# Draft Methodological Tool

## "Project and leakage emissions from anaerobic digesters"

**(Version 01.0.0)**

## I. DEFINITIONS, SCOPE, APPLICABILITY AND PARAMETERS

### Definitions

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

**Anaerobic digestion.** Degradation and stabilization of organic materials by the action of anaerobic bacteria that result in production of methane and carbon dioxide. Typical organic materials that undergo anaerobic digestion are municipal solid waste (MSW), animal manure, wastewater, organic industrial effluent and biosolids from aerobic wastewater treatment plants.

**Anaerobic digester.** Equipment that is used to generate biogas from liquid or solid waste through anaerobic digestion. The digester is covered or encapsulated to enable biogas capture for flaring, heat and/or power generation or feeding biogas into a natural gas network. The following types of digesters are considered:

- Covered anaerobic lagoons: anaerobic lagoons that are covered with a flexible membrane to capture methane produced during the digestion process. Covered anaerobic lagoons are typically used for high volume effluent such as animal manure and organic industrial effluent like starch industry effluent;
- Conventional digesters: digesters that are operated similar to a covered anaerobic lagoon, with no mixing or liquid and biogas recirculation;
- High rate digesters, such as upflow anaerobic sludge blanket (UASB) reactors, anaerobic filter bed reactors and fluidized bed reactors; and
- Two stage digesters: anaerobic digestion takes place in a two stage process, solubilization of particulate matter occurs and volatile acids are formed in the first stage digester. The second stage is carried out in a separate digester, at a neutral pH and a longer solid retention time.

**Anaerobic lagoon.** A treatment system consisting of a deep earthen basin with sufficient volume to permit sedimentation of settable solids, to digest retained sludge, and to anaerobically reduce some of the soluble organic substrate. Anaerobic conditions prevail except for a shallow surface layer in which excess undigested grease and scum are concentrated.

**Biogas.** Gas generated from an anaerobic digester. Typically, the composition of the gas is 50 to 70% $CH_4$ and 30 to 50% $CO_2$, with traces of $H_2S$ and $NH_3$ (1 to 5%).

**Digestate.** Spent contents of a digester. Digestate may be liquid or solid. Digestate is considered to be solid if the total solids are 20% or more of the total weight of the digestate. The digestate has a lower biodegradability than the original material as the easily biodegradable organic matter has been degraded and stabilized in the digester. Digestate may be further stabilized aerobically, applied to land, sent to a solid waste disposal site (SWDS) or kept in a storage or evaporation pond.

**Solid waste disposal site (SWDS).** Designated areas intended as the final storage place for solid waste. Stockpiles are considered a SWDS if: (a) their volume to surface area ratio is 1.5 ($m^3/m^2$) or larger; and if (b) a visual inspection by the DOE confirms that the material is exposed to anaerobic conditions (i.e. it has a low porosity and is moist).

**Stockpile.** A pile of solid waste (not buried below ground). Anaerobic conditions are not assured in a stockpile with low volume to surface area ratios (less than 1.5) because the waste may be exposed to aeration.

**Total solids.** Weight of the dry matter of the material fed into the digester (total weight of the material minus the weight of the moisture contained in the material), which ranges from 10 to 70% of the total weight of the material.

**Un-aerated lagoon.** A treatment system where liquid digestate or a liquid fraction of solid digestate is further treated in a pond or series of ponds, without forced aeration. The treatment is based on aerobic processes (due to oxygen produced by algae and atmospheric oxygen diffusion into the liquid column) at the surface layers and anaerobic processes in the bottom layers. Types of un-aerated lagoons are stabilization ponds, sludge pits and uncovered anaerobic lagoons.

**Volatile matter.** Difference between the total solids and the weight of the ash content in the material fed into the digester. The range is typically about 60 to 80% of the total solids.

**Scope and applicability**

This tool provides procedures to calculate project and leakage emissions associated with anaerobic digestion in an anaerobic digester. The tool is not applicable to other systems where waste may be decomposed anaerobically, for instances stockpiles, SWDS or un-aerated lagoons.

