CLEAN DEVELOPMENT MECHANISM

AMS-III.H.

Small-scale Methodology

Methane recovery in wastewater treatment

Version 19.0

Sectoral scope(s): 01 and 13

United Nations
Framework Convention on
Climate Change

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1. Introduction

1. The following table describes the key elements of the methodology:

Table 1. Methodology key elements

Typical project(s)	Recovery of biogas resulting from anaerobic decay of organic matter in wastewaters through introduction of an anaerobic treatment system for wastewater and/or sludge treatment with biogas recovery
Type of GHG emissions mitigation action	GHG destruction. Destruction of methane emissions

2. Scope, applicability, and entry into force

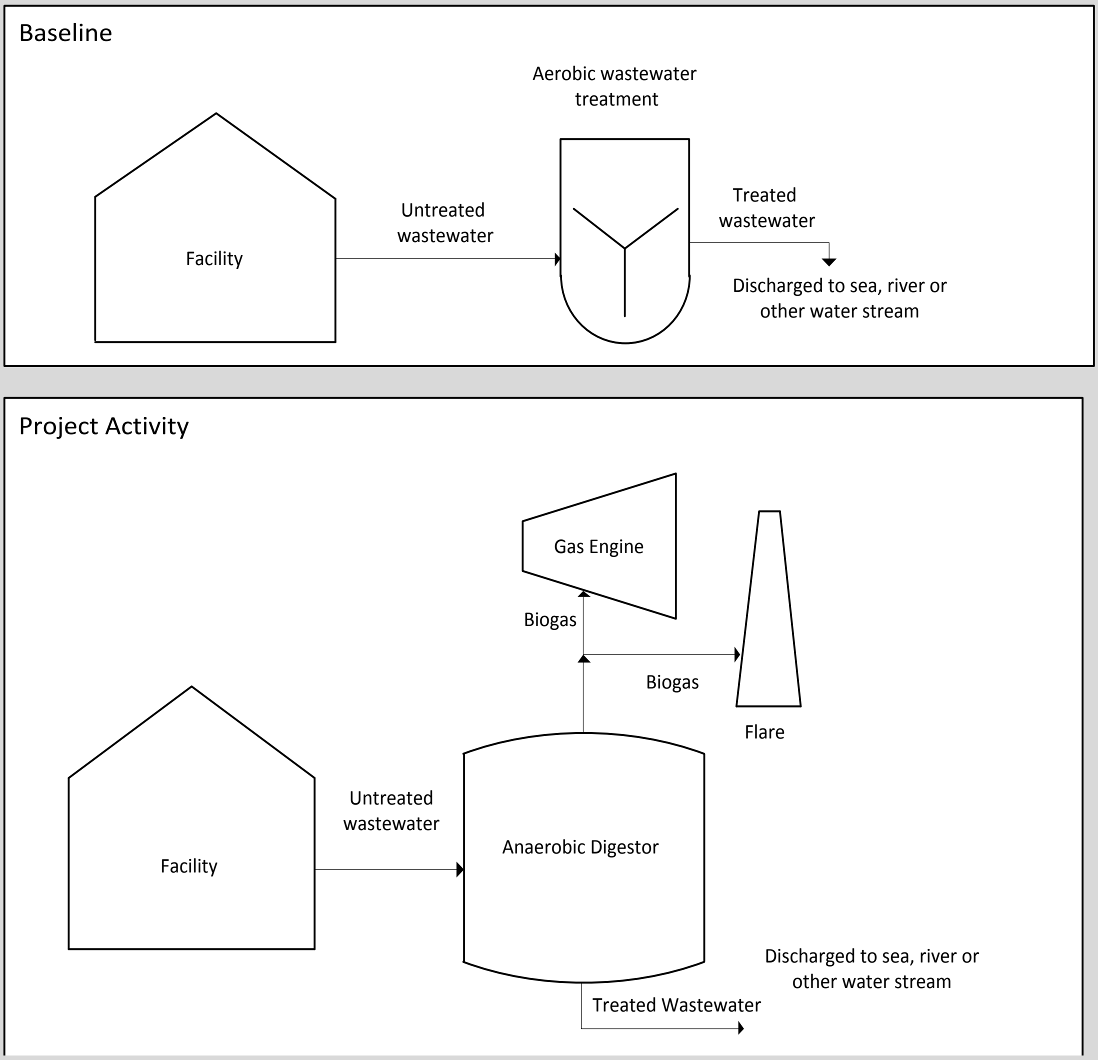
2.1. Scope

2. This methodology comprises measures that recover biogas from biogenic organic matter in wastewater by means of one, or a combination, of the following options:

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

Figure 1. Non-binding best practice example 1: Application of paragraph 2 (a)

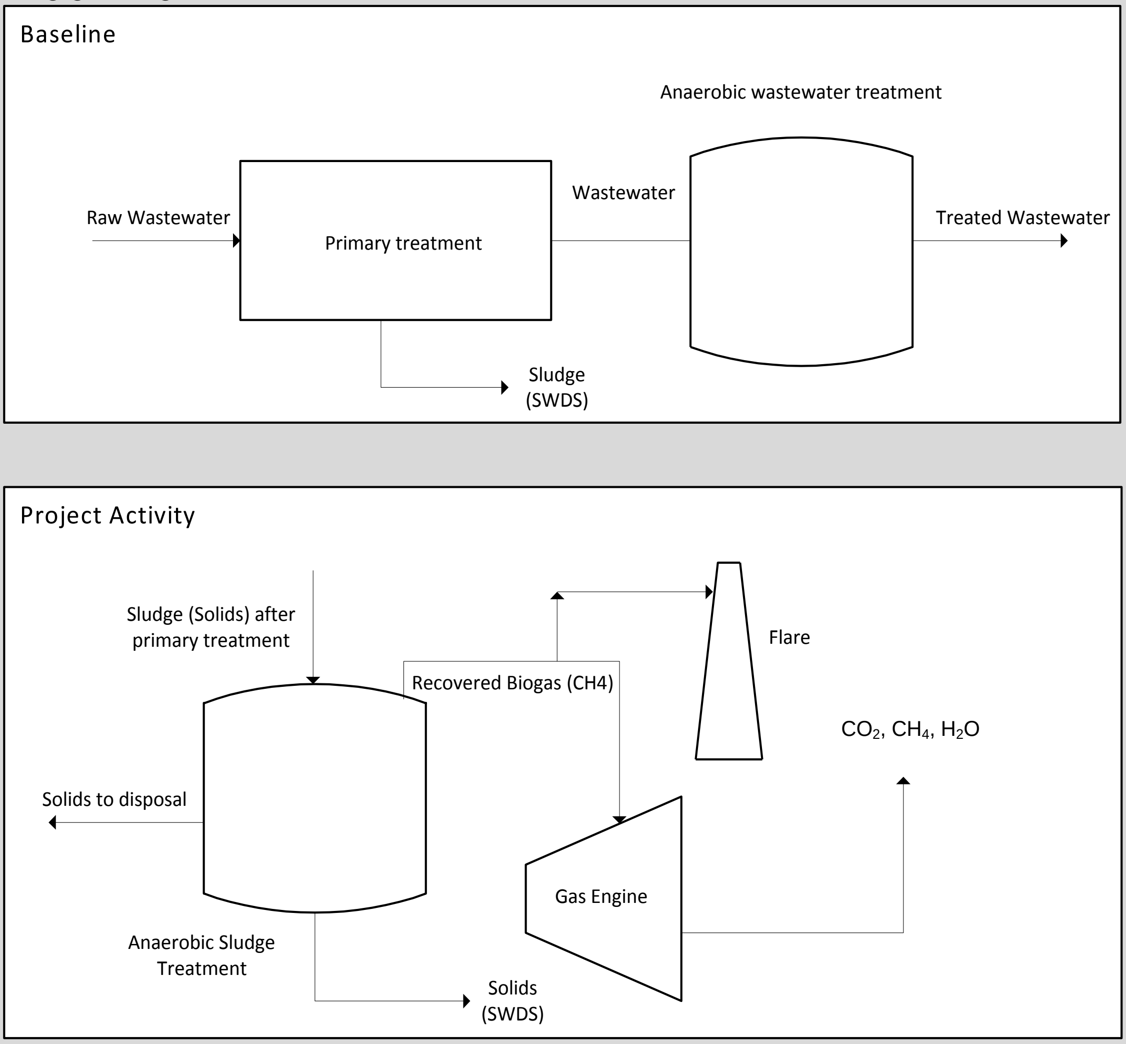
In absence of the project activity, the wastewater is treated aerobically. The project activity aims to recover biogas using anaerobic digester and utilize it for electricity generation using a gas engine.



