



## **T-VER-P-TOOL-02-04**

### **Tool to Calculate Project Emissions from Flaring**

#### **Version 01**

**Entry into force on 1 March 2023**

## 1. Introduction

This document is a tool for calculating the project emissions from the burning of biogas containing high concentrations of methane. The source of the residual gas is biogenic (e.g. landfill gas or biogas from wastewater treatment) including method/source identification of parameters to be monitored.

## 2. Definitions

- **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 processed natural gas from a gas main.
- **Enclosed flare** - devices where the residual gas is burned in a cylindrical or rectilinear enclosure and where the flame enclosure is more than two times the diameter of the enclosure. The device includes a burning system and air intake system based on natural or forced draft for the combustion reaction.
- **Exhaust gas (EG)** - combustion gases emitted from the flaring of residual gas.
- **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).
- **Flare operating specifications** - the manufacturer's specification for operating the flare, which includes: the minimum and maximum flow rate and other minimum and maximum operating conditions ; and the details for the controlling devices.
- **Low height flare** - an enclosed flare for which the flame enclosure has a height between two and ten times the diameter of the combustion enclosure.
- **Open flare** - device where the residual gas is burned in an open-air tip with or without any auxiliary assistance or a flare with a vertical cylindrical or rectilinear enclosure, for which the flame enclosure is less than two times the diameter of the enclosure.
- **Reference conditions** - reference conditions are defined as 0°C (273.15 K, 32°F) and 1 atm (101.325 kN/m<sup>2</sup>, 101.325 kPa, 14.69 psia, 29.92 in Hg, and 760 torr).
- **Residual gas (RG)** – the flammable gas containing methane that is to be flared as part of the project activity.

### 3. Applicability

3.1 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 PDD the type of flare used in the project activity.

3.2 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).

3.3 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. In the case of an enclosed flare, there shall be operating specifications provided by the manufacturer of the flare and these shall be followed by the project participant.

### 4. Determination of project emission.

Calculation of greenhouse gas emissions from the burning of biogas from project implementation This defines the following computational parameters.

Parameter	Unit	Description:
$PE_{flare,y}$	tCO <sub>2</sub> e	Project emissions from flaring of the residual gas in year y

#### 4.1 Activities that consider greenhouse gas emissions from project implementation.

Type	Activity
Biogas flare	The use of biogas flare systems.

#### 4.2 Calculation of project emissions from flaring.

Greenhouse gas emissions from biogas incineration are calculated based on flare efficiency. and the mass flow of methane to the incineration system. The details are described as follows.

$$PE_{\text{flare},y} = \frac{525,600}{GWP_{\text{CH}_4}} \times \sum_{m=1} F_{\text{CH}_4,\text{RG},m} \times (1 - \eta_{\text{flare},m}) \times 10^{-3} \quad \text{Equation (1)}$$

Where;

- $PE_{\text{flare},y}$  = Project emissions from flaring of the residual gas in year y (tCO<sub>2</sub>e)  
 $GWP_{\text{CH}_4}$  = Global warming potential of methane valid for the commitment period (tCO<sub>2</sub>e/tCH<sub>4</sub>)  
 $F_{\text{CH}_4,\text{RG},m}$  = Mass flow of methane in the residual gas in the minute m (kg)  
 $\eta_{\text{flare},m}$  = Flare efficiency in the minute m

The calculation procedure is as follows.

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

Parameter	Unit SI	Description:
$F_{\text{CH}_4,m}$	kg	Mass flow of methane in the residual gaseous stream in the minute m

The following requirements apply:

- Tool of TVER-TOOL-02-05 to calculate the mass flow of a greenhouse gas in a gaseous stream shall be applied to the residual gas.
- The flow of the gaseous stream shall be measured continuously.
- CH<sub>4</sub> is the greenhouse gas i for which the mass flow should be determined.
- A simple calculation of the molecular mass of a gas stream. Based on Equations (3) and (17) in tool of TVER-TOOL-02-05 to determine the mass flow of a greenhouse gas in a gaseous stream.
- The time interval t for which mass flow should be averaged is every minute m.

$F_{\text{CH}_4,m}$  which is measured as the mass flow during minute m, shall be used to determine the mass of methane in kilograms fed to the flare in the minute m ( $F_{\text{CH}_4,\text{RG},m}$ ).  $F_{\text{CH}_4,m}$  shall be determined on a dry basis.