The following sources of project emissions are accounted for in this tool:

(a) $CO_2$ emissions from consumption of electricity associated with the operation of the anaerobic digester;

(b) $CO_2$ emissions from consumption of fossil fuels associated with the operation of the anaerobic digester;

(c) $CH_4$ emissions from the digester (emissions during maintenance of the digester, physical leaks through the roof and side walls, and release through safety valves due to excess pressure in the digester); and

(d) $CH_4$ emissions from flaring of biogas.

The following sources of leakage emissions are accounted for in this tool:

(a) $CH_4$ and $N_2O$ emission from composting of digestate;

(b) $CH_4$ emissions from the anaerobic decay of digestate disposed in a SWDS or subjected to anaerobic storage, such as in a stabilization pond.

Emission sources associated with $N_2O$ emissions from physical leakages from the digester, transportation of feed material and digestate or any other on-site transportation, piped distribution of the biogas, aerobic treatment of liquid digestate and land application of the digestate are neglected because these are minor emission sources or because they are accounted in the methodologies referring to this tool.

This tool also refers to the latest approved versions of the following tools:

- "Tool to calculate baseline, project and/or leakage emissions from electricity consumption";
- "Tool to calculate project or leakage $CO_2$ emissions from fossil fuel combustion";
- "Tool to determine project emissions from flaring gases containing methane";
- "Emissions from solid waste disposal sites";
- "Project and leakage emissions from composting"; and

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

To access these tools refer to <http://cdm.unfccc.int/goto/MPappmeth>.

The applicability conditions of these tools also apply.

**Parameters**

This tool provides procedures to determine the following parameters:

| Parameter | SI Unit | Description |
|---|---|---|
| $PE_{AD,y}$ | t $CO_2e$ | Project emissions associated with the anaerobic digester in year *y* (t $CO_2e$) |
| $LE_{AD,y}$ | t $CO_2e$ | Leakage emissions associated with the anaerobic digester in year *y* (t $CO_2e$) |

## II. PROJECT EMISSIONS PROCEDURE

The project emissions associated with the anaerobic digester ($PE_{AD,y}$) are determined as follows:

$$PE_{AD,y} = PE_{EC,y} + PE_{FC,y} + PE_{CH4,y} + PE_{flare,y} \quad (1)$$

Where:

| | | |
|---|---|---|
| $PE_{AD,y}$ | = | Project emissions associated with the anaerobic digester in year *y* (t $CO_2e$) |
| $PE_{EC,y}$ | = | Project emissions from electricity consumption associated with the anaerobic digester in year *y* (t $CO_2e$) |
| $PE_{FC,y}$ | = | Project emissions from fossil fuel consumption associated with the anaerobic digester in year *y* (t $CO_2e$) |
| $PE_{CH4,y}$ | = | Project emissions of methane from the anaerobic digester in year *y* (t $CO_2e$) |
| $PE_{flare,y}$ | = | Project emissions from flaring of biogas in year *y* (t $CO_2e$) |

These parameters are determined through the steps outlined below.

***Step 1: Determination of the quantity of methane produced in the digester ($Q_{CH4,y}$)***

There are two different procedures to determine the quantity of methane produced in the digester in year *y* ($Q_{CH4,y}$). For large scale projects only Option 1 shall be used. For small scale projects, project participants may choose between Option 1 or Option 2.

**Option 1: Procedure using monitored data**

$Q_{CH4,y}$ shall be measured using the "Tool to determine the mass flow of a greenhouse gas in a gaseous stream". When applying the tool, the following applies:

- The gaseous stream to which the tool is applied is the biogas collected from the digester;
- $CH_4$ is the greenhouse gas *i* for which the mass flow should be determined; and
- The flow of the gaseous stream should be measured on an hourly basis or a smaller time interval; and then accumulated for the year *y*. Please note that units need to be converted to tons, when applying the results in this tool.