(b) Introduction of anaerobic sludge treatment system with biogas recovery and combustion to a wastewater treatment plant without sludge treatment;

Figure 2. Non-binding best practice example 2: Application of paragraph 2 (b)

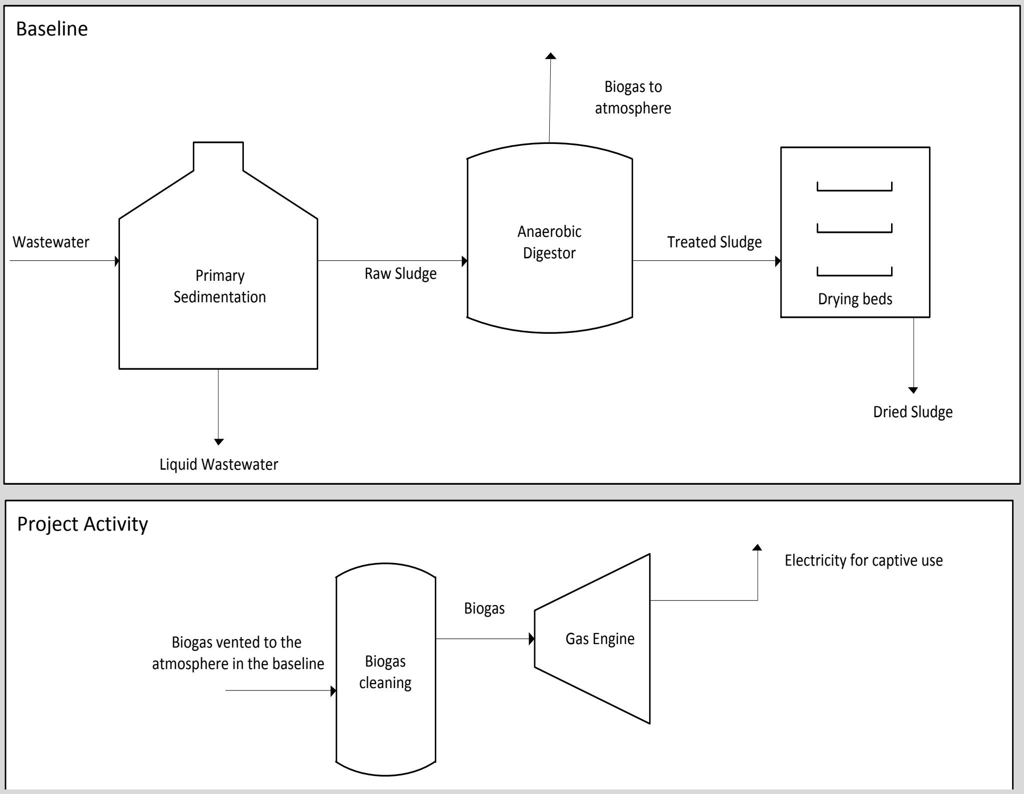
In absence of the project activity, wastewater is treated (aerobically or anaerobically) without sludge treatment (e.g. the sludge is disposed anaerobically in a solid waste disposal site without methane recovery). The project activity aims to treat the sludge in anaerobic digester to recover biogas and to flare it or utilize it to generate electricity using gas engines.



(c) Introduction of biogas recovery and combustion to a sludge treatment system;

Figure 3. Non-binding best practice example 3: Application of paragraph 2 (c)

In absence of the project activity, the biogas generated in the anaerobic digester is vented. The project activity aims to capture and use the biogas for electricity generation using a gas engine. The project involves the installation of gas cleaning facility, gas engines and eventually an enclosed flaring system to burn the excess biogas. The electricity will be used for captive use, replacing electricity from the grid.



(d) 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;[1]

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

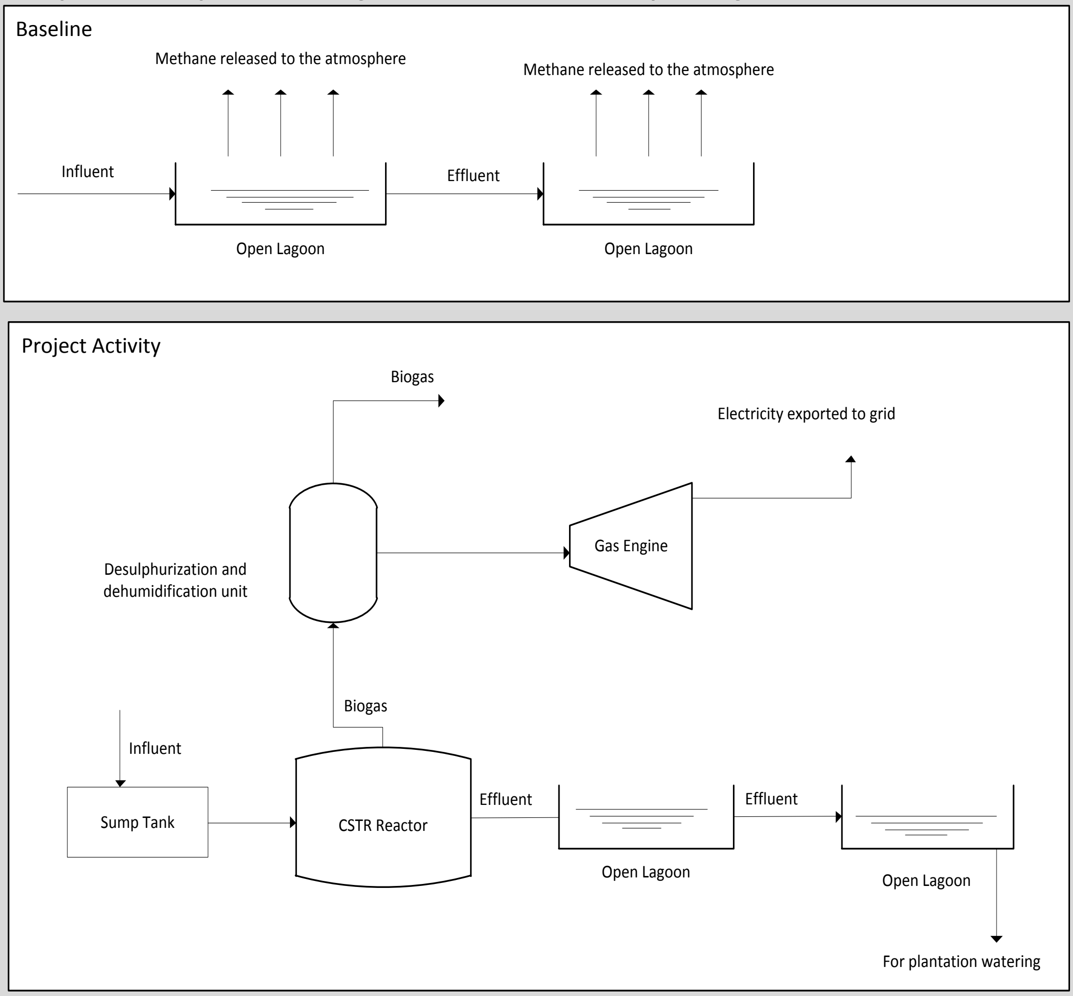
(f) Introduction of a sequential stage of wastewater treatment with biogas recovery and combustion, with or without sludge treatment, to an anaerobic wastewater treatment system without biogas recovery (e.g. introduction of treatment in an

[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.

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).

Figure 4. Non-binding best practice example 4: Application of paragraph 2 (f)

In absence of the project activity, the wastewater would have been treated in anaerobic open lagoons. The project activity involves the installation of a new stage in the wastewater system (for example CSTR reactor in the figure below); the wastewater is treated sequentially in a sump tank, then treated in the biogas reactor with methane recovery and it's utilization for electricity generation, without sludge separation, and finally treated by the existing series of anaerobic open lagoons.