By calculating the molecular mass of the gas stream simply as follows:

- The molecular mass of the gas stream ( $MM_{t,\text{db}}$ ) can be calculated from the Equation 3 in tool of TVER-TOOL-02-05 to calculate the mass flow of a greenhouse gas in a gaseous stream

2) The molecular mass of the gas stream ( $MM_{t,wb}$ ) can be calculated from the Equation 17 in T-VER tool 02-05 Tool to calculate the mass flow of a greenhouse gas in a gaseous stream

## Step 2: Determination of flare efficiency.

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

### 1) Open flare

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%.

### 2) Enclosed flare

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 PDD which option is selected:

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

In case of missing data for parameters relevant to the measurement of the flare efficiency as per Option B above, the project participants may also choose to follow the provisions of Option A above as a backup approach. The project participant shall document this choice in the PDD.

### Option A: Default value

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 operating specification for the flare ( $SPEC_{flare}$ ) in the minute  $m$ ; and
- (b) The flame is detected in the minute  $m$  ( $Flame_m$ )

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

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 <sup>2</sup>

### Option B: Measured flare efficiency

The flare efficiency in the 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 ( $F_{RG,m}$ ) is within the manufacturer's operating specification for the flare ( $SPEC_{flare}$ ) in the minute  $m$ ; and
- (b) The flame is detected in the minute  $m$  ( $Flame_m$ )

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

For the measurement of the flare efficiency, the project participants may choose one of the options below:

- (a) Option B.1: The measurement is conducted by an accredited entity at least on a biannual basis<sup>3</sup>
- (b) Option B.2: The flare efficiency is measured in each minute.

<sup>2</sup> For example, the default value applied shall be 80%, rather than 90%.

<sup>3</sup> If the monitoring period is shorter than one year, the measurement should be at least twice in a monitoring period and in a maximum timeframe of six months between each measurement.

### 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 is sensitive to both ultraviolet 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.

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

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

$$\eta_{\text{flare,calc,y}} = 1 - \frac{1}{n} \sum_{t=1}^n \left( \frac{F_{\text{CH}_4,\text{EG},t}}{F_{\text{CH}_4,\text{RG},t}} \right) - 0.05 \quad \text{Equation (4)}$$

โดยที่

- $\eta_{\text{flare,calc,y}}$  = Flare efficiency in the year  $y$
- $F_{\text{CH}_4,\text{EG},t}$  = Mass flow of methane in the exhaust gas of the flare on a dry basis at reference conditions in the time period  $t$  (kg)
- $F_{\text{CH}_4,\text{RG},t}$  = 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

$F_{\text{CH}_4,\text{EG},t}$  is measured according to an appropriate national or international standard.  $F_{\text{CH}_4,\text{RG},t}$  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 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.

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

The flare efficiency ( $\eta_{\text{flare,calc,m}}$ ) 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:

$$\eta_{\text{flare,calc,m}} = 1 - \frac{F_{\text{CH}_4,\text{EG,m}}}{F_{\text{CH}_4,\text{RG,m}}} \quad \text{Equation (5)}$$

Where;

- $\eta_{\text{flare,calc,m}}$  = Flare efficiency in the minute m
- $F_{\text{CH}_4,\text{EG,m}}$  = Mass flow of methane in the exhaust gas of the flare on a dry basis at reference conditions in the minute m (kg)
- $F_{\text{CH}_4,\text{RG,m}}$  = Mass flow of methane in the residual gas on a dry basis at reference conditions in the minute m (kg)

$F_{\text{CH}_4,\text{RG,m}}$  is calculated according to Step 1.

Determine  $F_{\text{CH}_4,\text{EG,m}}$  according to Steps 2.1 - 2.4 below:



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

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:

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

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 the 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 the minute m ( $mg / m^3$ )

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

Determine the average volume flow of the exhaust gas in the 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:

$$V_{EG,m} = Q_{EG,m} \times M_{RG,m} \quad \text{Equation (7)}$$

Where;

$V_{EG,m}$  = Volumetric flow of the exhaust gas on a dry basis at reference conditions in the 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 the 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)

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

Project participants may select to monitor the mass flow of the residual gas in the 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.

$$M_{RG,m} = \rho_{RG,ref,m} \times V_{RG,m} \quad \text{Equation (8)}$$

Where;

$M_{RG,m}$  = Mass flow of the residual gas on a dry basis at reference conditions in the minute m (kg)

