane destruction efficiency ($\eta_{flare,m}$), as follows:

$$PE_{flare,y} = GWP_{CH4} \times \sum_{m=1}^{525,600} F_{CH4,RG,m} \times \left(1 - \eta_{flare,calc,m}\right) \times 10^{-3}$$ Equation (12)

Where:

$PE_{flare,y}$	=	Project emissions from flaring of the residual gas in year *y* (tCO_2e)
GWP_{CH4}	=	Global warming potential of methane valid for the commitment period (tCO_2e/tCH_4)
$F_{CH4,RG,m}$	=	Mass flow of methane in the residual gas in minute *m* (kg)
$\eta_{flare,calc,m}$	=	Methane destruction efficiency in the minute *m*, determined based on Equation (2) above

46. For enclosed flares defined as low-height flares, the methane destruction efficiency in minute *m* ($\eta_{flare,m}$) shall be adjusted conservatively by subtracting 10 percentage points from the efficiency. For example, if the measured value was 99 per cent, the value to be used shall be 89 per cent.

5.4. Uncertainty determination

47. The uncertainty shall be determined by considering the uncertainty in data and measurements of all required parameters, following the guidance in “2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories,” Volume 1: General Guidance and Reporting, Chapter 3: Uncertainties. The uncertainty shall be expressed as the standard error of the mean and incorporated into the uncertainty calculations in the mechanism methodology.

5.5. Data and parameters not monitored

48. Parameters and data that are not monitored include the constants used in equations, as listed in Table 2 below. The atomic masses and their uncertainties for C, H, N and O were sourced from the periodic table published by the International Union of Pure and Applied Chemistry (IUPAC).[7] The molar mass of the substances (CH_4, CO, CO_2, O_2, H_2, N_2 and NH_3) were determined based on the number of atoms and their atomic masses, and the uncertainties were calculated based on the error propagation method.

Table 2. Constants used in equations

Parameter	SI Unit	Description	Value	Uncertainty (%)
MM_{CH4}	kg/kmol	Molecular mass of methane	16.0430	± 0.0137

[7] See https://iupac.org/what-we-do/periodic-table-of-elements/

Parameter	SI Unit	Description	Value	Uncertainty (%)
MM_{CO}	kg/kmol	Molecular mass of carbon monoxide	28.0100	± 0.0079
MM_{CO2}	kg/kmol	Molecular mass of carbon dioxide	44.0090	± 0.0064
MM_{O2}	kg/kmol	Molecular mass of oxygen	31.9980	± 0.0063
MM_{H2}	kg/kmol	Molecular mass of hydrogen	2.0160	± 0.0198
MM_{N2}	kg/kmol	Molecular mass of nitrogen	28.0140	± 0.0071
MM_{NH3}	kg/kmol	Molecular mass of ammonia	17.0310	± 0.0070
AM_C	kg/kmol (g/mol)	Atomic mass of carbon	12.011	± 0.0167
AM_H	kg/kmol (g/mol)	Atomic mass of hydrogen	1.0080	± 0.0198
AM_O	kg/kmol (g/mol)	Atomic mass of oxygen	15.999	± 0.0063
AM_N	kg/kmol (g/mol)	Atomic mass of nitrogen	14.007	± 0.0071
P_{ref}	Pa	Atmospheric pressure at reference conditions	101,325	-
R_u	$Pa.m^3/kmol.K$	Universal ideal gas constant	0.008314472	-
T_{ref}	K	Temperature at reference conditions	273.15	-
$v_{O2,air}$	Dimensionless	O_2 volumetric fraction of air	0.21	-
GWP_{CH4}	tCO_2/tCH_4	Global warming potential of methane valid for the commitment period	28	-
$\rho_{CH4,n}$	kg/m^3	Density of methane gas at reference conditions	0.716	± 0.0137
$NA_{i,j}$	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_{CH4}
Description	Global warming potential of methane valid for the commitment period
Data unit	tCO_2e/tCH_4
Equations referred	(12)
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions
Value(s) applied	28
Source of data	☐ Measured ☒ Other sources
Choice of data or measurement methods and procedures	Default value from IPCC AR5. Shall be updated according to any future CMA decisions
Additional comments	-

Data / Parameter table 2.

Data/parameter	***$SPEC_{flare}$***
Description	Manufacturer's flare operating specifications for temperature, flow rate and maintenance schedule
Data unit	**Temperature:** °C **Flow rate or heat flux:** kg/h or m³/h **Maintenance schedule:** number of days
Equations referred	-
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions
Value(s) applied	Document in the PDD the flare operating 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
Source of data	☐ Measured ☒ Other sources
Choice of data or measurement methods and procedures	Operating specifications sourced from the flare manufacturer
Additional comments	Only applicable in case of enclosed flares. The maintenance schedule is not required if Option A is selected to determine methane destruction efficiency of an enclosed flare

6. Monitoring methodology

6.1. Data and parameters to be monitored

49. All monitored data shall be linked in time; that is, calculations shall be performed using only data acquired within the same time interval in the case of continuous monitoring. Activity participants shall use a one-minute or smaller discrete time interval for reporting purposes. The data and parameters to be monitored include:

Data / Parameter table 3.