**Option 2: Procedure using a default value**

Under this option, the flow of the biogas is measured and a default value is used for the fraction of methane in the biogas, as follows:

$$Q_{CH4,y} = Q_{biogas,y} \cdot f_{CH4,default} \cdot \rho_{CH4} \quad \textbf{(2)}$$

Where:

| | | |
|---|---|---|
| $Q_{CH4,y}$ | = | Quantity of methane produced in the digester in year *y* (t $CH_4$) |
| $Q_{biogas,y}$ | = | Amount of biogas collected at the digester outlet in year *y* ($Nm^3$ biogas) |
| $f_{CH4,default}$ | = | Default value for the fraction of methane in the biogas ($Nm^3$ $CH_4$ / $Nm^3$ biogas) |
| $\rho_{CH4}$ | = | Density of methane at normal conditions (t $CH_4$ / $Nm^3$ $CH_4$) |

***Step 2: Determination of project emissions from electricity consumption ($PE_{EC,y}$)***

This step is applicable if the anaerobic digester consumes electricity, such as for mixing, recirculation of digestate, or processing of feed material. If the electricity consumed is generated on-site using biomass residues, wind, hydro or geothermal power, then $PE_{EC,y} = 0$. Otherwise, the project participants may choose between the following two options to calculate $PE_{EC,y}$:

**Option 1: Procedure using monitored data**

$PE_{EC,y}$ shall be calculated using the "Tool to calculate baseline, project and/or leakage emissions from electricity consumption", where the project emission source *j* referred to in the tool is the total electricity consumption associated with the anaerobic digestion facility.

**Option 2: Procedure using a default value**

Project emissions from electricity consumption associated with the anaerobic digester are calculated as follows:

$$PE_{EC,y} = Q_{CH4,y} \cdot F_{EC,default} \cdot EF_{EL,default} \quad \textbf{(3)}$$

Where:

| | | |
|---|---|---|
| $PE_{EC,y}$ | = | Project emissions from electricity consumption associated with the anaerobic digester in year *y* (t $CO_2$) |
| $Q_{CH4,y}$ | = | Quantity of methane produced in the anaerobic digester in year *y* (t $CH_4$) |
| $F_{EC,default}$ | = | Default factor for the electricity consumption associated with the anaerobic digester per ton of methane generated (MWh / t $CH_4$) |
| $EF_{EL,default}$ | = | Default emission factor for the electricity consumed in year *y* (t $CO_2$ / MWh) |

***Step 3: Determination of project emissions from fossil fuel consumption ($PE_{FC,y}$)***

Where the anaerobic digester facility uses fossil fuels, project participants shall calculate $PE_{FC,y}$ using the "Tool to calculate project or leakage $CO_2$ emissions from fossil fuel combustion". The project emission source *j* referred to in the tool is fossil fuel consumption associated with the anaerobic digestion facility (not including fossil fuels consumed for transportation of feed material and digestate or any other on-site transportation).

***Step 4: Determination of project emissions of methane from the anaerobic digester ($PE_{CH4,y}$)***

Project emissions of methane from the anaerobic digester include emissions during maintenance of the digester, physical leaks through the roof and side walls, and release through safety valves due to excess pressure in the digester. These emissions are calculated using a default emission factor ($EF_{CH4,default}$), as follows:

$$PE_{CH4,y} = Q_{CH4,y} \cdot EF_{CH4,\,default} \cdot GWP_{CH4} \tag{4}$$

Where:

| | | |
|---|---|---|
| $PE_{CH4,y}$ | = | Project emissions of methane from the anaerobic digester in year *y* (t $CO_2$e) |
| $Q_{CH4,y}$ | = | Quantity of methane produced in the anaerobic digester in year *y* (t $CH_4$) |
| $EF_{CH4,default}$ | = | Default emission factor for the fraction of $CH_4$ produced that leaks from the anaerobic digester (fraction) |
| $GWP_{CH4}$ | = | Global warming potential of $CH_4$ (t $CO_2$ / t $CH_4$) |

***Step 5: Determination of project emissions from flaring of biogas ($PE_{flare,y}$)***

If the project activity includes flaring of biogas, then project emissions from flaring of biogas ($PE_{flare,y}$) shall be estimated using the "Tool to determine project emissions from flaring gases containing methane". The following applies:

- For small scale projects, project participants may adopt a default value for the fraction of methane in the biogas ($f_{CH4,default}$) in applying the tool; and
- The tool provides default factors for the flare efficiency, which can be used for large or small scale projects as described in the tool.