$\rho_{RG,ref,m}$  = Density of the residual gas at reference conditions in the minute m ( $\text{kg/m}^3$ )

$V_{RG,m}$  = Volumetric flow of the residual gas on a dry basis at reference conditions in the minute m ( $\text{m}^3$ )

and

$$\rho_{RG,ref,m} = \frac{p_{ref}}{\frac{R_u \times T_{ref}}{MM_{RG,m}}} \quad \text{Equation (9)}$$

Where;

$\rho_{RG,ref,m}$  = Density of the residual gas at reference conditions in the minute m ( $\text{kg/m}^3$ )

$p_{ref}$  = Atmospheric pressure at reference conditions (Pa)

$R_u$  = Universal ideal gas constant ( $\text{Pa}\cdot\text{m}^3/\text{kmol}\cdot\text{K}$ )

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

$T_{ref}$  = Temperature at reference conditions (K)

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 ( $\text{N}_2$ ). The same equation applies, irrespective of which option is selected.

$$MM_{RG,m} = \sum_i (V_{i,RG,m} \times MM_i) \quad \text{Equation (10)}$$

Where

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

$MM_i$  = Molecular mass of residual gas component i (kg/km)

$V_{i,RG,m}$  = 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 = CH<sub>4</sub>, CO, CO<sub>2</sub>, O<sub>2</sub>, H<sub>2</sub>, H<sub>2</sub>S, NH<sub>3</sub>, N<sub>2</sub>

if Option (b) is selected then i = CH<sub>4</sub> และ N<sub>2</sub>

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

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

$$Q_{EG,m} = Q_{CO2,EG,m} + Q_{O2,EG,m} + Q_{N2,EG,m} \quad \text{Equation (11)}$$

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<sup>3</sup>/kg residual gas)

$Q_{CO2,EG,m}$  = CO<sub>2</sub> volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m<sup>3</sup>/kg residual gas)

$Q_{O2,EG,m}$  = N<sub>2</sub> volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m<sup>3</sup>/kg residual gas)

$Q_{N2,EG,m}$  = O<sub>2</sub> volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m<sup>3</sup>/kg residual gas)

and

$$Q_{O2,EG,m} = n_{O2,EG,m} \times VM_{ref} \quad \text{Equation (12)}$$

Where;

$Q_{O_2,EG,m}$  = O<sub>2</sub> volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m<sup>3</sup>/kg residual gas)

$n_{O_2,EG,m}$  = O<sub>2</sub> (moles) in the exhaust gas per kg of residual gas flared on a dry basis at reference conditions in the minute m (kmol / kg residual gas)

$VM_{ref}$  = Volume of one mole of any ideal gas at reference temperature and pressure (m<sup>3</sup>/kmol)

$$Q_{n_2,EG,m} = VM_{ref} \times \left( \left( \frac{MF_{N,RG,m}}{2 \times AM_N} + \left( \frac{1 - v_{O_2,air}}{v_{O_2,air}} \right) \times (F_{O_2,RG,m} + n_{O_2,RG,m}) \right) \right) \quad \text{Equation (13)}$$

Where

$Q_{N_2,EG,m}$  = N<sub>2</sub> (volume) in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m<sup>3</sup>/ kg residual gas)

$VM_{ref}$  = Volume of one mole of any ideal gas at reference temperature and pressure (m<sup>3</sup>/ 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<sub>2</sub> in air

$F_{O_2,RG,m}$  = Stoichiometric quantity of moles of O<sub>2</sub> required for a complete oxidation of one kg residual gas in the minute m (kmol/ kg residual gas)

$n_{O_2,EG,m}$  = O<sub>2</sub> (moles) in the exhaust gas per kg of residual gas flared on a dry basis at reference conditions in the minute m (kmol/ kg residual gas)

$$Q_{CO_2,EG,m} = \frac{MF_{C,RG,m} \times VM_{ref}}{AM_C} \quad \text{Equation (14)}$$

Where;

$Q_{N_2,EG,m}$  = CO<sub>2</sub> volume in the exhaust gas per kg of residual gas on a dry basis at reference conditions in the minute m (m<sup>3</sup> / 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 ( $m^3/kmol$ )

$$n_{O_2,EG,m} = \frac{v_{O_2,EG,m}}{\left(1 - \left(\frac{v_{O_2,EG,m}}{v_{O_2,air}}\right)\right)} \times \left( \left(\frac{MF_{C,RG,m}}{AM_C} + \frac{MF_{N,RG,m}}{2 \times AM_N} + \left(\frac{1 - v_{O_2,air}}{v_{O_2,air}}\right) \times F_{O_2,RG,m}\right) \right) \quad \text{Equation (15)}$$

