



T-VER-P-METH-12-01

**Methane Capture from Anaerobic Wastewater Treatment
for Utilization or Flaring**

Version 01

Sector 13: Waste handling and disposal

Entry into force on 1 March 2023

1. Methodology	Methane Capture from Anaerobic Wastewater Treatment for Utilization or Flaring
2. Project Type	Industrial wastewater management
3. Sector scope	13 - Waste handling and disposal
4. Project Outline	The project aims to methane capture from anaerobic wastewater treatment for utilization or flaring
5. Applicability	<p>It is a project where methane storage activities are carried out from the decomposition of organic matter in wastewater or sludge by an anaerobic treatment system to utilize or flare the methane gas before it is released into the atmosphere one way or several methods as follows:</p> <ol style="list-style-type: none"> 1) Installing an anaerobic treatment system and collecting the generated biogas for utilize or flare (Greenfield). 2) Retrofit of an existing anaerobic wastewater system and collecting the generated biogas for utilize or flare. 3) Installing an anaerobic treatment system and collecting the generated biogas for utilize or flare to replace the existing treatment system that releases methane into the atmosphere or no methane collection system
6. Project Conditions	<ol style="list-style-type: none"> 1. In the case of the base case is an open anaerobic wastewater treatment pond The depth of the well must be at least 2 meters. No aerators are installed. and sludge is removed at least every 30 days. 2. Biogas utilized with at least one of the following characteristics; <ol style="list-style-type: none"> 2.1) Thermal or mechanical, electrical energy generation directly. 2.2) Thermal or mechanical, electrical energy generation after bottling of upgraded biogas if bottles with upgraded biogas are sold outside the project boundary, the end-use of the biogas shall be ensured via a contract between the bottled biogas vendor and the end-user. No emission reductions may be claimed from the displacement of fuels from the end use of bottled biogas in such situations.

	<p>2.3) Thermal or mechanical, electrical energy generation after upgrading and distribution.</p> <p>2.3.1) Upgrading and injection of biogas into a natural gas distribution grid with no significant transmission constraints;</p> <p>2.3.2) Upgrading and transportation of biogas via a dedicated piped network to a group of end users; or</p> <p>2.3.3) Upgrading and transportation of biogas (e.g. by trucks) to distribution points for end users;</p> <p>2.4) Hydrogen production</p> <p>2.5) Use as fuel in transportation applications after upgrading</p>
<p>7. Project Starting Date</p>	<p>The date is that the project owner (client) and the contractor have signed to construct the project of greenhouse gas emission reduction which will be developed to the T-VER project.</p>
<p>8. Definition</p>	<p>Anaerobic digestion is the anaerobic decomposition process of organic matter, such as municipal solid waste, animal manure, waste water, industrial wastewater. and biological substances from aerobic wastewater treatment plants produces methane and carbon dioxide.</p> <p>Anaerobic Lagoon is an anaerobic treatment system consisting of a soil pit with suitable volume and depth for decomposing stored sludge. and can reduce some organic matter in wastewater</p> <p>Biogas is Gas generated from anaerobic digestion of organic matter. Typically, the composition of the gas is 50 to 70 per cent CH₄ and 30 to 50 per cent CO₂, with traces of H₂S and NH₃ (1 to 5 per cent);</p>

**Details of T-VER methodology for
Methane Capture from Anaerobic Wastewater Treatment for Utilization or Flaring**

1. Greenhouse gas emission reduction activities used in the calculations

Table 1. Sources and types of greenhouse gases

Greenhouse gas emission	Source	Greenhouse Gas	Details of activities that emit greenhouse gas emissions
Baseline Emission	The use of electricity or fossil fuels	CO ₂	The use of electricity or fossil fuels in wastewater treatment and sludge processing
	Wastewater treatment process	CH ₄	Emissions from anaerobic wastewater treatment process.
	Sludge treatment process	CH ₄	Emissions from anaerobic sludge treatment process.
	Secondary wastewater treatment process	CH ₄	Emissions from decomposing organic matter in wastewater treatment processes before releasing into rivers/lakes/sea
	Final Sludge Treatment Process	CH ₄	Emissions from anaerobic final sludge treatment process.
Project Emission	The use of electricity or fossil fuels	CO ₂	The use of electricity or fossil fuels from wastewater and sludge treatment processes.
	Wastewater treatment process	CH ₄	Emissions from wastewater treatment processes without biogas recovery.
	Sludge treatment process	CH ₄	Emissions from sludge treatment processes without biogas recovery

Greenhouse gas emission	Source	Greenhouse Gas	Details of activities that emit greenhouse gas emissions
	Secondary wastewater treatment process	CH ₄	Emissions from Degradation of Organic Substances in Wastewater Treatment Process before Discharging into Rivers/Lakes/Seas
	Secondary sludge treatment process	CH ₄	Emissions from the final decomposition of sludge from the treatment process
	Biogas release in capture systems	CH ₄	Methane leakage from biogas production and storage systems
	Biogas flaring	CH ₄	Emissions from incomplete combustion of flare
	Biomass storage	CH ₄	Emissions from biomass storage under anaerobic conditions This will not happen in the baseline scenario.
Leakage	-	-	If the technology or equipment used in a project activity transfers from another activity Must consider and assess the impact of greenhouse gas emissions outside the project scope.

2. Scope of Project

2.1 Project Characteristics

It is a project with methane capture activities obtained from anaerobic wastewater treatment process for utilization or flaring as follows:

1) It is a project with methane capture from anaerobic wastewater treatment for utilization or flaring, including

- 1.1) Substitution of aerobic wastewater or sludge treatment systems with anaerobic systems with biogas recovery and combustion;
- 1.2) Introduction of anaerobic sludge treatment system with biogas recovery and combustion to a wastewater treatment plant without sludge treatment;
- 1.3) Introduction of biogas recovery and combustion to a sludge treatment system;
- 1.4) Introduction of biogas recovery and combustion to an anaerobic wastewater treatment system such as anaerobic reactor, lagoon, septic tank or an on-site industrial plant; (Greenfield)
- 1.5) Introduction of anaerobic wastewater treatment with biogas recovery and combustion, with or without anaerobic sludge treatment, to an untreated wastewater stream;
- 1.6) Introduction of a sequential stage of wastewater treatment with biogas recovery and combustion, with or without sludge treatment, to an anaerobic wastewater treatment system without biogas recovery (e.g. introduction of treatment in an anaerobic reactor with biogas recovery as a sequential treatment step for the wastewater that is presently being treated in an anaerobic lagoon without methane recovery).

2. The recovered biogas from the above measures may also be utilized for the following applications instead of combustion/flaring:

- 2.1) Thermal or mechanical, electrical energy generation directly;
- 2.2) Thermal or mechanical, electrical energy generation after bottling of upgraded biogas, if bottles with upgraded biogas are sold outside the project boundary, the end-use of the biogas shall be ensured via a contract between the bottled biogas vendor and the end-user. No emission reductions may be claimed from the displacement of fuels from the end use of bottled biogas in such situations in this case additional guidance provided in the appendix 1 shall be followed; or

2.3) Thermal or mechanical, electrical energy generation after upgrading and distribution, in this case additional guidance provided in the appendix shall be followed:

2.3.1) Upgrading and injection of biogas into a natural gas distribution grid with no significant transmission constraints;

2.3.2) Upgrading and transportation of biogas via a dedicated piped network to a group of end users; or

2.3.3) Upgrading and transportation of biogas (e.g. by trucks) to distribution points for end users;

2.4) Hydrogen production;

2.5) Use as fuel in transportation applications after upgrading.

2.2 Project scope

It is an area that is subject to methane sequestration activities from wastewater treatment by various activities caused by methane storage Including the use of methane for incineration will be taken into account.

3. Additionality

The project must undergo further proof of operation from normal operations. (Additionality) by using the "Guidelines to prove operations in addition to normal operations. (Additionality) under the Thailand Voluntary Emission Reduction Program (T-VER)" as prescribed by the TGO.

4. Baseline Scenario

When considering the guidelines for determining the base case data below normal operations (Below Business as Usual or Below BAU), base case data for greenhouse gas emissions from wastewater treatment or anaerobic sludge. with anaerobic wastewater treatment process together with methane storage for incineration with an open system This is replaced by anaerobic wastewater treatment combined with methane sequestration for utilization and/or incineration with a closed system. The project baseline is therefore considered by adjusting the treatment system uncertainty based on the principle Conservativeness Factor according to IPCC good practice guidance to make the value lower than normal project operation.

