Indicative simplified baseline and monitoring methodologies
for selected small-scale CDM project activity categories

TYPE III - OTHER PROJECT ACTIVITIES

Project participants shall take into account the general guidance to the methodologies, information on additionality, abbreviations and general guidance on leakage provided at http://cdm.unfccc.int/methodologies/SSCmethodologies/approved.html.

III.H. Methane Recovery in Wastewater Treatment

Technology/measure

1. This project category comprises measures that recover methane from biogenic organic matter in wastewaters by means of one of the following options:

(i) Substitution of aerobic wastewater or sludge treatment systems with anaerobic systems with methane recovery and combustion;

(ii) Introduction of anaerobic sludge treatment system with methane recovery and combustion to an existing wastewater treatment plant without sludge treatment;

(iii) Introduction of methane recovery and combustion to an existing sludge treatment system;

(iv) Introduction of methane recovery and combustion to an existing anaerobic wastewater treatment system such as anaerobic reactor, lagoon, septic tank or an on site industrial plant[1];

(v) Introduction of anaerobic wastewater treatment with methane recovery and combustion, with or without anaerobic sludge treatment, to an untreated wastewater stream;

(vi) Introduction of a sequential stage of wastewater treatment with methane recovery and combustion, with or without sludge treatment, to an existing wastewater treatment system without methane recovery (e.g. introduction of treatment in an anaerobic reactor with methane recovery as a sequential treatment step for the wastewater that is presently being treated in an anaerobic lagoon without methane recovery).

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

(a) Thermal or electrical energy generation directly; or

(b) Thermal or electrical energy generation after bottling of upgraded biogas; or

(c) Thermal or electrical energy generation after upgrading and distribution:

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

[1] Other technologies in table 6.3 of Chapter 6: Wastewater Treatment and Discharge of 2006 IPCC Guidelines for National Greenhouse Gas Inventories are included.

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

(d) Hydrogen production.

3. If the recovered methane is used for project activities covered under paragraph 2 (a), that component of the project activity can use a corresponding category under type I.

4. If the recovered methane is utilized for production of hydrogen (project activities covered under paragraph 2 (d)), that component of project activity shall use corresponding category AMS III.O.

5. In case of project activities covered under paragraph 2 (b) 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. If however the end use of the bottled biogas is included in the project boundary and is monitored during the crediting period CO_2 emissions avoided by the displacement of the fuels is eligible under a corresponding type I methodology, e.g. AMS I.C.

6. In case of project activities covered under paragraph 2 (c i) emission reductions from the displacement of the use of natural gas is eligible under this methodology, provided the geographical extent of the natural gas distribution grid is within the host country boundaries.

7. In case of project activities covered under paragraph 2 (c ii) emission reductions for the displacement of the use of fuels can be claimed following the provision in the corresponding type I methodology, e.g. AMS I.C.

8. In case of project activities covered under paragraph 2 (b) and (c), methodology is only applicable if upgrade is done by way of absorption with water (with or without recovery of methane emissions from discharge) such that the methane content of the upgraded biogas shall be in accordance with national regulations (where these exist) or a minimum of 96% (by volume). These conditions are necessary to ensure that the recovered biogas is completely destroyed through combustion in an end use.

9. Measures are limited to those that result in aggregate emission reductions of less than or equal to 60 kt CO_2 equivalent annually from all type III components of the project activity.

Boundary

10. The project boundary is the physical, geographical site where the wastewater and sludge treatment takes place.

11. In case of project activityies covered under paragraph 2 (b) and (c), case 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.

Project Activity Emissions

12. Project activity emissions consist of:

(i) CO_2 emissions on account of power used by the project activity facilities. Emission factors for grid electricity or diesel fuel use as the case may be shall be calculated as described in category AMS I.D.;

(ii) Methane emissions on account of inefficiency of the wastewater treatment and presence of degradable organic carbon in treated wastewater;

(iii) Methane emissions from the decay of the final sludge generated by the treatment systems;

(iv) Methane fugitive emissions on account of inefficiencies in capture and flare systems;

(v) Methane emissions resulting from dissolved methane in the treated wastewater effluent.