## III. LEAKAGE EMISSIONS PROCEDURE

The leakage[1] emissions associated with the anaerobic digester ($LE_{AD,y}$) depend on how the digestate is managed. They include emissions associated with storage and composting of the digestate and are determined as follows:

$$LE_{AD,y} = LE_{storage,y} + LE_{comp,y} \tag{5}$$

Where:

| | | |
|---|---|---|
| $LE_{AD,y}$ | = | Leakage emissions associated with the anaerobic digester in year *y* (t $CO_2$e) |
| $LE_{storage,y}$ | = | Leakage emissions associated with storage of digestate in year *y* (t $CO_2$e) |
| $LE_{comp,y}$ | = | Leakage emissions associated with composting digestate in year *y* (t $CO_2$e) |

***Step 1: Determination of leakage emissions associated with storage of digestate ($LE_{storage,y}$)***

This step applies in the case that the digestate is stored under the following anaerobic conditions:

- In an un-aerated lagoon that has a depth of more than one meter; or
- In a SWDS, including stockpiles that are considered a SWDS as per the definitions section.

Storage of digestate under anaerobic conditions can cause $CH_4$ emissions due to further anaerobic digestion of the residual biodegradable organic matter. The procedure for determining $LE_{storage,y}$ is distinguished for liquid digestate and solid digestate.

[1] If the storage of digestate or the composting of digestate is occurring within the project boundary, these emissions will be considered as project emissions.

*Determining $LE_{storage,y}$ for liquid digestate*

Where digestate is liquid, as per the definitions section, or where a liquid fraction of mechanically separated digestate is stored, then choose between Options 1 or 2 below to determine $LE_{storage,y}$.

**Option 1: Procedure using monitored data**

$$LE_{storage,y} = Q_{stored,y} \cdot P_{COD,y} \cdot B_0 \cdot MCF_p \cdot GWP_{CH4} \tag{6}$$

Where:

| | | |
|---|---|---|
| $LE_{storage,y}$ | = | Leakage emissions associated with storage of digestate in year *y* (t $CO_2$e) |
| $Q_{stored,y}$ | = | Amount of liquid digestate stored anaerobically in year *y* ($m^3$) |
| $P_{COD,y}$ | = | Average chemical oxygen demand (COD) of the liquid digestate in year *y* (t COD / $m^3$) |
| $B_o$ | = | Maximum methane producing capacity of the COD applied (t $CH_4$ / t COD) |
| MCF | = | Methane conversion factor (fraction) |
| $GWP_{CH4}$ | = | Global warming potential of $CH_4$ (t $CO_2$ / t $CH_4$) |

**Option 2: Procedure using a default value**

$$LE_{storage,y} = F_{ww,CH4,default} \cdot Q_{CH4,y} \cdot GWP_{CH4} \tag{7}$$

Where:

| | | |
|---|---|---|
| $LE_{storage,y}$ | = | Leakage emissions associated with storage of digestate in year *y* (t $CO_2$e) |
| $F_{ww,CH4,default}$ | = | Default factor representing the remaining methane production capacity of liquid digestate (fraction) |
| $Q_{CH4,y}$ | = | Quantity of methane produced in the digester in year *y* (t $CH_4$) |
| $GWP_{CH4}$ | = | Global warming potential of $CH_4$ (t $CO_2$ / t $CH_4$) |

*Determining $LE_{storage,y}$ for solid digestate*

Where solid digestate is disposed in a SWDS or a stockpile that can be considered a SWDS, as per the definition section, then project participants may choose between Option 1 or Option 2 to determine $LE_{storage,y}$.

**Option 1: Procedure using monitored data**

$LE_{storage,y}$ is determined using the methodological tool "Emissions from solid waste disposal sites". In this case, $LE_{storage,y}$ corresponds to the parameter $LE_{CH4,SWDS,y}$ in the tool and *j* represents the digestate that is disposed at a SWDS.

