

1 [References to the Methodological tool “Emissions from solid waste disposal sites” and the
2 Methodological tool “Project and leakage emissions from composting”
3 are pending EB 65 approval]

4 **Draft Methodological Tool**

5 **“Project and leakage emissions from anaerobic digesters”**

6 **(Version 01.0.0)**

7 **I. DEFINITIONS, SCOPE, APPLICABILITY AND PARAMETERS**

8 **Definitions**

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

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

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

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

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

33 **Biogas.** Gas generated from a digester. Typically, the composition of the gas is 50 to 70% CH₄ and 30 to
34 50% CO₂, with traces of H₂S and NH₃ (1 to 5%).

35 **Digestate.** Spent contents of a digester. Digestate may be liquid, semi solid or solid. The digestate has
36 lower biodegradability than the original material as the easily biodegradable organic matter has been
37 degraded and stabilized in the digester. Digestate may be further stabilized aerobically, applied to land,
38 sent to a solid waste disposal site (SWDS) or kept in a storage or evaporation pond.

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

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

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

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

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

55 **Scope and applicability**

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

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

- 60 (a) CO₂ emissions from consumption of electricity associated with the operation of the anaerobic
61 digester;
- 62 (b) CO₂ emissions from consumption of fossil fuels associated with the operation of the anaerobic
63 digester;
- 64 (c) CH₄ emissions from the digester (emissions during maintenance of the digester, physical leaks
65 through the roof and side walls, and release through safety valves due to excess pressure in
66 digester); and
- 67 (d) CH₄ emission from flaring of biogas.

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

- 69 (a) CH₄ and N₂O emission from composting of digestate;
- 70 (b) CH₄ emissions from the anaerobic decay of digestate disposed in a SWDS or subjected to
71 anaerobic storage such as in a stabilization pond.

72 Emission sources associated with N₂O emissions from physical leakages from the digester, transportation
73 of feed material and digestate or any other on-site transportation, piped distribution of the biogas, aerobic
74 treatment of liquid digestate and land application of the digestate are neglected because these are minor
75 emission sources or because they are accounted in the methodologies referring to this tool.

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

- 77 • “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”;

- 78 • “Tool to calculate project or leakage CO₂ emissions from fossil fuel combustion”;
- 79 • “Tool to determine project emissions from flaring gases containing methane”;
- 80 • Methodological Tool “Emissions from solid waste disposal sites”;
- 81 • Methodological Tool “Project and leakage emissions from composting”; and
- 82 • “Tool to determine the mass flow of a greenhouse gas in a gaseous stream”.

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

84 The applicability conditions of these tools also apply.

85 Parameters

86 This tool provides procedures to determine the following parameters:

Parameter	SI Unit	Description
PE _{AD,y}	t CO ₂ e	Project emissions associated with an anaerobic digester in year <i>y</i> (t CO ₂ e)
LE _{AD,y}	t CO ₂ e	Leakage emissions associated with an anaerobic digester in year <i>y</i> (t CO ₂ e)

87 II. PROJECT EMISSIONS PROCEDURE

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

$$89 \quad PE_{AD,y} = PE_{EC,y} + PE_{FC,y} + PE_{CH_4,y} + PE_{flare,y} \quad (1)$$

90 Where:

- PE_{AD,y} = Project emissions associated with the anaerobic digester in year *y* (t CO₂e)
- PE_{EC,y} = Project emissions from electricity consumption associated with the anaerobic digester in year *y* (t CO₂e)
- PE_{FC,y} = Project emissions from fossil fuel consumption associated with the anaerobic digester in year *y* (t CO₂e)
- PE_{CH₄,y} = Project emissions of methane from the anaerobic digester in year *y* (t CO₂e)
- PE_{flare,y} = Project emissions from flaring of biogas in year *y* (t CO₂e)

91 *Step 0: Determination of quantity of methane produced in the digester (Q_{CH₄,y})*

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

95 Option 1: Procedure using monitored data

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

- 98 • The gaseous stream to which the tool is applied is the biogas collected from the digester;
- 99 • CH₄ is the greenhouse gas *i* for which the mass flow should be determined; and

- 100 • The flow of the gaseous stream should be measured on an hourly basis or a smaller time interval;
101 and then accumulated for the year y . Please note that units need to be converted to tons, when
102 applying the results in this tool.

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

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

$$106 \quad Q_{\text{CH}_4,y} = Q_{\text{biogas},y} \cdot f_{\text{CH}_4,\text{default}} \cdot D_{\text{CH}_4} \quad (2)$$

107 Where:

$Q_{\text{CH}_4,y}$	=	Quantity of methane produced in the digester in year y (t CH ₄)
$Q_{\text{biogas},y}$	=	Amount of biogas collected at the digester outlet in year y (Nm ³ biogas)
$f_{\text{CH}_4,\text{default}}$	=	Default value for the fraction of methane in the biogas (volume basis)
D_{CH_4}	=	Density of methane (t CH ₄ / Nm ³ CH ₄)

108 **Step 1: Determination of project emissions from electricity consumption ($PE_{EC,y}$)**

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

113 **Option 1: Procedure using monitored data**

114 $PE_{EC,y}$ shall be calculated using the “Tool to calculate baseline, project and/or leakage emissions from
115 electricity consumption”, where the project emission source j referred to in the tool is the total electricity
116 consumption associated with the anaerobic digestion facility.