2.2. Applicability

3. In cases where baseline system is anaerobic lagoon the methodology is applicable if:

(a) The lagoons are ponds with a depth greater than two meters, without aeration. The value for depth is obtained from engineering design documents, or through direct measurement, or by dividing the surface area by the total volume. If the

lagoon filling level varies seasonally, the average of the highest and lowest levels may be taken;

(b) Ambient temperature above 15°C, at least during part of the year, on a monthly average basis;

(c) The minimum interval between two consecutive sludge removal events shall be 30 days.

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

(a) Thermal or mechanical,[2] electrical energy generation directly;

(b) Thermal or mechanical, electrical energy generation after bottling of upgraded biogas, in this case additional guidance provided in the appendix shall be followed; or

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

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

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

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

(d) Hydrogen production;

(e) Use as fuel in transportation applications after upgrading.

5. If the recovered biogas is used for project activities covered under paragraph 4(a), that component of the project activity can use a corresponding methodology under Type I.

6. For project activities covered under paragraph 4(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 fossil fuel can be claimed under the corresponding Type I methodology, e.g. "AMS-I.C.: Thermal energy production with or without electricity".

7. For project activities covered under paragraph 4(c)(i), emission reductions from the displacement of the use of natural gas are eligible under this methodology, provided the geographical extent of the natural gas distribution grid is within the host country boundaries.

[2] For example combusted in a prime mover such as an engine coupled to a machine such as grinding machine.

8. For project activities covered under paragraph 4(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.

9. In particular, for the case of paragraph 4(b) and (c)(iii), the physical leakage during storage and transportation of upgraded biogas, as well as the emissions from fossil fuel consumed by vehicles for transporting biogas shall be considered. Relevant procedures in paragraph 18 of the appendix of “AMS-III.H.: Methane recovery in wastewater treatment” shall be followed in this regard.

10. For project activities covered under paragraph 4(b) and (c), this methodology is applicable if the upgraded methane content of the biogas is in accordance with relevant national regulations (where these exist) or, in the absence of national regulations, a minimum of 96 per cent (by volume).

11. If the recovered is utilized for the production of hydrogen (project activities covered under paragraph 3(d)), that component of the project activity shall use the corresponding methodology “AMS-III.O.: Hydrogen production using methane extracted from biogas”.

12. If the recovered biogas is used for project activities covered under paragraph 4(e), that component of the project activity shall use corresponding methodology “AMS-III.AQ.: Introduction of Bio-CNG in transportation applications”.

13. New facilities (Greenfield projects) and project activities involving a change of equipment resulting in a capacity addition of the wastewater or sludge treatment system compared to the designed capacity of the baseline treatment system are only eligible to apply this methodology if they comply with the relevant requirements in the “General guidelines for SSC CDM methodologies”. In addition, the requirements for demonstrating the remaining lifetime of the equipment replaced, as described in the general guidelines shall be followed.

Box 1. Non-binding best practice example 5: Application of “General guidelines to SSC CDM methodologies” as per paragraph 13

New facilities (Greenfield projects) and project activities involving capacity addition should follow step-wise approach (step 1 to step 4) in accordance with the “General guidelines to SSC CDM methodologies”.

In regard to the application of Step 1 under paragraph 19 of “General guidelines to SSC CDM methodologies”, EB 61 Annex 21 (i.e. Identify the various alternatives available to the project proponent that deliver comparable levels of service), practices carried out in the industry or similar industry should also be considered.

For a project activity involving capacity addition, e.g. because the industrial process increases its production capacity, the continuation of the current practice can be an available alternative if it is demonstrated that it is able to attend the increasing quantity of wastewater from the production facility and/or the difference of the quality of the inflowing wastewater. For example, if the existing practice is the use of anaerobic lagoons, it needs to be demonstrated that there is enough land area available in the neighboring terrains, adequate to be used for increasing the size or to build new lagoons such as to attend the increased capacity for wastewater treatment plant using the same technology.

14. The location of the wastewater treatment plant as well as the source generating the wastewater shall be uniquely defined and described in the PDD.

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

2.3. Entry into force

16. The date of entry into force is the date of the publication of the EB 103 meeting report on 14 June 2019.

2.4. Applicability of conditional sectoral scopes

17. For validation and verification of CDM projects and programme of activities by a designated operation entity (DOE) using this methodology:

(a) If the recovered biogas from the waste water treatment plant is only flared and not used for any other purpose, then sectoral scope 13 is mandatory;

(b) If the recovered biogas is used for any other purpose, then sectoral scope 13 and sectoral scope 1 are mandatory.

3. Normative references

18. Project participants shall apply the “General guidelines for SSC CDM methodologies and information on additionality (attachment A to Appendix B) provided at <http://cdm.unfccc.int/methodologies/SSCmethodologies/approved.html> mutatis mutandis.

19. This methodology also refers to the latest approved versions of the following approved methodologies and methodological tools:

(a) “AMS-I.C.: Thermal energy production with or without electricity”;

(b) “AMS-III.H.: Methane recovery in wastewater treatment”;

(c) “AMS-III.O.: Hydrogen production using methane extracted from biogas”;

(d) “AMS-III.AQ.: Introduction of Bio-CNG in transportation applications”;

(e) “AM0053: Biogenic methane injection to a natural gas distribution grid”;

(f) “Project emissions from flaring”;

(g) “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”;

(h) “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”;

(i) “Emissions from solid waste disposal sites”;

(j) “Positive lists of technologies”.

4. Definitions

20. The definitions contained in the Glossary of CDM terms shall apply.

5. Baseline methodology

5.1. Project boundary

21. The project boundary is the physical, geographical site where the wastewater and sludge treatment takes place, in the baseline and project situations. It covers all facilities affected by the project activity including sites where processing, transportation and application or disposal of waste products as well as biogas takes place.

22. Implementation of the project activity at a wastewater and/or sludge treatment system will affect certain sections of the treatment systems while others may remain unaffected. The treatment systems not affected by the project activity, i.e. sections operating in the project scenario under the same operational conditions as in the baseline scenario (e.g. wastewater inflow and COD content, temperature, retention time, etc.), shall be described in the PDD, but emissions from those sections do not have to be accounted for in the baseline and project emission calculations (since the same emissions would occur in both baseline and project scenarios).[3] The assessment and identification of the systems affected by the project activity will be undertaken ex ante, and the PDD shall justify the exclusion of sections or components of the system. The treatment systems (lagoons, reactors, digesters, etc.) that will be covered and/or equipped with biogas recovery by the project activity, but continue to operate with the same quality of feed inflow, volume (retention time), and temperature (heating) as in the baseline scenario, may be considered as not affected i.e. the methane generation potential[4] remains unaltered.

5.2. Additionality

23. For the simplified procedure to demonstrate additionality, the project proponent shall refer to the methodological tool “Positive lists of technologies”, and while applying this tool, the project proponent is not required to demonstrate compliance with conditions 12 (c) and 12 (d) of this tool. The simplified procedure to demonstrate additionalitydoes not apply to Greenfield project activities.

5.3. Baseline

24. Wastewater and sludge treatment systems equipped with a biogas recovery facility in the baseline shall be excluded from the baseline emission calculations.

25. Baseline emissions for the systems affected by the project activity may consist of:

    (a) Emissions on account of electricity or fossil fuel used ($BE_{power,y}$);

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[3] As per EB 22, annex 2 “Guidance regarding methodological issues” section E.

[4] The covering of lagoons and the installation of biogas recovery equipment may result in changes in the operational conditions (such as temperature, COD removal, etc.) of an anaerobic treatment system. These changes are considered small and hence not accounted for under this methodology.

(b) Methane emissions from baseline wastewater treatment systems ($BE_{ww,treatment,y}$);

(c) Methane emissions from baseline sludge treatment systems ($BE_{s,treatment,y}$);

(d) Methane emissions on account of inefficiencies in the baseline wastewater treatment systems and presence of degradable organic carbon in the treated wastewater discharged into river/lake/sea ($BE_{ww,discharge,y}$);

(e) Methane emissions from the decay of the final sludge generated by the baseline treatment systems ($BE_{s,final,y}$).