5. Baseline Emission

$$BE_y = BE_{power,y} + BE_{ww,treatment,y} + BE_{s,treatment,y} + BE_{ww,discharge,y} + BE_{S,final,y} \quad \text{Equation (1)}$$

Where

- BE_y = Baseline emissions in year y (tCO₂eq/year)
- $BE_{power,y}$ = Baseline emissions from electricity or fuel consumption in year y (tCO₂eq/year)
- $BE_{ww,treatment,y}$ = Baseline emissions from anaerobic wastewater treatment process with methane capture and flaring with an open system in year y (tCO₂/year)
- $BE_{s,treatment,y}$ = Baseline emissions of the sludge treatment systems affected by the project activity in year y (tCO₂eq/year)
- $BE_{ww,discharge,y}$ = Baseline methane emissions from degradable organic carbon in treated wastewater discharged into sea/river/lake in year y (tCO₂eq/year)
- $BE_{S,final,y}$ = Baseline methane emissions from anaerobic decay of the final sludge produced in year y (tCO₂eq/year)

Values used to calculate the amount of greenhouse gas emissions from the base case according to equation (1), such as the COD removal efficiency of the wastewater treatment process. Sludge content by dry weight Amount of electricity consumption per volume of treated wastewater The final sludge produced per COD removed and other parameters, etc., are detailed to consider as follows.

- 1) Historical records of at least one year prior to the project implementation shall be used.
- 2) For wastewater treatment plant that has been operating for at least three years and if one year of historical data is not available; the following procedures shall be followed.
 - 2.1) All the available data in determining the required parameters (COD removal efficiency, specific energy consumption and specific sludge production) shall be used to determine the baseline emissions in year y;
 - 2.2) The forecasted parameters of the parameters required in the Project Design Document (PDD) are: COD removal efficiency, specific energy consumption rate. and the specific sludge production rate, etc. Such parameters should be measured for at least 10 days, during which time they represent the general operating conditions of the system. and environmental conditions (e.g. temperature, etc.),

and the mean obtained from the measurements must be multiplied by 0.89 considering the uncertainty. (Uncertainty in the range of 30% - 50%)

2.3) The baseline emissions in year y is taken as the minimum between the result of (2.1) and (2.2)

3) In the case of Greenfield and capacity addition projects, or existing plant without three-year operating history, the following procedures shall be used to determine the baseline emissions:

3.1) For existing plant without three-year operating history, procedures in subheading 2) shall be followed;

3.2) For a new wastewater treatment project and installation of additional treatment systems Perform one of the following steps.

3.2.1) Use the values obtained from measurements from other projects with wastewater treatment systems with similar environment and technology to the base line, such as wastewater treatment system technology, wastewater characteristic, the amount of wastewater, etc. by multiplying the measured average by 0.89 with the following measurement conditions:

- (1) The two sources of wastewater (wastewater treated in the selected plant and from the project activity) are of the same type, e.g. either domestic or industrial wastewater;
- (2) The selected plant and the baseline plants employ the same treatment technology (e.g. anaerobic lagoons or activated sludge), and the hydraulic retention times in their biological and physical treatment systems do not vary by more than 20 percent; and
- (3) For project activity treating industrial wastewater, both industries have the same raw material and final products, and apply the same industrial technology. Alternatively, different industrial wastewaters may be considered as similar if the following requirements are fulfilled:
 - The ratio COD/BOD does not differ by more than 20 percent (related to the proportion of biodegradable organic matter) and
 - The ratio total COD/soluble COD does not differ by more than 20 percent. (related to the proportion of suspended organic matter, and therefore to the sludge generation capacity)

3.2.2) Value provided by the manufacturer/designer of a Greenfield wastewater treatment plant using the same technology, demonstrated to be conservative, e.g. average values from the top 20 percent plants with lowest emission rate per ton COD removed among the plants installed in the last five years designed for the same country/region to treat the same type of wastewaters as the project activity.

5.1 Baseline emissions from electricity or fossil fuel consumption

The energy consumption must include all equipment/equipment in the wastewater treatment system and sludge in the base case. If the base case uses biogas to be recycled to power the auxiliary equipment It should be taken into account accordingly using the emission factor = 0.

Baseline emissions from electricity or fossil fuel consumption can be calculate as follow;

$$BE_{power,y} = BE_{EC,y} + BE_{FF,y} \quad \text{Equation (2)}$$

Where;

$BE_{power,y}$ = Baseline emissions from electricity or fossil fuel consumption in year y (tCO₂eq/year)

$BE_{EC,y}$ = Baseline emissions from electricity consumption in year y (tCO₂eq/year)

$BE_{FF,y}$ = Baseline emissions from fossil fuel consumption in year y (tCO₂eq/year)

5.1.1 Baseline emissions from electricity consumption

Baseline emissions from the use of electricity from the project implementation can be calculated from the amount of electricity consumption. Baseline emissions from electricity generation and power loss in the national grid's power generation system as follows:

$$BE_{EC,y} = \sum_j EC_{PJ,j,y} \times EF_{Elec,y} \times (1 + TD_{L,j,y}) \quad \text{Equation (3)}$$

Where

$BE_{EC,y}$ = Baseline emissions from electricity consumption in year y (tCO₂eq/year)

$EC_{PJ,j,y}$ = Quantity of electricity consumed by the baseline electricity consumption source j in year y (MWh/year)

$EF_{Elec,y}$ = Emission factor for electricity generation/consumption in year y (tCO₂/MWh)

- $TDL_{j,y}$ = Average technical transmission and distribution losses for providing electricity to source j in year y
 j = Sources of electricity consumption in the project

5.1.2 Baseline emissions from fossil fuel consumption

To calculate greenhouse gas emissions from fossil fuel use due to project implementation, use the Calculation Tool of T-VER-TOOL-02-01 "Calculating Greenhouse Gas Emissions from the Burning of Fossil Fuels from Project Emission and Leakage Emission", latest edition.

5.2 Baseline emissions from wastewater treatment process

Methane emissions from the sewage system in the base case Based on the efficiency of COD removal of the baseline plant.

$$\begin{aligned}
 BE_{\text{ww,treatment},y} &= \sum_i (Q_{\text{ww},i,y} \times \text{COD}_{\text{inflow},i,y} \times \eta_{\text{COD,BL},i} \times \text{MCF}_{\text{ww,treatment,BL},i}) && \text{Equation (4)} \\
 &\times B_{\text{o,ww}} \times \text{UF}_{\text{BL}} \times \text{GWP}_{\text{CH}_4}
 \end{aligned}$$

Where;

- $BE_{\text{ww,treatment},y}$ = Baseline emissions from wastewater treatment process in year y (tCO₂eq/year)
 $Q_{\text{ww},i,y}$ = Volume of wastewater treated in baseline wastewater treatment system i in year y (m³/year) In the case of calculating values in PDD (ER_{ex-ante}), the estimated or designed wastewater volume from the anaerobic wastewater treatment process can be used. The reduction in greenhouse gas emissions from the actual measurement (ER_{ex-post}) must depend on the measurement of the amount of treated wastewater.
 $\text{COD}_{\text{inflow},i,y}$ = Chemical oxygen demand of the wastewater inflow to the baseline treatment system i in year y (tCOD/m³). The mean may be sampled with a confidence/accuracy level of 90/10.
 $\eta_{\text{COD,BL},i}$ = COD removal efficiency of the baseline treatment system i
 $\text{MCF}_{\text{ww,treatment,BL},i}$ = Methane correction factor for baseline wastewater treatment systems i
 $B_{\text{o,ww}}$ = Methane producing capacity of the wastewater (kgCH₄/kgCOD_{removal})
 UF_{BL} = Model correction factor to account for model uncertainties
 GWP_{CH_4} = Global Warming Potential for methane (tCO₂e/tCH₄)
 i = Type of wastewater treatment system in baseline

5.3 Baseline emissions of the sludge treatment systems

Baseline emissions of the sludge treatment systems can be calculated in two ways:

5.3.1 In case of sludge removal by sludge treatment process

$$BE_{s,treatment,y} = \sum_j S_{j,BL,y} \times MCF_{s,treatment,BL,i} \times DOC_s \times UF_{BL} \times DOC_F \times F \times 16/12 \times GWP_{CH_4} \quad \text{Equation (5)}$$

Where

$BE_{s,treatment,y}$ = Baseline emissions of the sludge treatment systems in year y (tCO₂eq/year)

$S_{j,BL,y}$ = Amount of dry matter in the sludge that would have been treated by the sludge treatment system j in the baseline scenario (t). In the case of calculating values in PDD ($ER_{ex-ante}$), the estimated or designed sludge content from the anaerobic sludge treatment process can be used. Must be based on the measurement of the treated wastewater.

j = Index for baseline sludge treatment system

$MCF_{s,treatment,BL,i}$ = Methane correction factor for the baseline sludge treatment system i

DOC_s = Degradable organic content of the untreated sludge generated in the year y (fraction, dry basis)

UF_{BL} = Model correction factor to account for model uncertainties

DOC_F = Fraction of DOC dissimilated to biogas

F = Fraction of CH₄ in biogas

5.3.2 In case of sludge removal by composting process

$$BE_{s,treatment,y} = \sum_j S_{j,BL,y} \times EF_{composting} \times GWP_{CH_4} \quad \text{Equation (6)}$$

Where

$S_{j,BL,y}$ = Amount of dry matter in the sludge that would have been treated by the sludge treatment system j in the baseline (t). In the case of calculating values in PDD ($ER_{ex-ante}$), the estimated or designed sludge content from the anaerobic sludge treatment process can be used. Must be based on the measurement of the treated wastewater.