(vi) Where relevant, emissions related to the upgrading and compression of biogas (cases covered under paragraph 2 (b) and 2 (c)).

(vii) Where relevant, emissions due to physical leakage from the dedicated piped network for transport of upgraded biogas to the end users (cases covered under paragraph 2 (c ii)).

$$PE_y = PE_{y,power} + PE_{y,ww,treated} + PE_{y,s,final} + PE_{y,fugitive} + PE_{y,dissolved} + PE_{y,upgrading} + \\ + PE_{y,leakage,pipeline} \quad \textbf{(1)}$$

Where:

PE_y	Project activity emissions in the year "y" (tCO_2e)
$PE_{y,power}$	Emissions from electricity or diesel consumption in the year "y"
$PE_{y,ww,treated}$	Emissions from degradable organic carbon in treated wastewater in year "y"
$PE_{y,s,final}$	Emissions from anaerobic decay of the final sludge produced in the year "y". If the sludge is controlled combusted, disposed in a landfill with methane recovery, or used for soil application, this term can be neglected, and the final disposal of the sludge shall be monitored during the crediting period
$PE_{y,fugitive}$	Emissions from methane release in capture and utilization/combustion/flare systems in year "y"
$PE_{y,dissolved}$	Emissions from dissolved methane in treated wastewater in year "y". Project emissions from this source are only considered for project activities involving measures described in cases (i), (v) and (vi) of paragraph 1
$PE_{y,upgrading}$	Emissions related to the upgrading and compression of biogas in year "y"

$PE_{y,leakage,pipeline}$ Emissions due to physical leakage from the dedicated piped network in year "y".

13. Project activity emissions from electricity consumption are determined as per the procedures described in AMS I.D. The energy consumption of all equipment/devices installed by the project activity, *inter alia* facilities for upgrade and compression, filling of bottles, distribution and the final end use of biogas shall be included. For project activity emissions from fossil fuel consumption the emission factor for the fossil fuel shall be used (tCO_2/tonne). Local values are to be used, if local values are difficult to obtain, IPCC default values may be used. If recovered methane is used to power auxiliary equipment of the project it should be taken into account accordingly, using zero as its emission factor.

14. Project activity emissions from degradable organic carbon in treated wastewater are determined as follows:

$$PE_{y,ww,treated} = Q_{y,ww} * GWP\_CH_4 * B_{o,ww} * COD_{y,ww,treated} * MCF_{ww,final} \quad \textbf{(2)}$$

Where:

$Q_{y,ww}$ Volume of wastewater treated in the year "y" (m^3)

$COD_{y,ww,treated}$ Chemical oxygen demand of the final treated wastewater discharged into sea, river or lake in the year "y" (tonnes/m^3)[2]

$B_{o,ww}$ Methane producing capacity of the wastewater (IPCC default value for domestic wastewater of 0.21 kg CH_4/kg.COD)[2]

$MCF_{ww,final}$ Methane correction factor based on type of treatment and discharge pathway of the wastewater (fraction) (MCF Higher Value in table III.H.1 for sea, river and lake discharge i.e. 0.2)

GWP_CH_4 Global Warming Potential for methane (value of 21 is used)

[2] The IPCC default value of 0.25 kg CH_4/kg COD was corrected to take into account the uncertainties. For domestic waste water, a COD based value of $B_{o,ww}$ can be converted to BOD_5 based value by dividing it by 2.4 i.e. a default value of 0.504 kg CH_4/kg BOD can be used.

Table III.H.1. IPCC default values[1)] for Methane Correction Factor (MCF)

Type of wastewater treatment and discharge pathway or system	MCF lower values	MCF higher values
Discharge of wastewater to sea, river or lake	0.0	0.2
Aerobic treatment, well managed	0.0	0.1
Aerobic treatment, poorly managed or overloaded	0.2	0.4
Anaerobic digester for sludge without methane recovery	0.8	1.0
Anaerobic reactor without methane recovery	0.8	1.0
Anaerobic shallow lagoon (depth less than 2 metres)	0.0	0.3
Anaerobic deep lagoon (depth more than 2 metres)	0.8	1.0
Septic system	0.5	0.5
[1)] Default values from chapter 6 of volume 5.Waste in *2006 IPCC Guidelines for National Greenhouse Gas Inventories*		