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

Where:

BE_y	=	Baseline emissions in year *y* (t CO_2e)
$BE_{power,y}$	=	Baseline emissions from electricity or fuel consumption in year *y* (t CO_2e)
$BE_{ww,treatment,y}$	=	Baseline emissions of the wastewater treatment systems affected by the project activity in year *y* (t CO_2e)
$BE_{s,treatment,y}$	=	Baseline emissions of the sludge treatment systems affected by the project activity in year *y* (t CO_2e)
$BE_{ww,discharge,y}$	=	Baseline methane emissions from degradable organic carbon in treated wastewater discharged into sea/river/lake in year y (t CO_2e). The value of this term is zero for the case 1(b)
$BE_{s,final,y}$	=	Baseline methane emissions from anaerobic decay of the final sludge produced in year *y* (t CO_2e). If the sludge is controlled combusted, disposed in a landfill with biogas recovery, or used for soil application in the baseline scenario, this term shall be neglected

26. Baseline emissions from electricity and fossil fuel consumption ($BE_{power,y}$) are determined as per the procedures described in the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption” and “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”, respectively. The energy consumption shall include all equipment/devices in the baseline wastewater and sludge treatment facility. If recovered biogas in the baseline is used to power auxiliary equipment it should be taken into account accordingly, using zero as its emission factor.

27. Methane emissions from the baseline wastewater treatment systems affected by the project ($BE_{ww,treatment,y}$) are determined using the COD removal efficiency of the baseline plant:

$$BE_{ww,treatment,y} = \sum_i (Q_{ww,i,y} \times COD_{inflow,i,y} \times \eta_{COD,BL,i} \times MCF_{ww,treatment,BL,i}) \times B_{o,ww} \times UF_{BL} \times GWP_{CH4}$$ Equation (2)

Where:

$Q_{ww,i,y}$	=	Volume of wastewater treated in baseline wastewater treatment system i in year y (m^3). For ex ante estimation, forecasted wastewater generation volume or the designed capacity of the wastewater treatment facility can be used. However, the ex post emissions reduction calculation shall be based on the actual monitored volume of treated wastewater
$COD_{inflow,i,y}$	=	Chemical oxygen demand of the wastewater inflow to the baseline treatment system *i* in year *y* (t/m^3). Average value may be used through sampling with the confidence/precision level 90/10
$\eta_{COD,BL,i}$	=	COD removal efficiency of the baseline treatment system *i*, determined as per the paragraphs 35, 36 or 37 below
$MCF_{ww,treatment,BL,i}$	=	Methane correction factor for baseline wastewater treatment systems *i* (MCF values as per Table 2 below)
i	=	Index for baseline wastewater treatment system
$B_{o,ww}$	=	Methane producing capacity of the wastewater (IPCC value of 0.25 kg CH_4/kg COD)[5]
UF_{BL}	=	Model correction factor to account for model uncertainties (0.89)[6]
GWP_{CH4}	=	Global Warming Potential for methane

28. If the baseline treatment system is different from the treatment system in the project scenario, the monitored values of the COD inflow during crediting period will be used to calculate the baseline emissions ex post.

[5] Project activities may use the default value of 0.6 kg CH_4/kg BOD, if the parameter $BOD_{5,20}$ is used to determine the organic content of the wastewater. In this case, baseline and project emissions calculations shall use BOD instead of COD in the equations, and the monitoring of the project activity shall be based in direct measurements of $BOD_{5,20}$, i.e. the estimation of BOD values based on COD measurements is not allowed.

[6] Reference: FCCC/SBSTA/2003/10/Add.2, page 25.

29. The Methane Correction Factor (*MCF*) shall be determined based on the following table:

Table 2. IPCC default values[7] for Methane Correction Factor (*MCF*)

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
Land application[(a)]	0.1

(a) Please refer SSC_664, "Clarification on methane correction factors for treated water used for irrigation under AMS-III.H ver. 16".

30. Methane emissions from the baseline sludge treatment systems affected by the project activity are determined using the methane generation potential of the sludge treatment systems:

$$BE_{treatment,s,y} = \sum_{j} S_{j,BL,y} \times MCF_{s,treatment,BL,j} \times DOC_s \times UF_{BL} \times DOC_F \times F \times 16 / 12 \times GWP_{CH4}$$ Equation (3)

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 scenario (t). For ex ante estimation, forecasted sludge generation volume or the designed capacity of the sludge treatment facility can be used. However, the ex post emissions reduction calculation shall be based on the actual monitored volume of treated sludge

7 Default values from chapter 6 of volume 5. Waste in 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

j	=	Index for baseline sludge treatment system
DOC_s	=	Degradable organic content of the untreated sludge generated in the year *y* (fraction, dry basis). Default values of 0.5 for domestic sludge and 0.257 for industrial sludge[8] shall be used
$MCF_{s,treatment,BL,j}$	=	Methane correction factor for the baseline sludge treatment system *j* (*MCF* values as per Table 2 above)
UF_{BL}	=	Model correction factor to account for model uncertainties (0.89)
DOC_F	=	Fraction of DOC dissimilated to biogas (IPCC default value of 0.5)
F	=	Fraction of CH_4 in biogas (IPCC default of 0.5)

31. If the sludge is composted, the following equation shall be applied:

$$BE_{s,treatment,y} = \sum_j S_{j,BL,y} \times EF_{composting} \times GWP_{CH4} \quad \text{Equation (4)}$$

Where:

$EF_{composting}$	=	Emission factor for composting organic waste (t CH_4/t waste treated). Emission factors can be based on facility/site-specific measurements, country specific values or IPCC default values (Table 4.1, chapter 4, Volume 5, 2006 IPCC Guidelines for National Greenhouse Gas Inventories). IPCC default value is 0.01 t CH_4/ t sludge treated on a dry weight basis

32. If the baseline wastewater treatment system is different from the treatment system in the project scenario, the sludge generation rate (amount of sludge generated per unit of COD removed) in the baseline may differ significantly from that of the project scenario. For example, it is known that the amount of sludge generated in aerobic wastewater systems is larger than in anaerobic systems, for the same COD removal efficiency. Therefore, for these cases, the monitored values of the amount of sludge generated during the crediting period will be used to estimate the amount of sludge generated in the baseline, as follows:

$$S_{j,BL,y} = S_{l,PJ,y} \times \frac{SGR_{BL}}{SGR_{PJ}} \quad \text{Equation (5)}$$

Where:

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

[8] The IPCC default values of 0.05 for domestic sludge (wet basis, considering a default dry matter content of 10 per cent) or 0.09 for industrial sludge (wet basis, assuming dry matter content of 35 per cent), were corrected for dry basis.

SGR_{BL}	=	Sludge generation ratio of the wastewater treatment plant in the baseline scenario (tonne of dry matter in sludge/t COD removed). This ratio will be determined as per paragraphs 35, 36 or 37 below
SGR_{PJ}	=	Sludge generation ratio of the wastewater treatment plant in the project scenario (tonne of dry matter in sludge/t COD removed). Calculated using the monitored values of COD removal (i.e. $COD_{inflow,i}$ minus $COD_{outflow,i}$) and sludge generation in the project scenario

33. Methane emissions from degradable organic carbon in treated wastewater discharged in e.g. a river, sea or lake in the baseline situation are determined as follows:

$$BE_{ww,discharge,y} = Q_{ww,y} \times GWP_{CH4} \times B_{o,ww} \times UF_{BL} \times COD_{ww,discharge,BL,y} \times MCF_{ww,BL,discharge}$$ Equation (6)

Where:

$Q_{ww,y}$	=	Volume of treated wastewater discharged in year y (m^3)
UF_{BL}	=	Model correction factor to account for model uncertainties (0.89)
$COD_{ww,discharge,BL,y}$	=	Chemical oxygen demand of the treated wastewater discharged into sea, river or lake in the baseline situation in the year y (t/m^3). If the baseline scenario is the discharge of untreated wastewater, the COD of untreated wastewater shall be used
$MCF_{ww,BL,discharge}$	=	Methane correction factor based on discharge pathway in the baseline situation (e.g. into sea, river or lake) of the wastewater (fraction) (MCF values as per Table 2 above)

34. To determine $COD_{ww,discharge,BL,y}$: if the baseline treatment system(s) is different from the treatment system(s) in the project scenario, the monitored values of the COD inflow during crediting period will be used to calculate the baseline emissions ex post. The outflow COD of the baseline systems will be estimated using the removal efficiency of the baseline treatment systems, estimated as per paragraphs 35, 36 or 37 below.