$EF_{composting}$ = Emission factor for composting organic waste (tCH₄/ t sludge treated on a dry weight basis)

GWP_{CH_4} = Global Warming Potential for methane (tCO_2e/tCH_4)

In the case that the baseline wastewater treatment system differs from the wastewater treatment system from the project activity. This may result in different sludge generation rates. For example, an activated sludge wastewater treatment system contains more sludge than an anaerobic wastewater treatment system. Therefore, the amount of sludge produced during the follow-up period. $S_{j,BL,y}$ values can be calculated as follows:

$$S_{j,BL,y} = S_{i,PJ,y} \times \frac{SGR_{BL}}{SGR_{PJ}} \quad \text{Equation (7)}$$

Where

$S_{i,PJ,y}$ = Amount of dry matter in the sludge treated by the sludge treatment system i in year y in the project activity (t)

SGR_{BL} = Sludge generation ratio of the wastewater treatment plant in the baseline (tonne of dry matter in sludge/t COD removed)

SGR_{PJ} = Sludge generation ratio of the wastewater treatment plant in the project activity (tonne of dry matter in sludge/t COD removed). Calculated using the monitored values of COD removal (i.e. $COD_{inflow,i} - COD_{outflow,i}$) and sludge generation in the project activity

5.4 Baseline methane emissions from degradable organic carbon in treated wastewater discharged into sea/river/lake

$$BE_{ww,discharge,y} = Q_{ww,i,y} \times GWP_{CH_4} \times B_{o,ww} \times UF_{BL} \times COD_{ww,discharge,BL,y} \times MCF_{ww,BL,discharge} \quad \text{Equation (8)}$$

Where

$Q_{ww,i,y}$ = Volume of treated wastewater discharged in year y (t)

UF_{BL} = Model correction factor to account for model uncertainties

$COD_{ww,discharge,BL,y}$ = Chemical oxygen demand of the treated wastewater discharged into sea, river or lake in the baseline in the year y ($tCOD/m^3$)

If the baseline is the discharge of wastewater into the water source without treatment Therefore, the COD value of untreated wastewater is used.

$MCF_{ww,BL,discharge}$ = Methane correction factor based on discharge pathway in the baseline

5.5 Baseline methane emissions from anaerobic decay of the final sludge produced

$$BE_{S,final,y} = S_{final,BL,y} \times DOC_s \times UF_{BL} \times MCF_{s,BL,final} \times DOC_F \times F \times 16/12 \times GWP_{CH4} \quad \text{Equation (9)}$$

Where

$S_{final,BL,y}$ = Amount of dry matter in the final sludge generated by the baseline wastewater treatment systems in the year y (t). If the baseline wastewater treatment system is different from the project system, it will be estimated using the monitored amount of dry matter in the final sludge generated by the project activity ($S_{final,PJ,y}$) corrected for the sludge generation ratios of the project and baseline systems as per equation (6) above

$MCF_{s,BL,final}$ = Methane correction factor of the disposal site that receives the final sludge in the baseline

UF_{BL} = Model correction factor to account for model uncertainties

If the sludge is controlled combusted, disposed in a sanitary landfill with landfill gas recovery, or used for soil amendment in the baseline, this term shall be neglected.

6. Project Emission

Project emission from project activities are accounted for only methane (CH₄) emissions from leaks from production/storage systems and from flaring. by project emission from project implementation can be calculated as follows:

$$PE_y = PE_{power,y} + PE_{ww,treatment,y} + PE_{s,treatment,y} + PE_{ww,discharge,y} + PE_{S,final,y} + PE_{fugitive,y} + PE_{biomass,y} + PE_{flare,y} \quad \text{Equation (10)}$$

Where

PE_y = Project emissions in year y (tCO₂eq/year)

$PE_{power,y}$ = Project emissions from electricity and fossil fuel consumption in year y (tCO₂eq/year)

- $PE_{ww,treatment,y}$ = Project emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery in year y (tCO₂eq/year)
- $PE_{s,treatment,y}$ = Project emissions from sludge treatment systems affected by the project activity, and not equipped with biogas recovery in year y (tCO₂eq/year)
- $PE_{ww,discharge,y}$ = Project emissions on account of inefficiency of the project activity wastewater treatment systems and presence of degradable organic carbon in treated wastewater in year y (tCO₂eq/year)
- $PE_{S,final,y}$ = Project emissions from the decay of the final sludge generated by the project activity treatment systems in year y (tCO₂eq/year)
- $PE_{fugitive,y}$ = Project emissions from methane release in capture systems in year y (tCO₂eq/year)
- $PE_{biomass,y}$ = Project emissions from biomass stored under anaerobic conditions which would not have occurred in the baseline situation in year y (tCO₂eq/year)
- $PE_{flare,y}$ = Project emissions due to incomplete flaring in year y (tCO₂eq/year)

6.1 Project emissions from electricity and fossil fuel consumption

Project emissions from electricity or fossil fuels consumption can be calculated as follows;

$$PE_{power,y} = PE_{EC,y} + PE_{FF,y} \quad \text{Equation (11)}$$

Where;

$PE_{power,y}$ = Project emissions from electricity or fossil fuel consumption in year y (tCO₂eq/year)

$PE_{EC,y}$ = Project emissions from electricity consumption in year y (tCO₂eq/year)

$PE_{FF,y}$ = Project emissions from fossil fuel consumption in year y (tCO₂eq/year)

6.1.1 Project emissions from electricity consumption

Project emissions from electricity generation is calculated ss follows:

$$PE_{EC,y} = \sum_j EC_{PJ,j,y} \times EF_{EF,j,y} \times (1 + TD_L_{j,y}) \quad \text{Equation (12)}$$

Where

$PE_{EC,y}$	=	Project emissions from electricity consumption in year y (tCO ₂ eq/year)
$EC_{PJ,j,y}$	=	Quantity of electricity consumed by the baseline electricity consumption source j in year y (MWh/year)
$EF_{EF,j,y}$	=	Emission factor for electricity generation for source j in year y (tCO ₂ /MWh)
$TDL_{j,y}$	=	Average technical transmission and distribution losses for providing electricity to source j in year y
j	=	Sources of electricity consumption in the project

6.1.2 Project emissions from fossil fuel consumption

To calculate greenhouse gas emissions from fossil fuel use due to project implementation, use the Calculation Tool of T-VER-TOOL-02-01 "Calculating Greenhouse Gas Emissions from the Burning of Fossil Fuels from Project Emission and Leakage Emission", latest edition.