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

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

$$120 \quad PE_{EC,y} = Q_{\text{CH}_4,y} \cdot F_{EC,\text{default}} \cdot EF_{EL,\text{default}} \quad (3)$$

121 Where:

$PE_{EC,y}$	=	Project emissions from electricity consumption associated with the anaerobic digester in year y (t CO ₂)
$Q_{\text{CH}_4,y}$	=	Quantity of methane produced in the anaerobic digester in year y (t CH ₄)
$F_{EC,\text{default}}$	=	Default factor for the electricity consumption associated with the anaerobic digester per ton of methane generated (MWh/t CH ₄)
$EF_{EL,\text{default}}$	=	Default emission factor for the electricity consumed in year y (t CO ₂ /MWh)

122 **Step 2: Determination of project emissions from fossil fuel consumption ($PE_{FC,y}$)**

123 Where the anaerobic digester uses fossil fuels, project participants shall calculate $PE_{FC,y}$ using the “Tool
124 to calculate project or leakage CO₂ emissions from fossil fuel combustion”. The project emission
125 source j referred to in the tool is fossil fuel consumption associated with the anaerobic digestion facility
126 (not including fossil fuels consumed for transportation of feed material and digestate or any other on-site
127 transportation).

128 **Step 3: Determination of project emissions of methane from the anaerobic digester ($PE_{CH_4,y}$)**

129 Project emissions of methane from the anaerobic digester include emissions during maintenance of the
130 digester, physical leaks through the roof and side walls, and release through safety valves due to excess
131 pressure in digester. These emissions are calculated using a default emission factor ($EF_{CH_4,default}$), as
132 follows:

$$133 \quad PE_{CH_4,y} = Q_{CH_4,y} \cdot EF_{CH_4,default} \cdot GWP_{CH_4} \quad (4)$$

134 Where:

$PE_{CH_4,y}$	=	Project emissions of methane from the anaerobic digester in year y (t CO ₂ e)
$Q_{CH_4,y}$	=	Quantity of methane produced in the anaerobic digester in year y (t CH ₄)
$EF_{CH_4,default}$	=	Default emission factor for the fraction of CH ₄ produced that leaks from the anaerobic digester (fraction)
GWP_{CH_4}	=	Global warming potential of CH ₄ (t CO ₂ /t CH ₄)

135 **Step 4: Determination of project emissions from flaring of biogas ($PE_{flare,y}$)**

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

- 139 • For small scale projects, project participants may adopt a default value for the fraction of
140 methane in the biogas ($f_{CH_4,default}$) in applying the tool; and
- 141 • The tool provides default factors for the flare efficiency, which can be used for large or small
142 scale projects as described in the tool.

143 **III. LEAKAGE EMISSIONS PROCEDURE**

144 The leakage emissions associated with the anaerobic digester ($LE_{AD,y}$) depend on how the digestate is
145 managed. They are determined as follows:

$$146 \quad LE_{AD,y} = LE_{storage,y} + LE_{comp,y} \quad (5)$$

147 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)

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

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

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

153 Storage of digestate under anaerobic conditions can cause CH₄ emissions due to further anaerobic
154 digestion of the residual biodegradable organic matter. The procedure for determining $LE_{storage,y}$ is
155 distinguished for liquid digestate and solid digestate.

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

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

159 **Option 1: Procedure using monitored data**

$$160 \quad LE_{storage,y} = Q_{stored,y} \cdot P_{COD,y} \cdot B_0 \cdot MCF_p \cdot GWP_{CH4} \quad (6)$$

161

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_0	=	Maximum methane producing capacity of the COD applied (t CH ₄ /t COD)
MCF_p	=	Methane conversion factor (fraction)
GWP_{CH4}	=	Global warming potential of CH ₄ (t CO ₂ / t CH ₄)

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

$$163 \quad LE_{storage,y} = F_{ww,CH4,default} \cdot Q_{CH4,y} \cdot GWP_{CH4} \quad (7)$$

164

Where:

$LE_{storage,y}$	=	Leakage emissions associated with digestate storage 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)

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

166 Where solid digestate is disposed in a SWDS or a stockpile that can be considered a SWDS as per the
167 definition section, then project participants may choose between Option 1 or Option 2 to determine
168 $LE_{storage,y}$.

169 **Option 1: Procedure using monitored data**

170 $LE_{storage,y}$ is determined using the methodological tool “Emissions from solid waste disposal sites”. In
171 this case, $LE_{storage,y}$ corresponds to the parameter $LE_{CH4,SWDS,y}$ in the tool and j represents the digestate that
172 is disposed at a SWDS.