35. Methane emissions from anaerobic decay of the final sludge produced are determined as follows:

$$BE_{s,final,y} = S_{final,BL,y} \times DOC_s \times UF_{BL} \times MCF_{s,BL,final} \times DOC_F \times F \times 16/12 \times GWP_{CH4}$$ Equation (7)

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 (5) above
$MCF_{s,BL,final}$	=	Methane correction factor of the disposal site that receives the final sludge in the baseline situation, estimated as per the procedures described in the methodological tool “Emissions from solid waste disposal sites”
UF_{BL}	=	Model correction factor to account for model uncertainties (0.89)

36. In determining baseline emissions using equation (1), historical records of at least one year prior to the project implementation shall be used. This shall include for example the COD removal efficiency of the wastewater treatment systems, the amount of dry matter in sludge, power and electricity consumption per m^3 of wastewater treated the amount of final sludge generated per tonne of COD removed, and all other parameters required for determination of baseline emissions.

37. 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:

(a) 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*;

(b) An ex ante measurement campaign shall be implemented to determine the required parameters (COD removal efficiency, specific energy consumption and specific sludge production). The measurement campaign shall be implemented in the baseline wastewater systems for at least 10 days. The measurements should be undertaken during a period that is representative for the typical operation conditions of the systems and ambient conditions of the site (temperature, etc). Average values from the measurement campaign shall be used and the result shall be multiplied by 0.89 to account for the uncertainty range (30 per cent to 50 per cent). The parameters from the measurement campaign are used to calculate the baseline emission in year *y*;

(c) The baseline emissions in year *y* is taken as the minimum between the result of (a) and (b).

Box 2. Non-binding best practice example 6: Ex-ante measurement campaign for existing facilities as per paragraph 40 (a) and (b)

The project activity involves the installation of a UASB digester in a palm oil industry to recover and utilize biogas. In the pre-project scenario, the wastewater was being treated in an existing anaerobic open lagoon system.

Partial historical COD data for the treatment system is available; therefore, an ex-ante measurement campaign has been carried out to determine the required parameters (CODinflow,y, CODoutflow,y, ηCOD,BL and Qww,y) to calculate the baseline emissions in year y. The average value of the baseline emissions obtained through measurement campaign was lower than the historical value, therefore, the minimum value was taken up for ex-ante calculation (see paragraph of 37 (c)).

The average baseline emissions value measured is thereafter multiplied by 0.89 to account for the uncertainty in accordance with the methodology paragraph 37 (b). During the 10-days COD-measurement campaign, the inflow and the outflow COD content of the open lagoon was measured. The efficiency was estimated as the quotient between the removal capacity and the inflow.

Table 1: Average value of the 10 days COD -measurement campaign may be demonstrated as follows:

	COD content before open lagoon	COD content after open lagoon	COD content before released to the river	Water temp. before covered lagoon	Air Tempe-rature	Amount of wastewater per ton of product
Unit	(mg/L)	(mg/L)	(mg/L)	(°C)	(°C)	(m^3/t)
Average 10 days	9558	3239	117	27.7	26.3	26.26

External data obtained from other wastewater treatment plants or registered PDDs are not allowed.

38. 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:

(a) For existing plant without three-year operating history, procedures in paragraph 37 shall be followed;

(b) For Greenfield and capacity addition projects, one of the following procedures shall be used:

(i) Value obtained from a measurement campaign in a comparable existing wastewater treatment plant i.e. having similar environmental and technological circumstances for example treating similar type of wastewater. Average values from the measurement campaign shall be

used and the result shall be multiplied by 0.89 to account for the uncertainty range (30 per cent to 50 per cent) associated with this approach. The treatment plant and wastewater source can be considered as similar as the baseline plant, whereby the measurement campaign can be implemented when following conditions can be fulfilled:

a. 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;

b. 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 per cent; and

c. 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:

   i. The ratio COD/BOD (related to the proportion of biodegradable organic matter) does not differ by more than 20 per cent; and

   ii. The ratio total COD/soluble COD (related to the proportion of suspended organic matter, and therefore to the sludge generation capacity) does not differ by more than 20 per cent.

(ii) 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 per cent plants with lowest emission rate per tonne 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.

Box 3. Non-binding best practice example 7: Ex-ante measurement campaign for greenfield projects as per paragraph 41 (b) (i)

This is a greenfield project which aims to build and operate a biogas plant that will process Palm Oil Mill Effluent (POME) from a new palm oil mill. The recovered biogas will be used to generate electricity in two units of 609 kWe biogas engines for the mill's own consumption.
The project activity only claims emission reductions from baseline emissions of the wastewater treatment system affected by the project activity. Other values such as electricity consumption, sludge generation etc. are not included in the baseline calculation and no emission reductions are claimed for the potential emissions that could be reduced.
Since this is a greenfield project, the estimation of COD values shall be based on paragraph 38(b) of the methodology.

The estimated COD values for the conventional open lagoon wastewater treatment system are obtained from a measurement campaign for a similar registered CDM project with all the baseline data clearly depicted in the PDD. The average values from the measurement campaign are multiplied by 0.89 to account for the uncertainty. The treatment plant and wastewater source is considered as similar as the baseline plant based on the following facts:

a) POME is the type of wastewater treated in the selected CDM project and from the proposed project activity. So, both of the plants are treating same type of wastewater;
b) The selected CDM project and the baseline plants employ the same treatment technology, which is comprised of a cooling/ acidification pond, anaerobic lagoons, aerobic lagoons. The hydraulic retention time for the selected plant in the CDM project is about 90 days, and the baseline plant of the proposed project activity is 106 days. The difference is no more than 20%;
c) The baseline plant of the selected CDM project and the proposed project activity are treating POME. Both of the mills process raw FFBs and produce crude palm oil.

5.4. Project emissions

39. Project emissions consists of:

(a) CO_2 emissions from electricity and fuel used by the project facilities ($PE_{power,y}$);

(b) Methane emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery in the project scenario ($PE_{ww,treatment,y}$);

(c) Methane emissions from sludge treatment systems affected by the project activity, and not equipped with biogas recovery in the project situation ($PE_{s,treatment,y}$);

(d) Methane emissions on account of inefficiency of the project activity wastewater treatment systems and presence of degradable organic carbon in treated wastewater ($PE_{ww,discharge,y}$);

(e) Methane emissions from the decay of the final sludge generated by the project activity treatment systems ($PE_{s,final,y}$);

(f) Methane fugitive emissions due to inefficiencies in capture systems ($PE_{fugitive,y}$);

(g) Methane emissions due to incomplete flaring ($PE_{flaring,y}$);

(h) Methane emissions from biomass stored under anaerobic conditions which would not have occurred in the baseline situation ($PE_{biomass,y}$).[9]

$$PE_y = \begin{Bmatrix} PE_{power,y} + PE_{ww,treatment,y} + PE_{s,treatment,y} + PE_{ww,discharge,y} + PE_{s,final,y} + \\ PE_{fugitive,y} + PE_{biomass,y} + PE_{flaring,y} \end{Bmatrix} \quad \text{Equation (8)}$$

Where:

PE_y — Project emissions in the year y (t CO2e)

$PE_{power,y}$ — Emissions from electricity or fuel consumption in the year y (t CO_2e). These emissions shall be calculated as per paragraph 26, for the situation of the project scenario, using energy consumption data of all equipment/devices used in the project activity wastewater and sludge treatment systems and systems for biogas recovery and flaring/gainful use

$PE_{ww,treatment,y}$ — Methane emissions from wastewater treatment systems affected by the project activity, and not equipped with biogas recovery, in year y (t CO_2e). These emissions shall be calculated as per equation (2) in paragraph 27 using an uncertainty factor of 1.12 and data applicable to the project situation ($MCF_{ww,treatment,PJ,k}$ and $\eta_{,PJ,k,y}$) and with the following changed definition of parameters:

- $MCF_{ww,treatment,PJ,k}$ — Methane correction factor for project wastewater treatment system k (MCF values as per Table 2 above)
- $\eta_{,PJ,k,y}$ — Chemical oxygen demand removal efficiency of the project wastewater treatment system k in year y (t/m[3]), measured based on inflow COD and outflow COD in system k

$PE_{s,treatment,y}$ — Methane emissions from sludge treatment systems affected by the project activity, and not equipped with biogas recovery, in year y (t CO_2e). These emissions shall be calculated as per equations (3)