6.2 Project emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery

$$PE_{ww,treatment,y} = (Q_{ww,k,y} \times COD_{inflow,k,y} \times \eta_{PJ,k,y} \times MCF_{ww,treatment,PJ,k}) \times B_{o,ww} \times UF_{PJ} \times GWP_{CH_4} \quad \text{Equation (13)}$$

Where

$PE_{ww,treatment,y}$	=	Methane emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery in year y (tCO ₂ eq/year)
$Q_{ww,k,y}$	=	Volume of wastewater treated in project wastewater treatment system k in year y (m ³ /year)
$COD_{inflow,k,y}$	=	Chemical oxygen demand of the wastewater inflow to the project treatment system k in year y (tCOD/m ³)
$\eta_{PJ,k,y}$	=	COD removal efficiency of the project treatment system k
$MCF_{ww,treatment,PJ,k}$	=	Methane correction factor for baseline wastewater treatment systems k
$B_{o,ww}$	=	Methane producing capacity of the wastewater (kgCH ₄ /kgCOD _{removal})
UF_{PJ}	=	Model correction factor to account for model uncertainties
GWP_{CH_4}	=	Global Warming Potential for methane (tCO ₂ e/tCH ₄)
k	=	Types of wastewater treatment processes from project activity

6.3 Project emissions from sludge treatment systems affected by the project activity, and not equipped with biogas recovery

$$PE_{s,treatment,y} = S_{i,PJ,y} \times MCF_{s,treatment,i} \times DOC_s \times UF_{PJ} \times DOC_F \times F \times 16/12 \times GWP_{CH_4} \quad \text{Equation (14)}$$

Where

- $PE_{s,treatment,y}$ = Methane emissions from sludge treatment systems affected by the project activity, and not equipped with biogas recovery in year y (tCO₂eq/year)
- $S_{i,PJ,y}$ = Amount of dry matter in the sludge treated by the sludge treatment system i in the project activity in year y (t)
- i = Type of sludge treatment system
- $MCF_{s,treatment,i}$ = Methane correction factor for the project sludge treatment system i
- DOC_s = Degradable organic content of the untreated sludge generated in the year y (fraction, dry basis)
- UF_{PJ} = Model correction factor to account for model uncertainties
- DOC_F = Fraction of DOC dissimilated to biogas
- F = Fraction of CH₄ in biogas

6.4 Project emissions on account of inefficiency of the project activity wastewater treatment systems and presence of degradable organic carbon in treated wastewater.

$$PE_{ww,discharge,y} = Q_{ww,i,y} \times GWP_{CH_4} \times B_{o,ww} \times UF_{PJ} \times COD_{ww,discharge,PJ,y} \times MCF_{ww,PJ,discharge} \quad \text{Equation (15)}$$

Where

- $Q_{ww,i,y}$ = Amount of wastewater released from the wastewater treatment process in year y (m³)
- UF_{BL} = Methane producing capacity of the wastewater
- $COD_{ww,discharge,PJ,y}$ = Chemical oxygen demand of the treated wastewater discharged into the sea, river or lake in the project activity in year y (t/m³)
- $MCF_{ww,PJ,discharge}$ = Methane correction factor based on the discharge in the project activity

6.5 Methane emissions from the decay of the final sludge generated by the project activity treatment systems

$$PE_{S,final,y} = S_{final,PJ,y} \times DOC_s \times UF_{PJ} \times MCF_{s,PJ,final} \times DOC_F \times F \times 16/12 \times GWP_{CH4} \quad \text{Equation (16)}$$

Where

$S_{final,PJ,y}$ = Amount of dry matter in final sludge generated by the project wastewater treatment systems in the year y (t)

$MCF_{s,PJ,final}$ = Methane correction factor of the disposal site that receives the final sludge in the project activity

UF_{PJ} = Model correction factor to account for model uncertainties

If the sludge is controlled combusted, disposed in a sanitary landfill with landfill recovery, or used for soil amendment in aerobic conditions in the project activity, this term shall be neglected.

6.6 Project emissions from methane release in capture systems

Project emissions from methane release in capture systems can be calculated as follows.

6.6.1 Based on the methane emission potential of wastewater and/or sludge:

$$PE_{fugitive,y} = PE_{fugitive,ww,y} + PE_{fugitive,s,y} \quad \text{Equation (17)}$$

Where

$PE_{fugitive,ww,y}$ = Fugitive emissions through capture inefficiencies in the anaerobic wastewater treatment systems in the year y (tCO₂/year)

$PE_{fugitive,s,y}$ = Fugitive emissions through capture inefficiencies in the anaerobic sludge treatment systems in the year y (tCO₂/year)

1) $PE_{fugitive,ww,y}$ can be calculated as follows.

$$PE_{fugitive,ww,y} = (1-CFE_{ww}) \times MEP_{ww,treatment,y} \times GWP_{CH4} \quad \text{Equation (18)}$$

Where

CFE_{ww} = Capture efficiency of the biogas recovery equipment in the wastewater treatment systems

$MEP_{ww,treatment,y}$ = Methane emission potential of wastewater treatment systems equipped with biogas recovery system in year y (t)

$MEP_{ww,treatment,y}$ can be calculated as follows;

$$MEP_{ww,treatment,y} = Q_{ww,y} \times B_{0,ww} \times UF_{PJ} \times \sum_k COD_{removed,PJ,k,y} \times MCF_{ww,treatment,PJ,k} \quad \text{Equation (19)}$$

Where

$COD_{removed,PJ,k,y}$ = The chemical oxygen demand removed¹⁰ by the treatment system k of the project activity equipped with biogas recovery in the year y (t/m^3)

$MCF_{ww,treatment,PJ,k}$ = Methane correction factor for the project wastewater treatment system k equipped with biogas recovery equipment

UF_{PJ} = Model correction factor to account for model uncertainties

2) $PE_{fugitive,s,y}$ can be calculated as follows;

$$PE_{fugitive,s,y} = (1-CFE_s) \times MEP_{s,treatment,y} \times GWP_{CH_4} \quad \text{Equation (20)}$$

Where

CFE_s = Capture efficiency of the biogas recovery equipment in the sludge treatment systems

$MEP_{s,treatment,y}$ = Methane emission potential of the sludge treatment systems equipped with a biogas recovery system in year y (t)

$MEP_{s,treatment,y}$ can be calculated as follows;

$$MEP_{s,treatment,y} = \sum_i (S_{i,PJ,y} \times MCF_{s,treatment,PJ,i}) \times DOC_s \times UF_{PJ} \times DOC_F \times F \times 16/12 \quad \text{Equation (21)}$$

Where

$S_{i,PJ,y}$ = Amount of sludge treated in the project sludge treatment system i equipped with a biogas recovery system (on a dry basis) in year y (t)

- $MCF_{s,treatment,P,j}$ = Methane correction factor for the sludge treatment system i equipped with biogas recovery equipment
- UF_{PJ} = Model correction factor to account for model uncertainties

2) Optionally, a default value of 0.05 m³ biogas leaked/m³ biogas produced may be used as an alternative to calculations per equation (17) to (21).

6.7 Project emissions from biomass stored under anaerobic conditions

Methane emissions from biomass stored under anaerobic conditions can be calculated by referring to the TVER-TOOL-02-03 " Tool to calculate Emissions from solid waste disposal sites " Latest version

For example, in the case of the project base, empty palm bunches are used as fuel in the boiler. From the project implementation, biogas is used as fuel in boilers to replace empty palm bunches. Thus, the use of palm bunches is no longer used. May cause a pile of empty palm bunches for a long time This could lead to anaerobic decomposition, releasing methane.

6.8 Project emissions due to incomplete flaring

Methane emissions due to incomplete flaring can be calculated by referring to the TVER-TOOL-02-04 " Tool to calculate project emissions from flaring " Latest version

7. Leakage Emission

If the technology or equipment used in a project activity transfers from another activity Must consider and assess the impact of greenhouse gas emissions outside the project scope.

8. Emission Reduction

Emission reductions shall be estimated ex ante in the PDD using the equations provided in the baseline, project and leakage emissions sections above. Emission reductions shall be estimated ex ante as follows:

$$ER_{y,ex\ ante} = BE_{y,ex\ ante} - (PE_{y,ex\ ante} + LE_{y,ex\ ante}) \quad \text{Equation (22)}$$

Where

$ER_{y,ex\ ante}$	=	Emission reductions calculated based on the PDD in year y (tCO ₂ eq/year)
$BE_{y,ex\ ante}$	=	Baseline emissions calculated based on the PDD in year y (tCO ₂ eq/year)
$PE_{y,ex\ ante}$	=	Project emissions calculated based on the PDD in year y (tCO ₂ eq/year)
$LE_{y,ex\ ante}$	=	Leakage emissions calculated based on the PDD in year y (tCO ₂ eq/year)

The calculation for emission reductions achieved by the project activity ($ER_{y,ex\ ante}$)