**Option 2: Procedure using default values**

$LE_{storage,y}$ is determined as follows:

$$LE_{storage,y} = F_{SD,CH4,default} \cdot Q_{CH4,y} \cdot GWP_{CH4} \tag{8}$$

Where:

| | | |
|---|---|---|
| $LE_{storage,y}$ | = | Leakage emissions associated with storage of digestate in year *y* (t $CO_2$e) |
| $F_{SD,CH4,default}$ | = | Default factor for the methane generation capacity of solid digestate (fraction) |
| $Q_{CH4,y}$ | = | Quantity of methane produced in the anaerobic digester in year *y* (t $CH_4$) |
| $GWP_{CH4}$ | = | Global warming potential of $CH_4$ (t $CO_2$/t $CH_4$) |

***Step 2: Determination of leakage emissions associate with composting digestate ($LE_{COMP,y}$)***

$LE_{COMP,y}$ shall be calculated using the methodological tool "Project and leakage emissions from composting". The term $PE_{COMP,y} + LE_{COMP,y}$ in the methodological tool "Project and leakage emissions from composting" provides the value for $LE_{COMP,y}$ of this tool.

## IV. DATA AND PARAMETERS NOT MONITORED

| **Data / Parameter:** | $f_{CH4,default}$ |
|---|---|
| Data unit: | $Nm^3$ $CH_4$ / $Nm^3$ biogas |
| Description: | Default value for the fraction of methane in the biogas |
| Source of data: | The default value was derived based on reported values from registered projects and research papers (Davidsson, 2007) |
| Value to be applied: | 0.6 |
| Any comment: | Use this value for Option 2 of the step "Determination of the quantity of methane produced in the digester" |

| **Data / Parameter:** | $\rho_{CH4}$ |
|---|---|
| Data unit: | t $CH_4$ / $Nm^3$ $CH_4$ |
| Description: | Density of methane at normal conditions |
| Source of data: | Technical literature |
| Value to be applied: | 0.00067 |
| Any comment: | Normal conditions are defined as 20$^o$C and 1 atm pressure |

| **Data / Parameter:** | $EF_{CH4,default}$ |
|---|---|
| Data unit: | t $CH_4$ leaked / t $CH_4$ produced |
| Description: | Default emission factor for the fraction of $CH_4$ produced that leaks from the anaerobic digester |
| Source of data: | IPCC (2006), Flesch et al. (2011) and Kurup (2003) |
| Value to be applied: | Use the default value corresponding to the type of digester used in the project activity. The digester type shall be identified by manufacturer information. If this is not possible, then the factor 0.1 shall be applied (upper range of the IPCC values).<br>• 0.028: Digesters with steel or lined concrete or fiberglass digesters and a gas holding system (egg shaped digesters) and monolithic construction;<br>• 0.05: UASB type digesters, floating gas holders with no external water seal;<br>• 0.10: Digesters with unlined concrete/ferrocement/brick masonry arched type gas holding section; monolithic fixed dome digesters, covered anaerobic lagoon.[2] |
| Any comment: | Applicable to the step "Determination of project emissions of methane from the anaerobic digester" |

[2] Project participants are invited to request for a revision of the tool to propose new default factors applicable to a particular technology, provided the relevant background information to support the values is submitted.

| **Data / Parameter:** | $GWP_{CH4}$ |
|---|---|
| Data unit: | t $CO_2$e / t $CH_4$ |
| Description: | Global Warming Potential of $CH_4$ |
| Source of data: | IPCC |
| Value to be applied: | 21 for the first commitment period. Shall be updated for future commitment periods according to any future COP/MOP decisions |
| Any comment: | - |

| **Data / Parameter:** | $F_{EC,default}$ |
|---|---|
| Data unit: | MWh / t $CH_4$ produced |
| Description: | Default factor for the electricity consumption associated with the anaerobic digester per ton of $CH_4$ generated |
| Source of data: | The values were derived based on a review of registered CDM projects, other projects using digesters and reference books (Metcalf & Eddy, 2003; and for solid waste Sri Bala et al., 2009). |
| Value to be applied: | 0 - Covered anaerobic lagoons (gravity fed) / conventional digesters;<br>0.01 - UASB / filter bed reactor for wastewater / fluidized bed reactor;<br>1.02 - Conventional digesters with continuously stirred tank reactor type for wastewater;<br>1.54 - Any anaerobic digester for solid waste with pre-processing of wastes (e.g. pulverizing).<br>For digesters other than those specified above, which are fed by gravity, and have no recirculation and therefore no electrical energy is required to operate, apply a value of 0 |
| Any comment: | Applicable to Option 2 in the step "Determination of project emissions from electricity consumption ($PE_{EC,y}$)" |