[9] For instance in the baseline situation Palm Kernel Shells (PKS) are used as fuel in a boiler. In the project situation PKS is replaced by biogas captured at a wastewater treatment system. The PKS will no longer be used as fuel in the boiler, but sold on the market. Before it is sold it is likely it will be stored for a period of time (few months or longer) on site which might lead to methane emissions from anaerobic decay.

and (4) in paragraphs 30 and 31, using an uncertainty factor of 1.12 and data applicable to the project situation ($S_{l,PJ,y}$, $MCF_{s,treatment,l}$) and with the following changed definition of parameters:

$S_{l,PJ,y}$	Amount of dry matter in the sludge treated by the sludge treatment system *l* in the project scenario in year *y* (t)
$MCF_{s,treatment,l}$	Methane correction factor for the project sludge treatment system l (*MCF* values as per Table 2 above)

$PE_{ww,discharge,y}$ Methane emissions from degradable organic carbon in treated wastewater in year *y* (tCO_2e). These emissions shall be calculated as per equation (6) in paragraph 33, using an uncertainty factor of 1.12 and data applicable to the project conditions ($COD_{ww,discharge,PJ,y}$, $MCF_{ww,PJ,discharge}$) and with the following changed definition of parameters:

$COD_{ww,discharge,PJ,y}$	Chemical oxygen demand of the treated wastewater discharged into the sea, river or lake in the project scenario in year *y* (t/m^3)
$MCF_{ww,PJ,discharge}$	Methane correction factor based on the discharge pathway of the wastewater in the project scenario (e.g. into sea, river or lake) (*MCF* values as per Table 2)

$PE_{s,final,y}$ Methane emissions from anaerobic decay of the final sludge produced in year *y* ($t\ CO_2e$). These emissions shall be calculated as per equation (7) in paragraph 35, using an uncertainty factor of 1.12 and data applicable to the project conditions ($MCF_{s,PJ,final}$, $S_{final,PJ,y}$). If the sludge is controlled combusted, disposed in a landfill with biogas recovery, or used for soil application in aerobic conditions in the project activity, this term shall be neglected, and the sludge treatment and/or use and/or final disposal shall be monitored during the crediting period with the following revised definition of the parameters:

$MCF_{s,PJ,final}$	Methane correction factor of the disposal site that receives the final sludge in the project situation, estimated as per the procedures described in the methodological tool "Emissions from solid waste disposal sites"
$S_{final,PJ,y}$	Amount of dry matter in final sludge generated by the project wastewater treatment systems in the year *y* (t)

$PE_{fugitive,y}$ Methane emissions from biogas release in capture systems in year *y*, calculated as per paragraph 40 ($t\ CO_2e$)

$PE_{flaring,y}$ Methane emissions due to incomplete flaring in year *y* ($t\ CO_2e$). For ex ante estimation, baseline emission calculation for wastewater and/or sludge treatment (i.e. equation (2) and/or equation (3)) can be used but without the consideration of GWP for CH_4. However, the ex post emission reduction shall be calculated as per methodological tool "Project emissions from flaring"

$PE_{biomass,y}$ Methane emissions from biomass stored under anaerobic conditions. If storage of biomass under anaerobic conditions takes place in the project and does not occur in the baseline, methane emissions due to anaerobic decay of this biomass shall be considered and be

determined as per the procedure in the methodological tool "Emissions from solid waste disposal sites" (t CO_2e)

40. Project emissions from methane release in capture systems are determined as follows:

(a) Based on the methane emission potential of wastewater and/or sludge:

$$PE_{fugitive,y} = PE_{fugitive,ww,y} + PE_{fugitive,s,y}$$ Equation (9)

Where:

$PE_{fugitive,ww,y}$ = Fugitive emissions through capture inefficiencies in the anaerobic wastewater treatment systems in the year y (t CO2e)

$PE_{fugitive,s,y}$ = Fugitive emissions through capture inefficiencies in the anaerobic sludge treatment systems in the year *y* (t CO_2e)

$$PE_{fugitive,ww,y} = (1 - CFE_{ww}) \times MEP_{ww,treatment,y} \times GWP_{CH4}$$ Equation (10)

Where:

CFE_{ww} = Capture efficiency of the biogas recovery equipment in the wastewater treatment systems (a default value of 0.9 shall be used)

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

$$MEP_{ww,treatment,y} = Q_{ww,y} \times B_{o,ww} \times UF_{PJ} \times \sum_k COD_{removed,PJ,k,y} \times MCF_{ww,treatment,PJ,k}$$ Equation (11)

Where:

$COD_{removed,PJ,k,y}$ = The chemical oxygen demand removed[10] 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 (*MCF* values as per Table 2 above)

[10] Difference between the inflow COD and the outflow COD.

UF_{PJ}	=	Model correction factor to account for model uncertainties (1.12)

$$PE_{fugitive,s,y} = (1 - CFE_s) \times MEP_{s,treatment,y} \times GWP_{CH4}$$ Equation (12)

Where:

CFE_s	=	Capture efficiency of the biogas recovery equipment in the sludge treatment systems (a default value of 0.9 shall be used)
$MEP_{s,treatment,y}$	=	Methane emission potential of the sludge treatment systems equipped with a biogas recovery system in year *y* (t)

$$MEP_{s,treatment,y} = \sum_{l} \left(S_{l,PJ,y} \times MCF_{s,treatment,PJ,l} \right) \times DOC_s \times UF_{PJ} \times DOC_F \times F \times 16/12$$ Equation (13)

Where:

$S_{l,PJ,y}$	=	Amount of sludge treated in the project sludge treatment system l equipped with a biogas recovery system (on a dry basis) in year *y* (t)
$MCF_{s,treatment,PJ,l}$	=	Methane correction factor for the sludge treatment system equipped with biogas recovery equipment (MCF values as per Table 2 above)
UF_{PJ}	=	Model correction factor to account for model uncertainties (1.12)

(b) Optionally a default value of 0.05 m³ biogas leaked/m³ biogas produced may be used as an alternative to calculations per equation (9) to (13).

5.5. Leakage

41. If the technology is using equipment transferred from another activity, leakage effects at the site of the other activity are to be considered and estimated (LE_y).

5.6. Emission reduction

42. For all options in paragraph 2, 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:

$$ER_{y,ex\ ante} = BE_{y,ex\ ante} - \left(PE_{y,ex\ ante} + LE_{y,ex\ ante} \right)$$ Equation (14)

Where:

$ER_{y,ex\ ante}$	=	Ex ante emission reduction in year *y* (t CO_2e)
$LE_{y,ex\ ante}$	=	Ex ante leakage emissions in year *y* (t CO_2e)
$PE_{y,ex\ ante}$	=	Ex ante project emissions in year *y* calculated as paragraph 39 (t CO_2e)
$BE_{y,ex\ ante}$	=	Ex ante baseline emissions in year *y* calculated as per paragraph 25 (t CO_2e)

43. Ex post emission reductions shall be determined for case 2(a) and 2(e) as per paragraph 49. For cases 2(b), 2(c), 2(d) and 2(f), ex post emission reductions shall be based on the lowest value of the following, as per paragraph 44:

(a) The amount of biogas recovered and fuelled or flared (MD_y) during the crediting period, that is monitored ex post;

(b) Ex post calculated baseline, project and leakage emissions based on actual monitored data for the project activity.

44. For cases 2(b), 2(c), 2(d) and 2(f): 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:

$$ER_{y,ex\ post} = min\left(\left(BE_{y,ex\ post} - PE_{y,ex\ post} - LE_{y,ex\ post}\right), \left(MD_y - PE_{power,y} - PE_{biomass,y} - LE_{y,ex\ post}\right)\right) \quad \text{Equation (15)}$$

Where:

$ER_{y,ex\ post}$	=	Emission reductions achieved by the project activity based on monitored values for year *y* (t CO_2e)
$BE_{y,ex\ post}$	=	Baseline emissions calculated as per paragraph 25 using ex post monitored values
$PE_{y,ex\ post}$	=	Project emissions calculated as per paragraph 39 using ex post monitored values
MD_y	=	Methane captured and destroyed/gainfully used by the project activity in the year *y* (t CO_2e)

45. In the case of flaring/combustion MD_y will be measured using the conditions of the flaring process:

$$MD_y = BG_{burnt,y} \times w_{CH4,y} \times D_{CH4} \times FE \times GWP_{CH4}$$ Equation (16)

Where:

$BG_{burnt,y}$	=	Biogas[11] flared/combusted in year y (m^3)
$w_{CH4,y}$	=	Methane content[13] of the biogas in the year y (volume fraction)
D_{CH4}	=	Density of methane at the temperature and pressure of the biogas in the year y (t/m^3)
FE	=	Flare efficiency in year y (fraction). If the biogas is combusted for gainful purposes, e.g. fed to an engine, an efficiency of 100 per cent may be applied

46. For the cases 2 (a) and (e) 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.

$$ER_y = BE_{y,ex\ post} - \left(PE_{y,ex\ post} + LE_{y,ex\ post}\right)$$ Equation (17)

47. The historical records of electricity and fuel consumption, the COD content of untreated and treated wastewater, and the quantity of sludge produced by the replaced units will be used for the baseline calculation.