1) Ex post emission reductions shall be determined for (1.2), Anaerobic sludge treatment system with biogas recovery and combustion to a wastewater treatment plant without sludge treatment; (1.3) Biogas recovery and combustion to a sludge treatment system; (1.4) Biogas recovery and combustion to an anaerobic wastewater treatment system and (1.6) A sequential stage of wastewater treatment with biogas recovery and combustion, with or without sludge treatment, to an anaerobic wastewater treatment system without biogas recovery. It is possible that the project activity involves wastewater and sludge treatment systems with higher methane conversion factors (MCF) or with higher efficiency than the treatment systems used in the baseline situation. Therefore, the emission reductions achieved by the project activity is limited to the ex post calculated baseline emissions minus project emissions using the actual monitored data for the project activity. The emission reductions achieved in any year are the lowest value of the following:

$$ER_{y,ex\ post} = \text{Min} ((BE_{y,ex\ post} - PE_{y,ex\ post} - LE_{y,ex\ post}), \quad \text{Equation (23)}$$

$$(MD_y - PE_{power,y} - PE_{biomass,y} - LE_{y,ex\ post}))$$

Where

$ER_{y,ex\ post}$	=	Emission reductions achieved by the project activity based on monitored values for year y (tCO ₂ eq/year)
$BE_{y,ex\ post}$	=	Baseline emissions by using ex post monitored values (tCO ₂ eq/year)
$PE_{y,ex\ post}$	=	Project emissions by using ex post monitored values (tCO ₂ eq/year)

MD_y = Methane captured and destroyed/gainfully used by the project activity in the year y (tCO₂eq/year)

MD_y can be calculated as follows;

$$MD_y = BG_{burnt,y} \times w_{CH_4,y} \times D_{CH_4} \times FE \times GWP_{CH_4} \quad \text{Equation (24)}$$

Where

$BG_{burnt,y}$ = Biogas flared/combusted in year y (m³)

$w_{CH_4,y}$ = Methane content of the biogas in the year y (volume fraction)

D_{CH_4} = Density of methane at the temperature and pressure of the biogas in the year y (t/m³)

FE = Flare efficiency in year y (fraction)

2) For the cases (1.1) Substitution of aerobic wastewater or sludge treatment systems with anaerobic systems with biogas recovery and combustion; and (1.5) Anaerobic wastewater treatment with biogas recovery and combustion, with or without anaerobic sludge treatment, to an untreated wastewater stream; the emission reduction achieved by the project activity (ex post) will be the difference between the baseline emissions and the sum of the project emissions and leakage.

$$ER_y = BE_{y,ex\ post} - (PE_{y,ex\ post} + LE_{y,ex\ post}) \quad \text{Equation (25)}$$

9. Monitoring Plan

9.1 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 parameters specified in Table 9.2.

9.2 Monitoring methodology

9.2.1 Data and parameters to be monitored emission from methane capture from anaerobic wastewater treatment for utilization or flaring.

Parameter:	GWP_{CH_4}
Data unit:	tCO_2e/tCH_4
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><u>For the preparation of project proposal documents</u></p> <ul style="list-style-type: none"> – Use the latest GWP_{CH_4} value as announced by TGO. <p><u>For monitoring the results of reducing emissions</u></p> <ul style="list-style-type: none"> - Use the value of GWP_{CH_4} 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.

Parameter:	$Q_{ww,i,y}, Q_{ww,k,y}$
Data unit:	$m^3/month$
Description:	Volume of wastewater treated in project wastewater treatment system i in year y Volume of wastewater treated in project wastewater treatment system k in year y
Source of data:	
Measurement procedures:	Measurements are undertaken using flow meters
Monitoring frequency:	Monitored continuously (at least hourly measurements)
Any comment:	

Parameter:	$COD_{inflow,i,y}, COD_{inflow,k,y}$
Data unit:	$tCOD/m^3$
Description:	Chemical oxygen demand of the wastewater inflow to the baseline treatment system i in year y

	Chemical oxygen demand of the wastewater inflow to the baseline treatment system k in year y
Source of data:	Analysis report
Measurement procedures:	The analysis was carried out in accordance with the latest Standard Method continuously throughout the measurement period. by reporting detailed data on a monthly basis

Parameter:	$COD_{ww, discharge, BL, y}$
Data unit:	tCOD/m ³
Description:	Chemical oxygen demand of the treated wastewater discharged into sea, river or lake in the baseline situation in the year y
Source of data:	Analysis report
Measurement procedures:	The analysis was carried out in accordance with the latest Standard Method continuously throughout the measurement period. by reporting detailed data on a monthly basis

Parameter:	$COD_{ww, discharge, PJ, y}$
Data unit:	tCOD/m ³
Description:	Chemical oxygen demand of the treated wastewater discharged into the sea, river or lake in the project activity in year y
Source of data:	Analysis report
Measurement procedures:	The analysis was carried out in accordance with the latest Standard Method continuously throughout the measurement period. by reporting detailed data on a monthly basis

Parameter:	$COD_{removed, PJ, k, y}$
Data unit:	tCOD/m ³
Description:	The chemical oxygen demand removed by the treatment system k of the project activity equipped with biogas recovery in the year y
Source of data:	Analysis report
Measurement procedures:	The analysis was carried out in accordance with the latest Standard Method continuously throughout the measurement period. by reporting detailed data on a monthly basis

Parameter:	$S_{i, PJ, y} , S_{final, PJ, y} , S_{final, BL, y}$
Data unit:	t
Description:	Amount of sludge treated in the project sludge treatment system i equipped with a biogas recovery system (on a dry basis) in year y (t)

	<p>Amount of dry matter in final sludge generated by the project wastewater treatment systems in the year y (t)</p> <p>Amount of dry matter in the final sludge generated by the baseline wastewater treatment systems in the year y (t).</p>
Source of data:	
Measurement procedures:	<p>Measure the total quantity of sludge on a wet basis. The volume (m³) and density or direct weighing may be used to determine the sludge amount (wet basis). Representative samples are taken to determine the moisture content to calculate the total sludge amount on dry basis. If the methane emissions from anaerobic decay of the final sludge are to be neglected because the sludge is controlled combusted, disposed of in a landfill with methane recovery, or used for soil application, then the end-use of the final sludge will be monitored during the crediting period. If the baseline emissions include the anaerobic decay of final sludge generated by the baseline treatment systems in a landfill without methane recovery, the baseline disposal site shall be clearly defined, and verified by the Validation and Verification Body (VVB)</p>
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

Parameter:	$BG_{burnt,y}$
Data unit:	m ³
Description:	Biogas volume in year y
Source of data:	-
Measurement procedures:	<p>In all cases, the amount of biogas recovered, fuelled, flared or otherwise utilized (e.g. injected into a natural gas distribution grid or distributed via a dedicated piped network) shall be monitored ex post, using continuous flow meters. If the biogas streams flared and fuelled (or utilized) are monitored separately, the two fractions can be added together to determine the total biogas recovered, without the need to monitor the recovered biogas before the separation. The methane content measurement shall be carried out close to a location in the system where a biogas flow measurement takes place</p>
Monitoring frequency:	Monitored continuously (at least hourly measurements)
QA/QC procedures:	-
Any comment:	-

Parameter:	$W_{CH_4,y}$
Data unit:	%
Description:	Methane content in biogas in the year y

Source of data:	
Measurement procedures:	The fraction of methane in the gas should be measured with a continuous analyzer or, alternatively, with periodical measurements at a 90 / 10 confidence/precision level. It shall be measured using equipment that can directly measure methane content in the biogas -the estimation of methane content of biogas based on measurement of other constituents of biogas such as CO ₂ is not permitted. The methane content measurement shall be carried out close to a location in the system where a biogas flow measurement takes place
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

Parameter:	T
Data unit:	°C
Description:	Temperature of the biogas
Source of data:	-
Measurement procedures:	The temperature of the gas is required to determine the density of the methane combusted. If the biogas flow meter employed measures flow, pressure and temperature and displays or outputs the normalized flow of biogas, then there is no need for separate monitoring of pressure and temperature of the biogas.
Monitoring frequency:	Shall be measured at the same time when methane content in biogas ($w_{CH_4,y}$) is measured
QA/QC procedures:	-
Any comment:	-

Parameter:	P
Data unit:	N/m ² or Pa
Description:	Pressure of the biogas
Source of data:	-
Measurement procedures:	The pressure of the gas is required to determine the density of the methane combusted. If the biogas flow meter employed measures flow, pressure and temperature and displays or outputs the normalized flow of biogas, then there is no need for separate monitoring of pressure and temperature of the biogas.
Monitoring frequency:	Shall be measured at the same time when methane content in biogas ($w_{CH_4,y}$) is measured.
QA/QC procedures:	-
Any comment:	-

Parameter:	$\eta_{\text{COD,BL},i}$
Data unit:	-
Description:	COD removal efficiency of the baseline treatment system i
Source of data:	-
Measurement procedures:	Measured based on inflow COD and outflow COD in system i
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Parameter:	$\eta_{\text{PJ},k,y}$
Data unit:	-
Description:	Chemical oxygen demand removal efficiency of the project wastewater treatment system k in year y
Source of data:	-
Measurement procedures:	Measured based on inflow COD and outflow COD in system k
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Parameter:	$\text{EF}_{\text{composting}}$
Data unit:	t CH ₄ / t sludge treated on a dry weight basis
Description:	Emission factor for composting organic waste (default 0.1)
Source of data:	Table 4.1, chapter 4, Volume 5, 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Measurement procedures:	-

Parameter:	SGR_{PJ}
Data unit:	tonne of dry matter in sludge/t COD removed
Description:	Sludge generation ratio of the wastewater treatment plant in the project activity
Source of data:	Analysis Report
Measurement procedures:	Calculated using the monitored values of COD removal (i.e. $\text{COD}_{\text{inflow},i} - \text{COD}_{\text{outflow},i}$) and sludge generation in the project activity

Parameter:	SGR_{BL}
Data unit:	tonne of dry matter in sludge/t COD removed

Description:	Sludge generation ratio of the wastewater treatment plant in the baseline scenario
Source of data:	Analysis report
Measurement procedures:	Calculated from the amount of sludge produced from the wastewater treatment system and the average COD removed.