| **Data / Parameter:** | $EF_{El,default}$ |
|---|---|
| Data unit: | t $CO_2$ / MWh |
| Description: | Default emission factor for the electricity consumed in year *y* |
| Source of data: | "Tool to calculate baseline, project and/or leakage emissions from electricity consumption" |
| Value to be applied: | 1.3 |
| Any comment: | |

| **Data / Parameter:** | $B_o$ |
|---|---|
| Data unit: | t $CH_4$ / t COD |
| Description: | Maximum $CH_4$ producing capacity of the COD applied |
| Source of data: | 2006 IPCC Guidelines |
| Value to be applied: | 0.25 |
| Any comment: | - |

| **Data / Parameter:** | $F_{ww,CH4,default}$ |
|---|---|
| Data unit: | Fraction |
| Description: | Default factor representing the remaining $CH_4$ production capacity of liquid digestate |
| Source of data: | Reference papers (see references below) and current industry practice |
| Value to be applied: | 0.10: Covered anaerobic lagoons<br>0.15: UASB type digesters / Anaerobic filter bed digesters / Anaerobic fluidized bed digesters<br>0.20: Conventional digesters<br>0.05: Two stage digesters |
| Any comment: | - |

| **Data / Parameter:** | $F_{SD,CH4,default}$ |
|---|---|
| Data unit: | Fraction |
| Description: | Default factor for the methane generation capacity of solid digestate |
| Source of data: | The values were derived based on the removal efficiency of the digesters, using reference papers (Davidsson, 2007) and current industry practice |
| Value to be applied: | Two phase digesters: 0.15<br>All other technologies: 0.35 |
| Any comment: | Applicable to Option 2 in the section "Determining $LE_{storage,y}$ for solid digestate" |

| **Data / Parameter:** | MCF |
|---|---|
| Data unit: | Dimensionless |
| Description: | Methane conversion factor |
| Source of data: | Table 6.3, Chapter 6, Volume 5, 2006 IPCC Guidelines for National Greenhouse Gas Inventories. |
| Value to be applied: | 0.8 for a depth of liquid digestate storage $\geq$ 2 m<br>0.2 for a depth of liquid digestate storage < 2 m and $\geq$ 1 m<br>0 for a depth of liquid digestate storage < 1 m |
| Any comment: | - |

## V. MONITORING METHODOLOGY PROCEDURE

**Monitoring procedures**

Describe and specify in the CDM-PDD all monitoring procedures, including the type of measurement instrumentation used, the responsibilities for monitoring and QA/QC procedures that will be applied. All meters and instruments should be calibrated regularly as per industry practices.

**Data and parameters monitored**

| **Data / Parameter:** | $Q_{biogas,y}$ |
|---|---|
| Data unit: | $Nm^3$ biogas |
| Description: | Amount of biogas collected at the digester outlet in year *y* |
| Measurement procedures: | The volumetric flow measurement should always refer to the actual pressure and temperature. Instruments with recordable electronic signal (analogical or digital) are required. |
| Monitoring/recording frequency: | Continuously measurement by the flow meter. Data to be aggregated monthly and yearly. |
| QA/QC procedures: | - |
| Any comment: | - |

| **Data / Parameter:** | $P_{COD,y}$ |
|---|---|
| Data unit: | t COD / $m^3$ |
| Description: | Average chemical oxygen demand (COD) of the liquid digestate in year *y* |
| Measurement procedures: | Manual collection of samples and laboratory analysis |
| Monitoring/recording frequency: | Monthly and averaged annually |
| QA/QC procedures: | Samples should be collected based on the “2005 Standard Methods for the Examination of Water and Wastewater, 21st. American Public Health Association, Water Environment Federation and American Water Works Association” or any other equivalent national or international standard. |
| Any comment: | - |

| **Data / Parameter:** | $Q_{stored,y}$ |
|---|---|
| Data unit: | $m^3$ |
| Description: | Amount of liquid digestate stored anaerobically in year *y* |
| Measurement procedures: | Using flow meters |
| Monitoring/recording frequency: | Continuously and aggregated annually. |
| QA/QC procedures: | |
| Any comment: | Applicable to Option 1 in the section “Determining $LE_{storage,y}$ for liquid digestate” |

## VI. REFERENCES AND ANY OTHER INFORMATION

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**History of the document**

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