15. Project activity emissions from anaerobic decay of the final sludge produced are determined as follows:

$$PE_{y,s,final} = S_{y,final} * DOC_{y,s,final} * MCF_{s,final} * DOC_F * F * 16/12 * GWP\_CH_4 \quad (3)$$

Where:

$PE_{y,s,final}$	Methane emissions from the anaerobic decay of the final sludge generated in the wastewater system in the year "y" (tCO_2e)
$S_{y,final}$	Amount of final sludge generated by the wastewater treatment in the year "y" (tonnes)
$DOC_{y,s,final}$	Degradable organic content of the final sludge generated by the wastewater treatment in the year "y" (fraction). IPCC default values of 0.05 for domestic sludge (wet basis, considering a default dry matter content of 10 percent) or 0.09 for industrial sludge (wet basis, assuming dry matter content of 35 percent) may be used. Optionally other values determined through ex post measurement of the sludge produced on a sampling basis may be used during the crediting period
$MCF_{s,final}$	Methane correction factor of the landfill that receives the final sludge, estimated as described in category AMS III.G.
DOC_F	Fraction of DOC dissimilated to biogas (IPCC default value of 0.5)
F	Fraction of CH_4 in landfill gas (IPCC default of 0.5)

16. Project activity emissions from methane release in capture and utilization/combustion/ flare systems are determined as follows:

$$PE_{y,fugitive} = PE_{y,fugitive,ww} + PE_{y,fugitive,s} \quad (4)$$

Where:

$PE_{y,fugitive,ww}$	Fugitive emissions through capture and utilization/combustion/flare inefficiencies in the anaerobic wastewater treatment in the year "y" (tCO_2e)
$PE_{y,fugitive,s}$	Fugitive emissions through capture and utilization/combustion/flare inefficiencies in the anaerobic sludge treatment in the year "y" (tCO_2e)

$$PE_{y,fugitive,ww} = (1 - CFE_{ww}) * MEP_{y,ww,treatment} * GWP\_CH_4 \quad (5)$$

Where:

CFE_{ww}	Capture and utilization/combustion/flare efficiency of the methane recovery and combustion/utilization equipment in the wastewater treatment (a default value of 0.9 shall be used, given no other appropriate value)
$MEP_{y,ww,treatment}$	Methane emission potential of wastewater treatment plant in the year "y" (tonnes)

$$MEP_{y,ww,treatment} = Q_{y,ww} * B_{o,ww} * \sum_j COD_{y,removed,j} * MCF_{ww,j} \quad (6)$$

Where:

$COD_{y,removed,j}$	The chemical oxygen demand removed[3] by the treatment system "j" of the project activity equipped with methane recovery in the year "y" (tonnes/m^3)
$MCF_{ww,j}$	Methane correction factor for the wastewater treatment system "j" equipped with methane recovery and combustion/flare/utilization equipment (MCF higher values in table III.H.1)

$$PE_{yfugitive,s} = (1 - CFE_s) * MEP_{y,s,treatment} * GWP\_CH_4 \quad (7)$$

Where:

CFE_s	Capture and utilization/combustion/flare efficiency of the methane recovery and combustion/utilization equipment in the sludge treatment (a default value of 0.9 shall be used, given no other appropriate value)
$MEP_{y,s,treatment}$	Methane emission potential of the sludge treatment system in the year "y" (tonnes)

$$MEP_{y,s,treatment} = S_{y,untreated} * DOC_{y,s,untreated} * DOC_F * F * 16/12 * MCF_{s,treatment} \quad (8)$$

Where:

$S_{y,untreated}$	Amount of untreated sludge generated in the year "y" (tonnes)
$DOC_{y,s,untreated}$	Degradable organic content of the untreated sludge generated in the year y (fraction). It shall be measured by sampling and analysis of the sludge produced,

[3] Difference of inflow COD and the outflow COD.

and estimated ex-ante using the IPCC default values of 0.05 for domestic sludge (wet basis, considering a default dry matter content of 10 percent) or 0.09 for industrial sludge (wet basis, assuming dry matter content of 35 percent)

$MCF_{s,treatment}$ Methane correction factor for the sludge treatment system that will be equipped with methane recovery and combustion/utilization/flare equipment (MCF Higher value of 1.0 as per table III.H.1).