Where;

$n_{O_2,EG,m}$  =  $O_2$  (moles) in the exhaust gas per kg of residual gas flared on a dry basis at reference conditions in the minute m (kmol/kg residual)

$v_{O_2,EG,m}$  = 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  $O_2$  required for a complete oxidation of one kg residual gas in the minute m (kmol / kg residual gas)

$$F_{O_2,RG,m} = \frac{MF_{C,RG,m}}{AM_C} + \frac{MF_{H,RG,m}}{4AM_H} - \frac{MF_{O,RG,m}}{2AM_O} \quad \text{Equation (16)}$$

Where;

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

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

$4AM_H$  = Atomic mass of oxygen (kg / kmol)

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

$2AM_O$  = Atomic mass of hydrogen (kg / kmol)

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 ( $N_2$ ). The same equation applies, irrespective of which option is selected.

$$MF_{j,RG,m} = \frac{\sum_i v_{i,RG,m} \times AM_j \times NA_{j,i}}{MM_{RG,m}} \quad \text{Equation (17)}$$

Where;

- $MF_{j,RG,m}$  = Mass fraction of element  $j$  in the residual gas in the minute  $m$
- $v_{i,RG,m}$  = 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 the 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  $i = CH_4, CO, CO_2, O_2, H_2, H_2S, NH_3, N_2$  or if Option (b) is selected then  $i = CH_4$  and  $N_2$

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%.

## 5. 5. Monitoring Plan

### 5.1 Monitoring methodology

1) The project developer explain and specify the steps for monitoring the project activity data (Activity data) or verify all measurement results in the project proposal document. including the type of measuring instruments used Person responsible for monitoring results and verifying information Calibration of measuring instruments (if any) and procedures for warranty and quality

control Where methods have different options, such as using default values or on-site measurements The project developer must specify which option to use. In addition, the installation, maintenance and calibration of measuring instruments should be carried out in accordance with the instructions of the equipment manufacturer and in accordance with national standards. or international standards such as IEC, ISO

2) All data collected as part of the greenhouse gas reduction monitoring. The data should be stored in electronic file format and the retention period is in accordance with the guidelines set by the Administrative Organization or the organization's quality system, but the period of time is not less than that specified by the TGO. Must follow the follow-up methods specified in the follow-up parameter specified in Table 5.2.

## 5.2. Data and parameters to be monitored

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 thirdparty accredited entity
Measurement procedures:	<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

Parameter:	$T_{EG,m}$
Data unit:	°C
Description:	Temperature in the exhaust gas of the enclosed flare in the minute m
Source of data:	Project participants

Measurement procedures:	<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 manufacturer's operating 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 operating specifications for operating temperature are met</p>

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 $i = CH_4, CO, CO_2, O_2, H_2, H_2S, NH_4, N_2$
Source of data:	Measurements by project participants using a continuous gas analyser (values are recorded with the same frequency as the flow).
Measurement procedures:	Measurement may be made on either dry or wet basis. If the value is made on a wet basis, then it shall be converted to dry basis for reporting
Monitoring frequency:	Continuously. Values are 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 <sub>4</sub> , CO and CO <sub>2</sub> of the residual gas and consider the remaining part as N <sub>2</sub> . Monitoring of this parameter is only applicable in case of enclosed flares and continuous monitoring of the flare efficiency. The methane content measurement shall be carried out close to a location in the system where a biogas flow measurement takes place.
--------------	--

Parameter:	$V_{RG,m}$
Data unit:	m <sup>3</sup>
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:	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 operating specifications for flow rate/heat flux are met. In this case the flow rate should be measured in a m <sup>3</sup> /h

Parameter:	$M_{RG,m}$
Data unit:	kg
Description:	Mass flow of the residual gas on a dry basis at reference conditions
Source of data:	-
Measurement procedures:	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:	<p>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 <math>M_{RG,m}</math> directly, instead of calculating.</p> <p>Monitoring of this parameter may also be necessary for confirming that the manufacturer's specifications for flow rate/heat flux are met.</p> <p>In this case the flow rate should be measured in a kg/h basis</p>
--------------	--