Parameter:	D_{CH_4}
Data unit:	t/m ³
Description:	Methane density at the temperature and pressure of biogas in year y
Source of data:	Analysis report
Measurement procedures:	Calculated from the methane content Biogas temperature and pressure

9.2.2 Data and parameters to be monitored from emission from electricity consumption

Parameter:	$EC_{PJ,i,y}$
Data unit:	MWh/year
Description:	Amount of electricity consumption in the source of electricity j in years y
Source of data:	Analysis report
Measurement procedures:	Measured by kWh Meter and continuously measured throughout the follow-up period. (Amount of electricity deducted from electricity generation for own use before being supplied to the transmission line)
Monitoring frequency:	continuous monitoring and at least monthly recording

Parameter:	TDL
Data unit:	-
Description:	Average technical transmission and distribution losses for providing electricity to source j in year y
Source of data:	Option 1 Measurement Report In the case of information on the amount of electricity released from the producer and the amount of electricity received by the consumer Option 2 uses a Default Value of 0.03 (3%).
Measurement procedures:	1) If using Option 1, the project developer will have to monitor the value every year throughout the monitoring of greenhouse gas emissions reductions. 2) If using Option 2, the project developer must use this value throughout the monitoring of greenhouse gas emissions reductions.
Monitoring frequency:	Defined once in the first year of the credit period.

QA/QC procedures:	If the measurement results differ from previous measurements or other sources that are significantly related make additional measurements.
Any comment:	-

Parameter:	$EF_{Elec,y}$
Data unit:	tCO ₂ /MWh
Description:	Emission factor for electricity generation/consumption in year y
Source of data:	Report on greenhouse gas emissions (Emission Factor) from electricity generation/consumption for projects and activities of greenhouse gas reduction published by TGO.
Measurement procedures:	<p><u>For the preparation of project design documents</u></p> <p>Use the latest $EF_{Elec,y}$ published by TGO</p> <p><u>For carbon credit issuance</u></p> <p>Use the $EF_{Elec,y}$ values announced by TGO according to the year of the carbon credit issuance. However, in the case that the year of the carbon credit issuance does not have $EF_{Elec,y}$ values published by TGO, use the latest $EF_{Elec,y}$ values published by TGO in that year instead.</p>

9.3 Data and parameters not monitored

Parameter:	$MCF_{ww,treatment,BL,i}$, $MCF_{ww,treatment,PJ,k}$, $MCF_{ww,BL,discharge}$, $MCF_{ww,PJ,discharge}$, $MCF_{s,treatment,BL,j}$, $MCF_{s,treatment,i}$, $MCF_{s,treatment,PJ,i}$																				
Data unit:	-																				
Description:	<p>The Methane Correction Factor (MCF) shall be determined based on the following table:</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Type of wastewater treatment and discharge pathway or system</th> <th>MCF value</th> </tr> </thead> <tbody> <tr> <td>Discharge of wastewater to sea, river or lake</td> <td>0.1</td> </tr> <tr> <td>Land application</td> <td>0.1</td> </tr> <tr> <td>Aerobic treatment, well managed</td> <td>0.0</td> </tr> <tr> <td>Aerobic treatment, poorly managed or overloaded</td> <td>0.3</td> </tr> <tr> <td>Anaerobic digester for sludge without methane recovery</td> <td>0.8</td> </tr> <tr> <td>Anaerobic reactor without methane recovery</td> <td>0.8</td> </tr> <tr> <td>Anaerobic shallow lagoon (depth less than 2 metres)</td> <td>0.2</td> </tr> <tr> <td>Anaerobic deep lagoon (depth more than 2 metres)</td> <td>0.8</td> </tr> <tr> <td>Septic system</td> <td>0.5</td> </tr> </tbody> </table>	Type of wastewater treatment and discharge pathway or system	MCF value	Discharge of wastewater to sea, river or lake	0.1	Land application	0.1	Aerobic treatment, well managed	0.0	Aerobic treatment, poorly managed or overloaded	0.3	Anaerobic digester for sludge without methane recovery	0.8	Anaerobic reactor without methane recovery	0.8	Anaerobic shallow lagoon (depth less than 2 metres)	0.2	Anaerobic deep lagoon (depth more than 2 metres)	0.8	Septic system	0.5
Type of wastewater treatment and discharge pathway or system	MCF value																				
Discharge of wastewater to sea, river or lake	0.1																				
Land application	0.1																				
Aerobic treatment, well managed	0.0																				
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Anaerobic reactor without methane recovery	0.8																				
Anaerobic shallow lagoon (depth less than 2 metres)	0.2																				
Anaerobic deep lagoon (depth more than 2 metres)	0.8																				
Septic system	0.5																				
Source of data:	Edit the values according to the new version, pages 20-21.																				

	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 5, CHAPTER 6, table 6.3)
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Parameter:	$MCF_{s,BL,final}$, $MCF_{s,PJ,final}$
Data unit:	-
Description:	Methane correction factor for sludge treatment process from base case and project implementation
Source of data:	TVER-TOOL-02-03- Tool to calculate Emissions from solid waste disposal sites

Parameter:	UF_{BL}
Data unit:	-
Description:	Model correction factor to account for model uncertainties (Default 0.89)
Source of data:	Page 13 AMS-III.H. : Methane recovery in wastewater treatment version 019

Parameter:	UF_{PJ}
Data unit:	-
Description:	Model correction factor to account for model uncertainties (Default 1.12)
Source of data:	Page 24 AMS-III.H. : Methane recovery in wastewater treatment version 019

Parameter:	$B_{O,ww}$
Data unit:	kgCH ₄ /kg COD _{removal}
Description:	Methane producing capacity of the wastewater (Default 0.25)
Source of data:	2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 5,CHAPTER 6, table 6.2)

Parameter:	CFE_{ww}
Data unit:	-
Description:	Capture efficiency of the biogas recovery equipment in the wastewater treatment systems (Default 0.90)
Source of data:	Page 23 AMS-III.H. : Methane recovery in wastewater treatment version 019

Parameter:	CFE_s
Data unit:	-
Description:	Capture efficiency of the biogas recovery equipment in the sludge treatment systems (Default 0.90)
Source of data:	Page 24 AMS-III.H. : Methane recovery in wastewater treatment version 019

Parameter:	FE
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Data unit:	-
Description:	Flare efficiency in year y Open Flare Efficiency 0.50 Enclosed Flare Efficiency 0.90
Source of data:	TVER-TOOL-02-04 Tool to calculate project emissions from flaring

Parameter:	F
Data unit:	-
Description:	Fraction of CH ₄ in biogas (Default 0.50)
Source of data:	Page 15 AMS-III.H. : Methane recovery in wastewater treatment version 019

Parameter:	DOC _F
Data unit:	-
Description:	Fraction of DOC dissimilated to biogas (Default 0.50)
Source of data:	Page 15 AMS-III.H. : Methane recovery in wastewater treatment version 019

Parameter:	DOC _s
Data unit:	-
Description:	Degradable organic content of the untreated sludge generated in the year y (fraction, dry basis). Default values of 0.5 for domestic sludge Default values of 0.257 for industrial sludge shall be used
Source of data:	Page 15 AMS-III.H. : Methane recovery in wastewater treatment version 019

10. Reference

Clean Development Mechanism (CDM)

AMS-III.H.: Methane recovery in wastewater treatment version 19.0

TOOL 03 : Tool to calculate project or leakage CO₂ emissions from fossil fuel combustion version 03.0

TOOL 04 : Emissions from solid waste disposal sites version 08.0

TOOL 05 : Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation version 03.0

TOOL 06 : Project emissions from flaring version 04.0

Appendix 1 Provisions for upgradation and distribution of biogas

1. Project boundary

In case of project activities covered under Thermal or mechanical, electrical energy generation after bottling of upgraded biogas and Thermal or mechanical, electrical energy generation after upgrading and distribution, if the project activity involves bottling of biogas the project boundary includes the upgrade and compression installations, the dedicated piped network/natural gas distribution grid for distribution of biogas from the wastewater treatment plant to the end user sites and all the facilities and devices connected directly to it.