17. Project activity emissions from dissolved methane in treated wastewater are determined as follows:

$$PE_{y,dissolved} = Q_{y,ww} * [CH_4]_{y,ww,treated} * GWP\_CH_4 \quad (9)$$

Where:

$[CH_4]_{y,ww,treated}$ Dissolved methane content in the treated wastewater ($tonnes/m^3$). In aerobic wastewater treatment default value is zero, in anaerobic treatment it can be measured, or a default value of $10e^{-4}$ $tonnes/m^3$ can be used[4].

18. In case of project activities covered under paragraph 2 (b) and 2 (c) the following project emissions related to the upgrading and compression of the biogas ($PE_{y,upgrading}$) shall be included:

(i) Methane emissions from the discharge of the water wash upgrading equipment (tCO_2e);

(ii) Fugitive methane emissions from leaks in compression equipment (tCO_2e);

(iii) Emissions on account of vent gases from the water wash upgrade equipment (tCO_2e);

$$PE_{y,upgrading} = PE_{y,ww,upgrade} + PE_{y,CH4,equip} + PE_{y,ventgas} \quad (10)$$

Where:

$PE_{y,ww,upgrade}$ Emissions from methane contained in waste water discharge of water wash upgrading installation in year "y" (tCO_2e)

$PE_{y,CH4,equip}$. Emissions from compressor leaks in year "y" (tCO_2e)

$PE_{y,ventgas}$ Emissions from venting gases retained in water wash upgrading equipment in year "y"(tCO_2e)

19. Project activity emissions from methane contained in waste water discharge of water wash upgrading installation are determined as follows:

[4] Value calculated using approach given by Greenfield, P.F. and Batstone, D.J. Anaerobic digestion: impact of future GHG mitigation policies on methane generation and usage. In: Proceedings of Anaerobic Digestion Congress, Montreal, Canada, 2004.

$$PE_{y,ww,upgrade} = Q_{y,ww,upgrade} * \left[CH_4\right]_{y,ww,upgrade} * GWP\_CH_4 \qquad \textbf{(11)}$$

Where:

$Q_{y,ww,upgrade}$	Volume of wastewater discharge from water wash upgrading installation in year "y"
$[CH_4]_{y,ww,upgrade}$	Dissolved methane contained in the wastewater discharge in year "y"

20. Project activity emissions from compressor leaks are determined as follows:

$$PE_{y,CH4,equip.} = GWP\_CH_4 * \left(\frac{1}{1000}\right) * \sum_{equipment} w_{CH4stream,y} * EF_{equipment} * T_{equipment,y} \qquad \textbf{(12)}$$

Where:

$w_{CH4,stream,y}$	Average methane weight fraction of the gas (kg-CH_4/kg) in year "y"
$T_{equipment,y}$	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)
$EF_{equipment}$	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.

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[5].

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 lines, etc.).

The following data needs to be obtained:

1. The number of each type of component in a unit (valve, connector, etc.);
2. The methane concentration of the stream;
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 table III.H.2 below.

[5] Please refer to document US EPA-453/R-95-017 at: http://www.epa.gov/ttn/chief/efdocs/equiplks.pdf, accessed on 23/10/2007.

Table III.H.2. Methane emission factors for equipment[6]

Equipment type	Emission Factor (kg/hour/ source) for methane
Valves	4.5E-0.3
Pump seals	2.4E-0.3
Others[7]	8.8E-0.3
Connectors	2.0E-0.4
Flangs	3.9E-0.4
Open ended lines	2.0E-0.3

21. Project activity emissions from venting gases retained in water wash upgrading equipment do not have to be considered if vent gases ($PE_{y,ventgas}$) 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 *"Tool to determine project emissions from flaring gases containing methane"*, as follows:

$$PE_{y,ventgas} = \sum_{h=1}^{8760} TM_{RG,h} * (1 - \eta_{flare,h}) * \frac{GWP_{CH4}}{1000} \quad (13)$$

Where:

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

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

In case vent gases are not flared the *"Tool to determine project emissions from flaring gases containing methane" 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:

$$PE_{y,ventgas} = \sum_{h=1}^{8760} TM_{RG,h} * \frac{GWP_{CH4}}{1000} \quad (14)$$

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 water wash 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 water wash 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.