48. In case (a), if the volumetric flow and the characteristic properties (e.g. COD) of the inflow and outflow of the wastewater 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 the higher energy consumption and sludge generation in the baseline scenario are the only significant differences contributing to emissions reductions in the project case. In this case, the emission reductions can be calculated as the difference between the historical energy consumption of the replaced unit and the recorded energy consumption of the new system, plus the difference in emissions from sludge treatment and/or disposal. Project emissions from fugitive emissions and incomplete flaring ($PE_{fugitive,y}$, $PE_{flaring,y}$) shall also be considered in the calculation of the emission reductions, however the emissions from the wastewater outflow and sludge ($PE_{ww,discharge,y}$, $PE_{s,final,y}$) may be disregarded, if they are equivalent in the baseline and project scenarios.

6. Monitoring methodology

49. Relevant parameters shall be monitored as indicated in the tables below. The applicable requirements specified in the “General guidelines for SSC CDM Methodologies” (e.g. calibration requirements, sampling requirements) are also an integral part of the monitoring guidelines specified below and therefore shall be referred by the project participants.

[11] Biogas volume and methane content measurements shall be on the same basis (wet or dry).

6.1. Parameters for monitoring during the crediting period

Data / Parameter table 1.

Data / Parameter:	$Q_{ww,i,y}$
Data unit:	m^3/month
Description:	The flow of wastewater
Measurement procedures (if any):	Measurements are undertaken using flow meters
Monitoring frequency:	Monitored continuously (at least hourly measurements are undertaken, if less, confidence/precision level of 90/10 shall be attained)
Any comment:	-

Data / Parameter table 2.

Data / Parameter:	$COD_{ww,untreated,y}$, $COD_{ww,treated,y}$, $COD_{ww,discharge,PJ,y}$
Data unit:	t COD/m^3
Description:	The chemical oxygen demand of the wastewater before and after the treatment system affected by the project activity
Measurement procedures (if any):	Measure the COD according to national or international standards. COD is measured through representative sampling
Monitoring frequency:	Samples and measurements shall ensure a 90/10 confidence/precision level
Any comment:	-
Data / Parameter:	-

Data / Parameter table 3.

Data / Parameter:	$S_{l,PJ,y}$, $S_{final,PJ,y}$
Data unit:	t
Description:	Amount of dry matter in the sludge
Measurement procedures (if any):	Measure the total quantity of sludge on a wet basis. The volume (m^3) 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 DOE
Monitoring frequency:	Monitoring of 100 per cent of the sludge amount through continuous or batch measurements and moisture content through representative sampling to ensure the 90/10 confidence/precision level

Any comment:	-

Data / Parameter table 4.

Data / Parameter:	$BG_{burnt,y}$
Data unit:	m^3
Description:	Biogas volume in year *y*
Measurement procedures (if any):	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
Monitoring frequency:	Monitored continuously (at least hourly measurements are undertaken, if less, confidence/precision level of 90/10 shall be attained)
Any comment:	-

Data / Parameter table 5.

Data / Parameter:	$w_{CH4,y}$
Data unit:	%
Description:	Methane content in biogas in the year *y*
Measurement procedures (if any):	The fraction of methane in the gas should be measured with a continuous analyser 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:	-
Any comment:	-

Data / Parameter table 6.

Data / Parameter:	***T***
Data unit:	^oC
Description:	Temperature of the biogas
Measurement procedures (if any):	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 normalised 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 ($w_{CH4,y}$) is measured
Any comment:	-

Data / Parameter table 7.

Data / Parameter:	***P***
Data unit:	Pa
Description:	Pressure of the biogas
Measurement procedures (if any):	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 normalised 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 ($w_{CH4,y}$) is measured
Any comment:	-

Data / Parameter table 8.

Data / Parameter:	**-**
Data unit:	%
Description:	The flare efficiency
Measurement procedures (if any):	As per the methodological tool “Project emissions from flaring”. Regular maintenance shall be carried out to ensure optimal operation of flares
Monitoring frequency:	-
Any comment:	-

Data / Parameter table 9.

Data / Parameter:	**-**
Data unit:	-
Description:	Parameters related to emissions from electricity and/or fuel consumption in year *y*
Measurement procedures (if any):	As per the procedure in the “Tool to calculate baseline, project and/or leakage emissions from electricity consumption” and/or “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”. Alternatively, it shall be assumed that all relevant electrical equipment operate at full rated capacity, plus 10 per cent to account for distribution losses, for 8760 hours per annum
Monitoring frequency:	-
Any comment:	-

Data / Parameter table 10.

Data / Parameter:	**-**
Data unit:	t CO_2e
Description:	Parameters related to methane emissions from biomass stored under anaerobic conditions which does not occur in the baseline situation
Measurement procedures (if any):	As per the latest version of the methodological tool “Emissions from solid waste disposal sites”
Monitoring frequency:	-
Any comment:	-

7. Project activity under a programme of activities

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

(a) 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.

Appendix. Provisions for upgradation and distribution of biogas

1. Project boundary

1. In case of project activities covered under paragraph 4(b) and 4 (c),[1] 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

2. In case of project activities covered under paragraph 4(c)(i) 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* (t CO_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 (t CO_2e/TJ); (Accurate and reliable local or national data may be used where available, otherwise appropriate IPCC default values shall be used)

3. 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:

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

[1] These are references to the section “Scope, applicability, and entry into force” in the methodology including upgrading of biogas before distribution to the quality of natural gas for use as fuel or for bottling or for injection into a natural gas distribution system. The eligible biogas upgrading technologies covered in this appendix include: (1) Pressure Swing Adsorption; (2) Absorption with/without water circulation; (3) Absorption with water, with or without water recirculation (with or without recovery of methane emissions from discharge). For those technologies, please refer to annex 1 of the approved methodology “AM0053: Biogenic methane injection to a natural gas distribution grid”/Version 04.0 regarding the description of these technologies project proponent may submit a request for revision to include more technology options.

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)

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

$$Q_{ug,y} = \min(Q_{ug,in,y}, Q_{cap,CH4,y})$$ Equation (3)

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)

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

$$Q_{cap,CH4,y} = w_{CH4,ww} \times Q_{cap,biogas,y}$$ Equation (4)

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)

3. Project emission

6. In case of project activities covered under paragraph 4(b) and 4(c) the following project emissions related to the upgrading and compression of the biogas ($PE_{process,y}$) shall be included:

(a) CO_2 emissions from electricity and fuel used by the upgrading facilities (t CO_2e);

(b) Methane emissions from the discharge of the upgrading equipment (t CO_2e);

(c) Fugitive methane emissions from leaks in compression equipment (t CO_2e);

(d) Emissions on account of vent gases from upgrading equipment (t CO_2e).

$$PE_{process,y} = PE_{power,upgrade,y} + PE_{ww,upgrade,y} + PE_{CH4,equip,y} + PE_{ventgas,y}$$ Equation (5)

Where:

$PE_{process,y}$	=	Project emissions related to the upgrading and compression of the biogas in year *y* (t CO_2e)
$PE_{power,upgrade,y}$	=	CO_2 emissions from electricity and fuel used by the upgrading facilities (t CO_2e), as per paragraph 39 of AMS-III.H.
$PE_{ww,upgrade,y}$	=	Emissions from methane contained in any waste water discharge of upgrading installation in year *y* (t CO_2e)
$PE_{CH4,equip,y}$	=	Emissions from compressor leaks in year *y* (t CO_2e)
$PE_{ventgas,y}$	=	Emissions from venting gases retained in upgrading equipment in year *y* (t CO_2e)

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

$$PE_{ww,upgrade,y} = Q_{ww,upgrade,y} \times [CH_4]_{ww,upgrade,y} \times GWP_{CH4}$$ Equation (6)

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*

8. Project emissions from compressor leaks are determined as follows:

$$PE_{CH4,equip,y} = GWP_{CH4} \times (\frac{1}{1000}) \times \sum_{equipment} w_{CH4,stream,y} \times EF_{equipment} \times T_{equipment,y}$$ Equation (7)

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

9. 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.[2]

10. 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.).