Data/parameter	$F_{CH4,EG,t}$
Description	Mass flow of methane in the exhaust gas of the flare on a dry basis at reference conditions in the time period *t*
Data unit	kg
Equations referred	(1), (2), (3)
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions
Measurement and updating frequency	Biannual

Measurement methods and procedures	Measure the mass flow of methane in the exhaust gas according to an appropriate national or international standard (e.g., UK Technical Guidance LFTGN05). The time period *t* over which the mass flow is measured shall be at least one hour. The average flow rate to the flare during the time period *t* shall be greater than the average flow rate observed over the previous six months	
Entity/person responsible for the measurement	Third-party accredited entity	
Measuring instrument(s)	*Type of instrument*	>> As per UK Technical Guidance LFTGN05
	Accuracy class	>> As per UK Technical Guidance LFTGN05
	Calibration requirements	>>As per UK Technical Guidance LFTGN05
	Location	>>
QA/QC procedures	According to the standard/guidance applied	
Additional comment	Monitoring of this parameter is required in the case of enclosed flares if activity participants select Option B.1 to determine the methane destruction efficiency	

Data / Parameter table 4.

Data/parameter	$T_{EG,m}$
Description	Temperature in the exhaust gas of the enclosed flare in minute *m*
Data unit	ºC
Equations referred	-
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions
Measurement and updating frequency	Once per minute
Measurement methods and procedures	Measure the temperature of the exhaust gas in the flare using 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. Flare manufacturers shall provide suitable monitoring ports for measuring the temperature of the flare. These would normally be expected to be in the middle third of the flare. Where more than one temperature port is fitted to the flare, manufacturer shall provide written instructions detailing the conditions under which each location shall be used, and which port is most suitable for monitoring the operation of the flare according to the manufacturer's operating specifications for temperature

Entity/person responsible for the measurement	Activity participants	
Measuring instrument(s)	*Type of instrument*	Temperature measurement equipment
	Accuracy class	N/A
	Calibration requirements	As per QA/QC below
	Location	Monitoring ports built on the flare (expected to be in the middle third of the flare)
QA/QC procedures	Temperature measurement equipment shall be replaced or calibrated in accordance with its maintenance schedule	
Additional comment	Unexpected changes, such as a sudden increase or drop in temperature, can occur for different reasons. These events shall be noted in the site records along with any corrective action implemented. Monitoring of this parameter is applicable in the case of enclosed flares. Measurements are required to determine whether the manufacturer's flare operating specifications for operating temperature are met	

Data / Parameter table 5.

Data/parameter	$v_{i,RG,m}$	
Description	Volumetric fraction of component *i* in the residual gas on a dry basis in minute *m* where *i* = CH_4, CO, CO_2, O_2, H_2, H_2S, NH_3, N_2	
Data unit	-	
Equations referred	(11)	
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions	
Measurement and updating frequency	As per the mass flow tool	
Measurement methods and procedures	As per the mass flow tool	
Entity/person responsible for the measurement	Activity participants	
Measuring instrument(s)	*Type of instrument*	As per the mass flow tool
	Accuracy class	As per the mass flow tool
	Calibration requirements	As per the mass flow tool
	Location	
QA/QC procedures	As per the mass flow tool	

Additional comment	As a simplified approach under the mass flow tool, activity participants may measure only the CH_4 content of the residual gas and consider the remaining part as N_2. Monitoring of this parameter is applicable in the case of enclosed flares and continuous monitoring of methane destruction efficiency. The methane content measurement shall be carried out close to a location in the system where a biogas flow measurement takes place

Data / Parameter table 6.

Data/parameter	$F_{CH4,RG,m}$; $F_{CH4,RG,t}$;	
Description	$F_{CH4,RG,m}$: Mass flow of the methane on a dry basis at reference conditions in minute *m* $F_{CH4,RG,t}$: Mass flow of the methane on a dry basis at reference conditions in the time period *t*	
Data unit	kg	
Equations referred	$F_{CH4,RG,m}$: (12) $F_{CH4,RG,t}$: (1)	
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions	
Measurement and updating frequency	As per the mass flow tool	
Measurement methods and procedures	As per the mass flow tool	
Entity/person responsible for the measurement	Activity participants	
Measuring instrument(s)	*Type of instrument*	As per mass flow tool
	Accuracy class	As per mass flow tool
	Calibration requirements	As per mass flow tool
	Location	As per the mass flow tool
QA/QC procedures	As per the mass flow tool	
Additional comment	Monitoring of this parameter is applicable for monitoring the methane destruction efficiency in enclosed flares continuously ($F_{CH4,RG,m}$) or biannually ($F_{CH4,RG,t}$).	

Data / Parameter table 7.