173 **Option 2: Procedure using default values**

174 $LE_{storage,y}$ is determined as follows:

$$175 \quad LE_{storage,y} = F_{SD,CH4,default} \cdot Q_{CH4,y} \cdot GWP_{CH4} \quad (8)$$

176

Where:

$LE_{storage,y}$	=	Leakage emissions associated with digestate storage in year y (t CO ₂ e)
$F_{SD,CH4,default}$	=	Default factor for the methane generation capacity of solid digestate (fraction)

$Q_{CH_4,y}$ = Quantity of methane produced in the anaerobic digester in year y (t CH_4)
 GWP_{CH_4} = Global warming potential of CH_4 (t CO_2/t CH_4)

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

178 $LE_{COMP,y}$ shall be calculated using the methodological tool “Project and leakage emissions from
 179 composting”. The term $PE_{COMP,y}$ in the methodological tool “Project and leakage emissions from
 180 composting” provides the value for $LE_{COMP,y}$ of this tool.

181 **IV. DATA AND PARAMETERS NOT MONITORED**

Data / Parameter:	$f_{CH_4,default}$
Data unit:	Volumetric fraction
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
Value to be applied:	0.6
Any comment:	Use this value for Option 2 of the “Determination of quantity of methane produced in the digester”

182

Data / Parameter:	D_{CH_4}
Data unit:	t CH_4 / Nm ³ CH_4
Description:	Density of methane at room temperature
Source of data:	Technical literature
Value to be applied:	0.00067
Any comment:	Room temperature is defined as 20°C and 1 atm pressure

183

Data / Parameter:	$EF_{CH_4,default}$
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 all (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 IPCC value). <ul style="list-style-type: none"> • 0.028: Digesters with steel or lined concrete or fiberglass digesters and a gas holding system (egg shaped digesters) and monolithic construction; • 0.05: UASB type digesters, floating gas holders with no external water seal • 0.10: Digesters with unlined concrete/ferrocement/brick masonry arched type gas holding section; monolithic fixed dome digesters, covered anaerobic lagoon
Any comment:	Applicable for the “Determination of project emissions of methane from digester”

184

185

Data / Parameter:	GWP_{CH_4}
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:	-

186

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; 0.01 - UASB / filter bed reactor for wastewater / fluidized bed reactor ; 1.02 - Conventional digesters with continuously stirred tank reactor type for wastewater; 1.54 - Any anaerobic digester for solid waste with pre-processing of wastes (e.g. pulverizing). 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 ($PE_{EC,y}$)”

187

Data / Parameter:	$EF_{El, default}$
Data unit:	t CO ₂ /MWh
Description:	Emission factor for 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:	This emission factor can also be calculated using the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”

188

Data / Parameter:	B_0
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:	-

189

Data / Parameter:	$F_{ww,CH_4,default}$
Data unit:	Fraction
Description:	Default factor representing the remaining CH ₄ production capacity of liquid digestate
Source of data:	Reference papers and current industry practice
Value to be applied:	0.10: Covered anaerobic lagoons 0.15: UASB type digesters/Anaerobic filter bed digesters/Anaerobic fluidized bed digesters 0.20: Conventional digesters 0.05: Two stage digesters
Any comment:	-

190

Data / Parameter:	$F_{SD,CH_4,default}$
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. Also reference papers and current industry practice (Davidsson, 2007)
Value to be applied:	Two phase digesters: 0.15 All other technologies: 0.35
Any comment:	Applicable to Option 2 in the section “Determining $LE_{storage,y}$ for solid digestate”

191

Data / Parameter:	MCF_p
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 depth of liquid digestate storage > 2 m 0.2 for depth of liquid digestate storage < 2 m and ≥ 1 m 0 for depth of liquid digestate storage < 1 m
Any comment:	-

192 V. MONITORING METHODOLOGY PROCEDURE

193 Monitoring procedures

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

197 **Data and parameters monitored**

Data / Parameter:	$Q_{\text{biogas},y}$
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:	Hourly measurement by flow meter. Data to be aggregated monthly and yearly.
QA/QC procedures:	-
Any comment:	-

198

Data / Parameter:	$P_{\text{COD},y}$
Data unit:	$\text{t COD} / \text{m}^3$
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 “2005 Standard Methods for the Examination of Water and Wastewater, 21 st . American Public Health Association, Water Environment Federation and American Water Works Association”
Any comment:	-

199

Data / Parameter:	$Q_{\text{stored},y}$
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 $LE_{\text{storage},y}$ for liquid or semi-solid digestate”

200 **V. REFERENCES AND ANY OTHER INFORMATION**

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219 **History of the document**

Version	Date	Nature of revision(s)
01.0.0	EB ##, Annex #	To be considered at EB ##
Decision Class: Regulatory Document Type: Tool Business Function: Methodology		

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