2. Baseline

In case of project activities covered under upgrading and injection of biogas into a natural gas distribution grid with no significant transmission constraints the baseline emissions for upgraded biogas injection ($BE_{injection,y}$) are determined as follows:

$$BE_{injection,y} = E_{ug,y} \times CEF_{NG} \quad \text{equation (1)}$$

Where;

- $BE_{injection,y}$ = Baseline emissions for injection of upgraded biogas into a natural gas distribution grid in year y (tCO₂eq/year)
- $E_{ug,y}$ = Energy delivered from the upgraded biogas in the project activity to the natural gas distribution grid in year y (TJ)
- CEF_{NG} = Carbon emission factor of natural gas (t CO₂e/TJ)

1) The energy delivered from the upgraded biogas in the project activity to the natural gas distribution grid in year y ($E_{ug,y}$) is calculated as follows:

$$E_{ug,y} = Q_{ug,y} \times NCV_{ug,y} \quad \text{equation (2)}$$

Where;

- $Q_{ug,y}$ = Quantity of upgraded biogas displacing the use of natural gas in the natural gas distribution grid in year y (kg or m³)
- $NCV_{ug,y}$ = Net calorific value of the upgraded biogas in year y (TJ/kg or J/m³)

1.1) The quantity of upgraded biogas displacing the use of natural gas in the natural gas distribution grid in year y is calculated as follows:

$$Q_{ug,y} = \text{Min} (Q_{ug,in,y}, Q_{cap,CH_4,y}) \quad \text{equation (3)}$$

Where;

$Q_{ug,in,y}$ = Quantity of upgraded biogas injected into the natural gas distribution grid in year y (kg or m³)

$Q_{cap,CH_4,y}$ = Quantity of methane captured at the wastewater treatment source facilities in year y (kg or m³)

1.1.1) The quantity of methane captured at the waste water treatment source facilities is calculated as follows:

$$Q_{cap,CH_4,y} = w_{CH_4,ww} \times Q_{cap,biogas,y} \quad \text{equation (4)}$$

Where;

$w_{CH_4,ww}$ = Methane fraction of biogas as monitored at the outlet of the wastewater treatment source facilities (kg or m³ CH₄/kg or m³ of biogas)

$Q_{cap,biogas,y}$ = Monitored amount of biogas captured at the source facilities in year y (kg or m³)

3. Project emission

3.1 Project emissions related to the upgrading and compression of the biogas

Project emissions related to the upgrading and compression of the biogas can be calculated as follows;

$$PE_{process,y} = PE_{power,upgrade,y} + PE_{ww,upgrade,y} + PE_{CH_4,equip,y} + PE_{ventgas,y} \quad \text{equation (5)}$$

Where;

$PE_{process,y}$ = Project emissions related to the upgrading and compression of the biogas in year y (tCO₂eq/year)

$PE_{power,upgrade,y}$ = Project emissions from electricity and fuel used by the upgrading facilities (tCO₂eq/year)

$PE_{ww,upgrade,y}$ = Project emissions from methane contained in any waste water discharge of upgrading installation in year y (tCO₂eq/year)

$PE_{CH_4,equip,y}$ = Project emissions from compressor leaks in year y (tCO₂eq/year)

$PE_{\text{ventgas},y}$ = Project emissions from venting gases retained in upgrading equipment in year y (tCO₂eq/year)

3.1.1 Project emissions from electricity and fuel used by the upgrading facilities

Project emissions from electricity and fuel used by the upgrading facilities can be calculated as follows;

$$PE_{\text{power,upgrade},y} = PE_{\text{EC},y} + PE_{\text{FF},y} \quad \text{equation (6)}$$

Where;

$PE_{\text{power,upgrade},y}$ = Project emissions from electricity and fuel used by the upgrading facilities in year y (tCO₂eq/year)

$PE_{\text{EC},y}$ = Project emissions from electricity used by the upgrading facilities in year y (tCO₂eq/year)

$PE_{\text{FF},y}$ = Project emissions from fuel used by the upgrading facilities in year y (tCO₂eq/year)

3.1.1.1 Project emissions from electricity used by the upgrading facilities

Project emissions from electricity used by the upgrading facilities can be calculate;

$$PE_{\text{EC},y} = \sum_j EC_{\text{PJ},j,y} \times EF_{\text{EF},j,y} \times (1 + \text{TDL}_{j,y}) \quad \text{equation (7)}$$

Where;

$PE_{\text{EC},y}$ = Project emissions from electricity consumption in year y (tCO₂eq/year)

$EC_{\text{PJ},j,y}$ = Quantity of electricity consumed by the baseline electricity consumption source j in year y (MWh/year)

$EF_{\text{EF},j,y}$ = Emission factor for electricity generation for source j in year y (tCO₂/MWh)

$\text{TDL}_{j,y}$ = Average technical transmission and distribution losses for providing electricity to source j in year y

j = Sources of electricity consumption in the project

3.1.1.2 Project emissions from fuel used by the upgrading facilities

To calculate greenhouse gas emissions from fossil fuel use due to project implementation, use the Calculation Tool of T-VER-TOOL-02-01 "Calculating Greenhouse Gas Emissions from the Burning of Fossil Fuels from Project Emission and Leakage Emission", latest edition

3.1.2 Project emissions from methane contained in waste water discharge of upgrading installation

$$PE_{ww,upgrade,y} = Q_{ww,upgrade,y} \times [CH_4]_{ww,upgrade,y} \times GWP_{CH_4} \quad \text{equation (8)}$$

Where;

$Q_{ww,upgrade,y}$ = Volume of wastewater discharge from upgrading installation in year y

$[CH_4]_{ww,upgrade,y}$ = Dissolved methane contained in the wastewater discharge in year y

3.1.3 Project emissions from compressor leaks are determined as follows:

$$PE_{CH_4,equip,y} = GWP_{CH_4} \times 10^{-3} \times \sum_{\text{equipment}} w_{CH_4,stream,y} \times EF_{\text{equipment}} \times T_{\text{equipment,y}} \quad \text{equation (9)}$$

Where;

$w_{CH_4,stream,y}$ = Average methane weight fraction of the gas in year y (kg-CH₄/kg)

$T_{\text{equipment,y}}$ = Operation time of the equipment in hours in year y (in absence of detailed information, it can be assumed that the equipment is used continuously, as a conservative approach)

$EF_{\text{equipment}}$ = Leakage rate for fugitive emissions from the compression technology as per specification from the compressor manufacturer in kg/hour/compressor. If no default value from the technology provider is available, the approach below shall be used

1) $EF_{\text{equipment}}$ can be done as follows.

Fugitive methane emissions occurring during the recovery and processing of gas may in some projects be small, but should be estimated as a conservative approach. Emission factors may be taken from the 1995 Protocol for Equipment Leak Emission Estimates, published by EPA. Emissions should be determined for all relevant activities and all equipment used for the upgrading of biogas (such as valves, pump seals, connectors, flanges, open-ended pipes, etc.). The following data needs to be obtained:

- 1.1) The number of each type of component in a unit (valve, connector, etc.);
- 1.2) The methane concentration of the stream;
- 1.3) The time period each component is in service.

The EPA approach is based on average emission factors for Total Organic Compounds (TOC) in a stream and has been revised to estimate methane emissions. Methane emissions are calculated for each single piece of equipment by multiplying the methane concentration with the appropriate emission factor from the table 1.

Table 1 Methane emission factors for equipment

Equipment type	Emission factor (kg/hour/source)
Valves	4.5 E-0.3
Pump seals	2.4 E-0.3
Other ¹	8.8 E-0.3
Connectors	2.0 E-0.4
Flangs	3.9 E-0.4
Open ended lines	2.0 E-0.3

Remark¹ The emission factor for “other” equipment type was derived from compressors, diaphragms, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, relief valves and vents. This “other” equipment type should be applied for any equipment type other than connectors, flanges, open-ended lines, pumps or valves.