Data/parameter	$M_{RG,m}$
Description	Mass flow of the residual gas on a dry basis at reference conditions in minute *m*
Data unit	Kg

Equations referred	(4), (11)	
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions	
Measurement and updating frequency	As per the mass flow tool	
Measurement methods and procedures	As per the mass flow tool	
Entity/person responsible for the measurement	Activity participants	
Measuring instrument(s)	*Type of instrument*	As per mass flow tool
	Accuracy class	As per mass flow tool
	Calibration requirements	As per mass flow tool
	Location	As per the mass flow tool
QA/QC procedures	As per the mass flow tool	
Additional comment	Monitoring of this parameter is applicable in the case of enclosed flares and continuous monitoring of methane destruction efficiency, and if activity participants select, to monitor $M_{RG,m}$ directly instead of calculating. Monitoring of this parameter may also be necessary to confirm that the manufacturer's specifications for flow rate or heat flux are met. In this case, the flow rate shall be measured in a kg/h basis Monitoring of this parameter may also be necessary to confirm that the manufacturer's specifications for flow rate or heat flux are met. In this case, the flow rate shall be measured in a kg/h basis	

Data / Parameter table 8.

Data/parameter	$v_{O2,EG,m}$
Description	Volumetric fraction of O_2 in the exhaust gas on a dry basis at reference conditions in minute *m*
Data unit	-
Equations referred	(9)
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions
Measurement and updating frequency	Continuously. Values to be averaged on a minute basis
Measurement methods and procedures	Extractive sampling analysers with water and particulate 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 per cent of total flare height)
Entity/person responsible for the measurement	Activity participants

Measuring instrument(s)	*Type of instrument*	Gas analyser
	Accuracy class	N/A
	Calibration requirements	Analysers shall be periodically calibrated according to the manufacturer’s recommendation. A zero check and a typical value check shall be performed by comparison with a standard gas
	Location	Sampling shall be conducted with appropriate probes suitable for high-temperature levels (e.g., Inconel probes)
QA/QC procedures	See calibration requirements	
Additional comment	Monitoring of this parameter is applicable only in the case of enclosed flares and continuous monitoring of methane destruction efficiency	

Data / Parameter table 9.

Data/parameter	$fc_{CH4,EG,m}$	
Description	Concentration of methane in the exhaust gas of the flare on a dry basis at reference conditions in the minute *m*	
Data unit	mg/m^3	
Equations referred	(3)	
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions	
Measurement and updating frequency	Continuously. Values shall be averaged on a minute basis	
Measurement methods and procedures	Extractive sampling analysers with water and particulate removal devices, or in situ analysers for wet basis determination Sampling shall be conducted with appropriate probes for high-temperature levels (e.g., Inconel probes)	
Entity/person responsible for the measurement	Activity participants	
Measuring instrument(s)	*Type of instrument*	Continuous gas analyser
	Accuracy class	N/A
	Calibration requirements	Analysers shall be calibrated periodically according to the manufacturer’s recommendations. A zero check and a typical value check shall be performed by comparison with a standard gas
	Location	The point of measurement (sampling point) shall be in the upper section of the flare (80 per cent of total flare height)
QA/QC procedures	See calibration requirements	
Additional comment	Monitoring of this parameter is only applicable in the case of enclosed flares with continuous monitoring of methane destruction efficiency.	

	Measurement instruments may display ppmv or per cent values. To convert from ppmv to mg/m[3], multiply by 0.716. One per cent equals 10,000 ppmv

Data / Parameter table 10.

Data/parameter	***$Flame_m$***	
Description	Flame detection of flare in the minute *m*	
Data unit	"Flame on" or "Flame off"	
Equations referred	-	
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions	
Measurement and updating frequency	Once per minute	
Measurement methods and procedures	Measure using a fixed installation optical flame detector	
Entity/person responsible for the measurement	Activity participants	
Measuring instrument(s)	*Type of instrument*	Ultra-Violet detector or Infra-Red, or both
	Accuracy class	N/A
	Calibration requirements	Equipment shall be maintained and calibrated in accordance with manufacturer's recommendations
	Location	
QA/QC procedures	See calibration requirements	
Additional comment	Detection of flame recorded as a minute that the flame was on, otherwise recorded as a minute that the flame was off	

Data / Parameter table 11.

Data/parameter	***$Maintenance_m$***
Description	Maintenance events completed in year y
Data unit	Calendar dates
Equations referred	-
Purpose of data	☐ Baseline emissions ☒ Project emissions ☐ Leakage emissions
Measurement and updating frequency	Annual
Measurement methods and procedures	Record the date that maintenance events were completed in year *y*. Maintenance logs shall include all aspects of maintenance, including the details of the person(s) undertaking the work, parts replaced or needing replacement, source of replacement parts, serial numbers, and calibration certificates

Entity/person responsible for the measurement	Activity participants	
Measuring instrument(s)	*Type of instrument*	N/A
	Accuracy class	N/A
	Calibration requirements	N/A
	Location	N/A
QA/QC procedures	Records shall be kept in a maintenance log for two years beyond the operational life of the flare	
Additional comment	Monitoring of this parameter is required for enclosed flares if the activity participants select Option B to determine methane destruction 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 ($SPEC_{flare}$)	

Appendix. Calculation workbook

1. Stakeholders may, on a voluntary basis, use the “Workbook: Project emissions from flaring” for calculating project emissions from flaring available on the UNFCCC website: https://unfccc.int/sites/default/files/resource/A6.4-AMT-004-W1.xlsx.

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