6 Please refer to document US EPA-453/R-95-017 table 2.4, page 2-15, accessed on 23/10/2007.

7 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.

22. In case of project activities covered under paragraph 2 (c ii) emissions due to physical leakage of upgraded biogas from the dedicated piped network ($PE_{y,leakage,pipeline}$) shall be determined as follows:

$$PE_{y,leakage,pipeline} = Q_{y,methane,pipeline} * LR_{pipeline} * GWP_{CH4} \tag{15}$$

Where:

$PE_{y,leakage,pipeline}$	Emissions due to physical leakage from the dedicated piped network in year “y” (tCO_2e)
$Q_{y,methane,pipeline}$	Total quantity of methane transported in the dedicated piped network in year “y” (m^3)
$LR_{pipeline}$	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 10^6 m^3 of utility sales shall be applied[8].)

Baseline

23. The baseline scenario will be one of the following situations:

(i) The existing aerobic wastewater or sludge treatment system, in the case of substitution of one or both of these systems for anaerobic ones with methane recovery and combustion;

(ii) The existing sludge disposal system, in the case of introduction of anaerobic sludge treatment system with methane recovery and combustion to an existing wastewater treatment plant;

(iii) The existing sludge treatment system without methane recovery and combustion;

(iv) The existing anaerobic wastewater treatment system without methane recovery and combustion;

(v) The untreated wastewater being discharged into sea, river, lake, stagnant sewer or flowing sewer, in the case of introducing the anaerobic treatment to an untreated wastewater stream;

(vi) The existing anaerobic wastewater treatment system without methane recovery for the case of introduction of a sequential anaerobic wastewater treatment system with methane recovery.

24. The baseline emissions are calculated as follows:

---

[8] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, chapter 4, table 4.2.5 provides default values for fugitive emissions from gas operations in developing countries. The default values provided for fugitive emissions for the distribution of natural gas to end users range from 1.1 E-3 to 2.5 E-3 Gg per 10^6 m^3 of utility sales. The uncertainty in this value is -20% to 500%. A conservative value of 2.5 E-3 * 500% = 0.0125 Gg per 10^6 m^3 of utility sales shall be taken.

(a) For the cases 23 (i) and 23 (ii) the baseline emissions (BE_y) are calculated as:

$$BE_y = BE_{y,power} + BE_{y,ww,treated} + BE_{y,s,final} \quad \textbf{(16)}$$

Where:

BE_y Baseline emissions in the year "y" (tCO_2 e)

$BE_{y,power}$ Emissions on account of electricity or diesel consumed in the year "y" by the replaced aerobic wastewater or sludge treatment system

$BE_{y,ww,treated}$ Emissions from degradable organic carbon in treated wastewater in year "y", calculated using the same formula as that used for calculating the project emissions ($PE_{y,ww,treated}$). The value of this term is zero for the case 23 (ii).

$BE_{y,s,final}$ Emissions on account of anaerobic decay of the final sludge produced in the year "y", calculated using the formula as for the project emission ($PE_{y,s,final}$). If the sludge is controlled combusted, disposed in a landfill with methane recovery, or used for soil application, this term shall be neglected, and the end-use of the final sludge will be monitored during the crediting period.