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 $m$
Source of data:	Measurements by project participants using a continuous gas analyser
Measurement procedures:	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

Parameter:	$F_{C_{CH_4,EG,m}}$
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 $m$
Source of data:	Measurements by project participants using a continuous gas analyser
Measurement procedures:	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
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 <sup>3</sup> simply multiply by 0.716. 1% equals 10,000 ppmv

Parameter:	Flame <sub>m</sub>
Data unit:	Flame on or Flame off
Description:	Flame detection of flare in the minute m
Source of data:	Project participants
Measurement procedures:	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

Parameter:	Maintenance <sub>y</sub>
Data unit:	Calendar dates
Description:	Maintenance events completed in year y
Source of data:	Project participants
Measurement procedures:	Record the date that maintenance events were completed in year y. 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 ( $SPEC_{Flare}$ )
--------------	---

Parameter:	$GWP_{CH_4}$
Data unit:	t CO <sub>2</sub> e/t CH <sub>4</sub>
Description:	The global warming potential of methane
Source of data:	It uses data from the IPCC Assessment Report produced by the Intergovernmental Commission on Climate Change. (Intergovernmental Panel on Climate Change or IPCC announced by TGO.
Measurement procedures:	<p><b><u>For the preparation of project proposal documents</u></b></p> <ul style="list-style-type: none"> <li>- Use the latest <math>GWP_{CH_4}</math> value as announced by TGO.</li> </ul> <p><b><u>For monitoring the results of reducing emissions</u></b></p> <ul style="list-style-type: none"> <li>- Use the value of <math>GWP_{CH_4}</math> as announced by TGO. for estimating the amount of greenhouse gases according to the crediting period that has been certified for the amount of greenhouse gases.</li> </ul>
Monitoring frequency:	-
QA / QC procedures:	-
Any comment:	-

### 5.3 Data and parameters not monitored

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
$MM_{CH_4}$	kg/kmol	Molecular mass of methane	16.04
$MM_{CO}$	kg/kmol	Molecular mass of carbon monoxide	28.01
$MM_{CO_2}$	kg/kmol	Molecular mass of carbon dioxide	44.01
$MM_{O_2}$	kg/kmol	Molecular mass of oxygen	32.00
$MM_{H_2}$	kg/kmol	Molecular mass of hydrogen	2.02

Parameter	SI Unit	Description	Value
$MM_{N_2}$	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 <sup>3</sup> /kmol.K	Universal ideal gas constant	0.008314472
$T_{ref}$	K	Temperature at reference conditions	273.15
$V_{O_2,air}$	-	O <sub>2</sub> volumetric fraction of air	0.21
$GWP_{CH_4}$	tCO <sub>2</sub> / tCH <sub>4</sub>	Global warming potential of methane valid for the commitment period	28
$MV_n$	m <sup>3</sup> /kmol	Volume of one mole of any ideal gas at reference conditions	22.414
$\rho_{CH_4,n}$	kg/m <sup>3</sup>	Density of methane gas at reference conditions	0.716
$NA_{i,j}$	-	Number of atoms of element j in component i, depending on molecular structure	-
$VM_{ref}$	kg/m <sup>3</sup>	Volume of one mole of any ideal gas at reference temperature and pressure	22.4

Parameter:	$SPEC_{flare}$
Data unit:	Temperature - °C Flow rate or heat flux - kg/h or m <sup>3</sup> /h Maintenance schedule - number of days
Description:	Manufacturer's flare operating specifications for temperature, flow rate and maintenance schedule
Source of data:	Flare manufacturer

Value to be applied:	<p>Document in the PDD the flare operating specifications set by the manufacturer for the correct operation of the flare for the following parameters:</p> <p>(a) Minimum and maximum inlet flow rate, if necessary converted to flow rate at reference conditions or heat flux;</p> <p>(b) Minimum and maximum operating temperature; and</p> <p>(c) Maximum duration in days between maintenance events</p>
Any comment:	<p>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.</p>

## 6. Reference

CDM Methodological tool:

TOOL06: Project emissions from flaring version 04.0

TOOL08: Tool to determine the mass flow of a greenhouse gas in a gaseous stream version 03.0

<b>Document information T-VER-P-TOOL-02-04</b>
--

<b>Version</b>	<b>Amendment</b>	<b>Entry into force</b>	<b>Description</b>
01	-	1 March 2023	Change document code from TVER-TOOL-02-04 Version 01.
01	-	24 August 2022	Initial adoption.