3.1.4 Project emissions from venting gases retained in upgrading equipment

Project emissions from venting gases retained in upgrading equipment do not have to be considered if vent gases ($PE_{ventgas,y}$) are channeled to storage bags. In case vent gases are flared, emissions due to the incomplete or inefficient combustion of the gases will be calculated using the TVER-TOOL-02-04 " Tool to calculate project emissions from flaring " Latest version, as follows:

$$PE_{ventgas,y} = \sum_{h=1}^{8760} TM_{RG,h} \times (1 - \eta_{flare,h}) \times GWP_{CH_4} \times 10^{-3} \quad \text{equation (10)}$$

Where;

$TM_{RG,h}$ = Mass flow rate of methane in the residual gas in hour h (kg/h)

$\eta_{flare,h}$ = Flare efficiency in hour h

In case vent gases are not flared the TVER-TOOL-02-04 " Tool to calculate project emissions from flaring " Latest version will be used, without considering measurements and calculations for the flare efficiency, which will be assumed to be zero. In this case, emissions due to the vent gases will be:

$$PE_{\text{ventgas},y} = \sum_{h=1}^{8760} TM_{\text{RG},h} \times GWP_{\text{CH}_4} \times 10^{-3} \quad \text{equation (11)}$$

Alternatively, in case vent gases are directly vented to the atmosphere, it may also be calculated by conservatively calculating the mass of the gases vented based on the volume, pressure and temperature of gas retained in upgrading equipment. This mass should be multiplied with the frequency with which it is vented and assuming that the vented gas is pure methane.

In order to account for emissions that occur when the upgrade facility is shut down due to maintenance, repair work or emergencies one of the alternatives proposed above should be used to calculate and include emissions from flaring or venting.

3.2 Project emissions due to physical leakage of upgraded biogas from the dedicated piped network

Project emissions due to physical leakage of upgraded biogas from the dedicated piped network can be calculate as follow;

$$PE_{\text{leakage,pipeline},y} = Q_{\text{methane,pipeline},y} \times LR_{\text{pipeline}} \times GWP_{\text{CH}_4} \quad \text{equation (12)}$$

Where;

- $PE_{\text{leakage,pipeline},y}$ = Emissions due to physical leakage from the dedicated piped network in year y (tCO₂eq/year)
- $Q_{\text{methane,pipeline},y}$ = Total quantity of methane transported in the dedicated piped network in year y (m³)
- LR_{pipeline} = Physical leakage rate from the dedicated piped network (if no project-specific values can be identified a conservative default value of 0.0125 Gg per 10⁶ m³ of utility sales shall be applied)

4. Leakage emissions

4.1 Leakage emissions related to the upgrading and compression of the biogas

Leakage emissions related to the upgrading and compression of the biogas can be calculate as follow;

$$LE_{\text{bottling}} = LE_{\text{leakage,bb,y}} + LE_{\text{trans,y}} \quad \text{equation (13)}$$

Where;

- LE_{bottling} = Leakage emissions project activities involving bottling of biogas in year y (tCO₂eq/year)
- $LE_{\text{leakage,bb,y}}$ = Leakage emissions from biogas bottles in year y (tCO₂eq/year)
- $LE_{\text{trans,y}}$ = Leakage emissions from fossil fuel use for transportation of bottles; biogas filled bottles to the end users and the return of empty bottles to the filling site in year y (tCO₂eq/year)

4.1.1 Leakage emissions from biogas bottles

Leakage emissions from biogas bottles can be calculate as follow;

$$LE_{\text{leakage,bb,y}} = Q_{\text{methane,bb,y}} \times LR_{\text{bb}} \times GWP_{\text{CH}_4} \quad \text{equation (14)}$$

Where;

- $Q_{\text{methane,bb,y}}$ = Total quantity of methane bottled in year y (m³)
- LR_{bb} = Physical leakage rate from biogas bottles (if no project-specific values can be identified a default value of 1.25 per cent shall be applied)

4.1.2 Leakage emissions from fossil fuel use for transportation of bottles; biogas filled bottles to the end users and the return of empty bottles to the filling site.

Leakage emissions due to fossil fuel use for transportation of bottles (biogas filled bottles to the end users and the return of empty bottles to the filling site) are determined as below. If some of the locations of the end-users are unknown a conservative approach assuming transport emissions of 250 km, shall be used.

$$LE_{trans,y} = (Q_{bb,y} / CT_{bb,y}) \times DAF_{bb} \times EF_{CO_2} \quad \text{equation (15)}$$

Where;

- $Q_{bb,y}$ = Total freight volume of upgraded biogas in bottles transported in year y (m^3)
- $CT_{bb,y}$ = Average truck freight volume capacity for the transportation of bottles with upgraded biogas (m^3 /truck)
- DAF_{bb} = Aggregated average distance for bottle transportation; biogas filled bottles to the end users and the return of empty bottles to the filling site (km/truck)
- EF_{CO_2} = CO₂ emission factor from fuel use due to transportation (t CO₂/km)

5. Monitoring methodology

5.1 The project proponents shall maintain a biogas (or methane) balance based on:

1) Continuous measurement of the amount of biogas captured at the wastewater treatment system;

2) Continuous measurement of the amount of biogas used for various purposes in the project activity: e.g. heat, electricity, flare, hydrogen production, injection into natural gas distribution grid, etc. The difference is considered as loss due to physical leakage and deducted from the emission reductions.

5.2 In case of project activities covered under Thermal or mechanical, electrical energy generation after upgrading and distribution. the quantity of biogas, temperature, pressure and concentration of methane in the biogas injected into the natural gas grid/distributed via the dedicated piped network shall be measured continuously using certified equipment. The net calorific value (NCV) shall be measured directly from the gas stream using an online Heating Value Meter or calculated based on the measured methane content using the NCV of methane. This measurement must be in mass or volume basis and the project participants shall ensure that units of the measurements of the amount of biogas injected and of the net calorific value are consistent. The methane content of the injected or transported biogas shall always be in accordance with national regulations or, in absence of national regulations, 96 per cent (by volume) or higher. Biogas injected or transported with inferior methane content shall be excluded from the emission reduction calculations.

5.3 In case of project activities covered under Thermal or mechanical, electrical energy generation after bottling of upgraded biogas and Thermal or mechanical, electrical energy

generation after upgrading and distribution, the following parameters shall be monitored and recorded.

1) The volume of discharge into the desorption pond from the upgrading installation ($Q_{ww,upgrade,y}$), monitored continuously;

2) The methane content ($[CH_4]_{ww,upgrade,y}$) of the discharge water from the upgrade facility, samples are taken at least every six months during normal operation of the facility

3) The annual operation time of the compressor and each piece of equipment in the biogas upgrading and compression installations in hours ($T_{equipment,y}$). In case this information is not available it shall be assumed that the upgrading installation and compressor is used continuously;

4) The quantity, pressure and composition of the bottled biogas, biogas injected into a natural grid or transported via a dedicated piped network; monitored continuously using flow meters and regularly calibrated methane monitors. The pressure of the biogas shall be regulated and monitored using a regularly calibrated pressure gauge. The methane content of the biogas shall always be in accordance with national regulations or, in absence of national regulations, 96 per cent (by volume) or higher in order to ensure that biogas could readily be used as a fuel, inferior methane content shall be excluded from the emission reduction calculations;

5) In case vent gases are calculated using the TVER-TOOL-02-04 " Tool to calculate project emissions from flaring " Latest version the monitoring criteria contained in this tool shall be used. In case this tool is not used and the alternative approach in equation 10 of this appendix is used, then temperature and pressure of gas retained in upgrading equipment shall be measured continuously and their values before the venting process are used, together with the volume capacity of the installation, to estimate the amount of methane released during the venting process;

6) During the periods when the biogas upgrading facility is closed due to scheduled maintenance or repair of equipment or during exigencies, project participants should ensure that the captured biogas is flared at the site of its capture using an (emergency) flare. Appropriate monitoring procedures should be established to monitor this emergency flare;

7) In case of project activities covered under Thermal or mechanical, electrical energy generation after bottling of upgraded biogas. the number and volume of biogas bottles produced and transported, the average truck capacity ($CT_{bb,y}$) and the average aggregated distance for transporting the bottled biogas (DAF_{bb}).

Document information T-VER-P-METH-12-01

Version	Amendment	Entry into force	Description
01	-	1 March 2023	<ul style="list-style-type: none"> - Change document code from TVER-METH-12-01 Version 01. - Add the definition of project starting date. - Change the sign and the meaning for parameter of $EF_{grid,y}$ and revise the data sources.
01	-	30 November 2022	Initial adoption