(b) For the cases 23 (iii) and 23 (iv) the baseline emissions are calculated as per the formulas below, MCF lower values in table III.H.1 are to be used:

$$BE_y = MEP_{y,ww,bl} * GWP\_CH_4 + MEP_{y,s,treatment} * GWP\_CH_4 \quad \textbf{(17)}$$

Where:

$MEP_{y,ww,bl}$ Methane emission potential of the anaerobic wastewater treatment plant(s) in the baseline situation in year "y" (tonnes) determined as follows:

$$MEP_{y,ww,bl} = Q_{y,ww} * \sum_i (COD_{y,removed,i} * B_{o,ww} * MCF_{ww,treatment,i}) \quad \textbf{(18)}$$

Where:

$COD_{y,removed,i}$ Chemical oxygen demand removed by the anaerobic wastewater treatment system "i" in the baseline situation in the year "y" ($tonnes/m^3$)

$MCF_{ww,\ treatment,i}$ Methane correction factor for the anaerobic wastewater treatment system "i" (MCF lower values in table III.H.1)

For determination of $MEP_{y,s,treatment}$ see formula (8) in paragraph (16).

(c) For the case of 23 (v) since the MCF lower value for discharge of wastewater to sea, river or lake is 0.0 as per Table III.H.1, but may vary up to 0.2, the project participants shall demonstrate by measurements or by mathematical modelling of the impact of the discharge on the receiving water body, that anaerobic conditions do appear and the baseline emissions occur (a positive MCF is found). This MCF is used to determine the baseline emission scenario:

$$BE_y = Q_{y,ww} * COD_{y,ww,untreated} * B_{o,ww} * MCF_{ww,final} * GWP\_CH_4 \tag{19}$$

(d) For the case 23 (vi) the baseline emissions are calculated as:

$$BE_y = Q_{y,ww} * \sum_i (COD_{y,removed,i} * B_{o,ww} * MCF_{ww,treatment,i} * GWP\_CH_4) \tag{20}$$

Where:

$COD_{y,removed,i}$	Chemical oxygen demand removed by the anaerobic wastewater treatment systems "i" in the baseline situation in the year "y" to which the sequential anaerobic treatment step is being introduced (tonnes/m^3)
$MCF_{ww,treatment,i}$	Methane correction factor for the existing anaerobic wastewater treatment systems "i" to which the sequential anaerobic treatment step is being introduced (MCF lower value in Table III.H.1.)

For the above cases (a), (b) and (c) the methane generation capacity of the treated wastewater ($B_{o,ww}$) shall be IPCC lower value of 0.21 kg CH_4/kg COD.

25. In case of project activities covered under paragraph 2 (c i) the baseline emissions for upgraded biogas injection ($BE_{y,injection}$) are determined as follows:

$$BE_{y,injection} = E_{ug,y} * CEF_{NG} \tag{21}$$

Where:

$BE_{y,injection}$	Baseline emissions for injection of upgraded biogas into a natural gas distribution grid in year "*y*" (tCO_2e)
$E_{ug,y}$	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 (tCO_2e/TJ) (Accurate and reliable local or national data may be used where available, otherwise appropriate IPCC default values shall be used)

26. 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:

$$E_{ug,y} = Q_{ug,y} * NCV_{ug,y} \tag{22}$$

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 m^3)
$NCV_{ug,y}$	Net calorific value of the upgraded biogas in year "*y*" (TJ/kg or TJ/m^3).

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

$$Q_{ug,y} = \min(Q_{ug,in,y}, Q_{cap,CH4,y}) \quad \textbf{(23)}$$

Where:

$Q_{ug,in,y}$	Quantity of upgraded biogas injected into the natural gas distribution grid in year "*y*" (kg or m^3)
$Q_{cap,CH4,y}$	Quantity of methane captured at the wastewater treatment source facility(ies) in year "y" (kg or m^3)

28. The quantity of methane captured at the waste water treatment source facility(ies) is calculated as follows:

$$Q_{cap,CH4,y} = w_{CH4,ww} * Q_{cap,biogas,y} \quad \textbf{(24)}$$

Where:

$w_{CH4,ww}$	Methane fraction of biogas as monitored at the outlet of the wastewater treatment source facility(ies) (kg or m^3 CH_4/kg or m^3 of biogas).
$Q_{cap,biogas,y}$	Monitored amount of biogas captured at the source facility(ies) in year "y" (kg or m^3)

Leakage

29. If the used technology is equipment transferred from another activity or if the existing equipment is transferred to another activity, leakage effects at the site of the other activity are to be considered.