11. The following data needs to be obtained:

(a) The number of each type of component in a unit (valve, connector, etc.);

(b) The methane concentration of the stream;

(c) The time period each component is in service.

12. 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 below.

Table. Methane emission factors for equipment[3]

Equipment type	**Emission factor (kg/hour/source) for methane**
Valves	4.5E-0.3
Pump seals	2.4E-0.3
Others[4]	8.8E-0.3
Connectors	2.0E-0.4
Flangs	3.9E-0.4
Open ended lines	2.0E-0.3

13. Project emissions from venting gases retained in upgrading equipment do not have to be considered if vent gases ($PE_{vent\ gas,y}$) 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 methodological tool “Project emissions from flaring”, as follows:

$$PE_{ventgas,y} = \sum_{h=1}^{8760} TM_{RG,h} \times (1 - \eta_{flare,h}) \times \frac{GWP_{CH4}}{1000}$$ Equation (8)

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

[3] Please refer to the document US EPA-453/R-95-017 Table 2.4, page 2-15, accessed on 23/10/2007.

[4] 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.

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*

14. In case vent gases are not flared the methodological tool "Project emissions from flaring" 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:

$$PE_{y,ventgas} = \sum_{h=1}^{8760} TM_{RG,h} * \frac{GWP_{CH4}}{1000} \quad \text{Equation (9)}$$

15. 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.

16. 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.

17. In case of project activities covered under paragraph 4(c)(ii) emissions due to physical leakage of upgraded biogas from the dedicated piped network ($PE_{leakage,pipeline,y}$) shall be determined as follows:

$$PE_{leakage,pipeline,y} = Q_{methane,pipeline,y} \times LR_{pipeline} \times GWP_{CH4} \quad \text{Equation (10)}$$

Where:

$PE_{leakage,pipeline,y}$	=	Emissions due to physical leakage from the dedicated piped network in year *y* (t CO_2e)
$Q_{methane,pipeline,y}$	=	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[5])

[5] 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 per cent to 500 per cent. A conservative value of 2.5 E-3 * 500% = 0.0125 Gg per 10^6 m^3 of utility sales shall be taken.

4. Leakage emissions

18. In case of project activities covered under paragraph 4(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 included and calculated as follows:

(a) Emissions due to physical leakage of biogas from the bottles during storage, transport etc. until final end use (t CO_2e);

(b) 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 (t CO_2e).

$$LE_{bottling,y} = LE_{leakage,bb,y} + LE_{trans,y}$$ Equation (11)

Where:

$LE_{bottling,y}$	=	Leakage emissions project activities involving bottling of biogas in year *y* (t CO_2e)
$LE_{leakage,bb,y}$	=	Emissions due to physical leakage from biogas bottles in year *y* (t CO_2e)
$LE_{trans,y}$	=	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* (t CO_2e)

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

$$LE_{leakage,bb,y} = Q_{methane,bb,y} \times LR_{bb} \times GWP_{CH4}$$ Equation (12)

Where:

$Q_{methane,bb,y}$	=	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 per cent shall be applied)[6]

20. 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.

$$PE_{trans,y} = \left(\frac{Q_{bb,y}}{CT_{bb,y}} \right) \times DAF_{bb} \times EF_{CO2}$$ Equation (13)

[6] 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.

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_{CO2}	=	CO_2 emission factor from fuel use due to transportation (t CO_2/km)

5. Monitoring methodology

21. 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.

22. In case of project activities covered under paragraph 4(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 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.

23. In case of project activities covered under paragraph 4(b) and 4(c), the following parameters shall be monitored and recorded:

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

(b) 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;

(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 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;

(e) In case vent gases are calculated using the methodological tool “Project emissions from flaring”, the monitoring criteria contained in this tool shall be used. In case this tool is not used and the alternative approach in paragraph 13 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;

(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 4(b) 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}).

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Document information

Version	*Date*	*Description*
19.0	14 June 2019	EB 103, Annex 8 Revision to include reference to methodological tool “TOOL32: Positive lists of technologies”.
18.0	16 October 2015	EB 86, Annex 16 Revision to include non-binding best practice examples.
17.0	28 November 2014	EB 81, Annex 34 Revision to standardize the requirements on additionality in the methodology in line with other waste sector methodology such as AMS-III.D. It includes provisions for automatic additionality.
16.0	26 November 2010	EB 58, Annex 22 To include additional guidelines pertaining to transport of biogas (e.g. by trucks) and biogas application for transportation; To clarify the conditions under which the measurement campaign can be used for baseline emissions determination.

Version	*Date*	*Description*
15.0	30 July 2010	EB 55 Annex 34 To clarify the criteria to be satisfied for the baseline lagoon treatments systems under the methodology; To include the monitoring table with the required frequency of measurements and options for collection and recording of data.
14.0	26 March 2010	EB 53, Annex 17 To include additional clarification on the monitoring requirements of biogas.
13.0	17 July 2009	EB 48, Annex 21 To include additional eligible technologies for upgrading biogas for bottling or feeding to natural gas distribution grid. Include an option to use the calculated net calorific value (NCV) of biogas based on methane content measurement instead of directly monitoring NCV using a NCV meter.
12.0	28 May 2009	EB 47, Annex 26 To include additional guidance on use of methane generation potential based on Biochemical Oxygen Demand ($BOD_{5,20}$).
11.0	25 March 2009	EB 46, Annex 22 To clarify the methods for determination of baseline for Greenfield projects; To specify minimum requirements concerning sludge removal interval in the baseline anaerobic lagoon; Further guidance on measuring equipment for biogas pressure, temperature and flow rate.
10.0	26 September 2008	EB 42, Annex 17 Additional guidance on baseline determination and project emission calculations; Restructured, provisions related to methane correction factor and related uncertainties were revised.
09.0	14 March 2008	EB 38, Annex 10 Expand applicability to include pipeline transport of the recovered and upgraded biogas; Additional guidance on sequential treatment of wastewater in anaerobic lagoons.
08.0	30 November 2007	EB 36, Annex 24 Expand applicability to bottling of recovered biogas; Additional guidance on emissions from dissolved methane in the treated wastewater; Guidance on use of IPCC default factors for the degradable organic content of sludge.
07.0	19 October 2007	EB 35, Annex 29 Expand the applicability to allow recovered biogas to be used for hydrogen production.
06.0	27 July 2007	EB 33, Annex 35 Additional leakage guidance to allow for application under a

Version	*Date*	*Description*
		programme of activities (PoA).
05.0	04 May 2007	EB 31, Annex 27 To exclude scope 15 from the methodology
04.0	15 December 2006	EB 28, Annex 26 Broaden the applicability to include sequential stage of anaerobic wastewater treatment; Additional guidance based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories on the following: (a) Methane correction factor (*MCF*) determined by wastewater discharge pathways or type of treatment; (b) Default values for sludge treatment, particularly for degradable organic carbon (DOC) and methane correction factor (*MCF*).
03.0	21 July 2006	EB 25, Annex 28 Clarify the inclusion of methane emission factor in the equation for baseline calculations.
02.0	10 May 2006	EB 24, paragraph 64 of the report The Board at its twenty-fourth meeting noted that Type III project activities might be able to achieve significant emission reductions, without exceeding the direct emissions limits i.e. 15 kilo tonnes CO_2e applicable at the time. As an interim solution, the Board agreed to include the following text in all Type III categories: "This category is applicable for project activities resulting in annual emission reductions lower than 25,000 tonnes CO_2e. If the emission reduction of a project activity exceeds the reference value of 25,000 tonnes CO_2e in any year of the crediting period, the annual emission reduction for that particular year is capped at 25,000 tonnes CO_2e."
01.0	24 February 2006	EB 23, Annex 23 Initial adoption.

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