30. In case of project activities covered under paragraph 2 (b) and the users of the bottles filled with upgraded biogas are not included in the project boundary then the following leakage emissions shall be taken into account:

(i) Emissions due to physical leakage of biogas from the bottles during storage, transport etc. until final end use (tCO_2e);

(ii) 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 (tCO_2e).

$$LE_{y,bottling} = LE_{y,leakage,bb} + LE_{y,trans} \quad \textbf{(25)}$$

Where:

$LE_{y,bottling}$	Leakage emissions project activities involving bottling of biogas in year "y" (tCO_2e)
$LE_{y,leakage,bb}$	Emissions due to physical leakage from biogas bottles in year "y" (tCO_2e)

$LE_{y,trans}$ 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 in year "y" (tCO_2e)

31. Leakage emissions due to physical leakage from biogas bottles are determined as follows:

$$LE_{y,leakage,bb} = Q_{y,methane,bb} * LR_{bb} * GWP_{CH4} \quad \textbf{(26)}$$

Where:

$Q_{y,methane,bb}$ Total quantity of methane bottled in year y (m^3)

LR_{bb} Physical leakage rate from biogas bottles (if no project-specific values can be identified a default value of 1.25% shall be applied[9])

32. 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.

$$PE_{y,trans} = \left(\frac{Q_{y,bb}}{CT_{y,bb}} \right) * DAF_{bb} * EF_{CO2} \quad \textbf{(27)}$$

Where:

$Q_{y,bb}$ Total freight volume of upgraded biogas in bottles transported in year "y" (m^3)

$CT_{y,bb}$ 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_{CO2} CO_2 emission factor from fuel use due to transportation (tCO_2/km)

Monitoring

33. For the cases listed in paragraph 1 as:

(i) Substitution of aerobic wastewater or sludge treatment system by an anaerobic treatment system with methane recovery and combustion; or

(v) Introduction of an anaerobic wastewater treatment system with methane recovery and combustion to an untreated wastewater stream;

[9] Victor (1989) Leaking Methane from Natural Gas Vehicles: Implication for Transportation Policy in the Greenhouse Era, in Climatic Change 20: 113-141, 1992 and American Gas Association (1986), 'Lost and Unaccounted for Gas', Planning and Analysis issues, issue brief 1986-28, p. 3

the emission reduction achieved by the project activity will be the difference between the baseline emission and the sum of the project emission and leakage.

$$ER_y = BE_y - \left(PE_y + Leakage_y\right) \quad \textbf{(28)}$$

The historical records of electricity consumption, COD content of treated wastewater, and quantity of sludge produced by the replaced aerobic units will be used for the baseline calculation in case (i).

In case (i) if the volumetric flow and the characteristic properties (e.g. COD) of the inflow and outflow of the wastewater and the produced sludge are equivalent in the project and the baseline scenarios (i.e. the project and baseline systems have the same efficiency for COD removal for wastewater treatment), then higher energy consumption in the case of baseline scenario is the only significant difference contributing to emission reduction in the project case. In this case the emission reduction can be simply calculated as the difference between the historical energy consumption of the replaced unit and the recorded energy consumption of the new system. Project emissions from dissolved methane and fugitive emissions ($PE_{y,fugitive}$ and $PE_{y,dissolved}$) shall also be considered in the calculation of the emission reduction, however the emissions from the wastewater outflow and sludge ($PE_{y,ww,treated}$ and $PE_{y,s,final}$) may be disregarded.

34. For the cases of (ii) introduction of anaerobic sludge treatment with methane recovery and combustion to untreated sludge; (iii) and (iv) introduction of methane recovery and combustion unit to an existing anaerobic wastewater or sludge treatment system, and (vi) introduction of a sequential stage of wastewater treatment with methane recovery and combustion to an existing wastewater treatment, the calculation of emission reductions shall be based on the amount of methane recovered and fuelled or flared, that is monitored ex-post. Also for these cases, the project emissions and leakage will be deducted from the emission reductions calculated from the methane recovered and combusted, except where it can be demonstrated that the technology implemented does not increase the amount of methane produced per unit of COD removed (COD removed is the difference between the inflow COD ($COD_{y,ww,untreated}$) and outflow COD ($COD_{y,ww,treated}$)), compared with the technology used in the baseline.

For cases covered under paragraph 2 (b) and 2 (c) project and leakage emissions due to those activities cannot be ignored and have to be considered.

35. For the cases listed in paragraph 1 where required as per the provisions for project emission calculations, the following parameters shall be monitored and recorded:

(a) The amount of fossil fuel and electricity used by the project activity facilities;

(b) The degradable carbon content of the wastewater and/or sludge before and after treatment ($COD_{y,,untreated}$, $COD_{y,ww,treated}$, $COD_{y,removed}$, $DOC_{y,s,untreated}$, $DOC_{y,s,treated}$);

(c) The flow of wastewater and/or sludge treated ($Q_{y,ww}$, $S_{y,\ final}$ and $S_{y,untreated}$);

(d) Where relevant, the dissolved methane in the wastewater just leaving the anaerobic reactor (if the default value for dissolved methane is not used).

36. In all cases, the amount of methane recovered, fuelled, flared or 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. The fraction of methane in the gas should be measured with a continuous analyser or, alternatively, with periodical measurements at a 95% confidence level. Temperature and pressure of the gas are required to determine the density of methane combusted.

37. In case of project activities covered under paragraph 2(b) and 2(c) the project proponents shall maintain a biogas (or methane) balance based on:

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

(b) 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.

38. Regular maintenance should ensure optimal operation of flares. The flare efficiency, defined as the fraction of time in which the gas is combusted in the flare, multiplied by the efficiency of the flaring process, shall be monitored. One of the two following options shall be used to determine the efficiency of the flaring process in an enclosed flare:

(a) To adopt a 90% default value, or

(b) To perform a continuous monitoring of the efficiency[10].

If option (a) is chosen continuous check of compliance with the manufacturers specification of the flare device (temperature, biogas flow rate) should be done. If in any specific hour any of the parameters is out of the range of specifications 50% of default value should be used for this specific hour. For open flare 50% default value should be used, as it is not possible in this case to monitor the efficiency. If at any given time the temperature of the flare is below 500ºC, 0% default value should be used for this period.

39. In case of project activities covered under paragraph 2 (c i) the emission reductions calculated in accordance with paragraph 33 or 34 shall be summed up with the baseline emissions calculated in accordance with paragraph 25.

40. In case of project activities covered under paragraph 2 (c) 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 NCV shall be measured directly from the gas stream using an online Heating Value Meter (monthly). 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

[10] The procedures described in the Tool to determine project emissions from flaring gases containing methane shall be used.

always be in accordance with national regulations or 96% (by volume) or higher. Biogas injected or transported with inferior methane content shall be excluded from the emission reduction calculations.

41. If the methane emissions from anaerobic decay of the final sludge were to be neglected because the sludge is controlled combusted, disposed 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.

42. In case of project activities covered under paragraph 2 (b) and 2 (c), the following parameters shall be monitored and recorded:

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

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

(c) 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;

(d) 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 96% 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;

(e) In case vent gases are calculated using the "Tool to determine project emissions from flaring gases containing methane", the monitoring criteria contained in this tool shall be used. In case this tool is not used and the alternative approach in paragraph 21 is used, then temperature and pressure of gas retained in water wash 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;

(f) 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.

(g) In case of project activities covered under paragraph 2 (b) the number and volume of biogas bottles produced and transported, the average truck capacity ($CT_{y,bb}$) and the average aggregated distance for transporting the bottled biogas (DAF_{bb}).

Project activity under a programme of activities

The following conditions apply for use of this methodology in a project activity under a programme of activities:

43. In case the project activity involves the replacement of equipment, and the leakage effect of the use of the replaced equipment in another activity is neglected, because the replaced equipment is scrapped, an independent monitoring of scrapping of replaced equipment needs to be implemented. The monitoring should include a check if the number of project activity equipment distributed by the project and the number of scrapped equipment correspond with each other. For this purpose scrapped equipment should be stored until such correspondence has been checked. The scrapping of replaced equipment should be documented and independently verified.

- - - - -