GHR002 Methodology for Assessing Methane Recovery from Anaerobic Digestion of Manure to Produce Biogas

Version 1.0
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GLOBAL HEAT REDUCTION™

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Contents

1. Introduction

This Methodology has been developed for use in connection with the Global Heat Reduction (GHR) Registry (the "Registry), consistent with the requirements of the GHR Registry Standard. It is intended for use in evaluating Projects under selected project types and within geographic regions identified herein.

The Methodology uses the standard nomenclature of "shall" or "must" for required clauses and "should" or "may" for suggested clauses. All documentation and reporting under this methodology must be conducted in English, with translations provided where necessary to accommodate local stakeholders.

2. Methodology Overview

2.1 Methodology Description

This methodology describes the requirements and standards for the installation, replacement, or modification of manure management systems in livestock farms to qualify for verified credits from the Global Heat Reduction (GHR) Registry. The primary goal is to achieve methane emission reductions through the anaerobic digestion of manure, producing biogas, which can be utilized, sold, or flared[1]. The methodology also includes the collection of manure from multiple farms for centralized digestion systems.

The methodology is consistent with the methane recovery procedures of the Clean Development Mechanism (CDM) under the United Nations Framework Convention on Climate Change (UNFCCC). Specifically, it draws upon the CDM methane recovery methodologies *AMS-III.D Methane recovery in animal manure management systems*[2] *and AMS-III.AO Methane recovery through controlled anaerobic digestion*[3].

This methodology is designed to ensure that credits issued represent additional, permanent, independently-verified, and rigorously-quantified reductions in methane emissions. Final approval of a project under this methodology is granted exclusively by the GHR Registry.

2.2 Project Activities Covered by the Methodology

Projects under this methodology capture and manage biogas produced from anaerobic digestion of manure. This process involves the collection of methane-rich biogas from digestion systems, which can then be used as a renewable energy source, sold as a commodity, or flared to prevent methane emissions. Projects will either install new or improve the efficiency of existing anaerobic digesters, biogas collection systems, flaring systems, or utilization equipment.

2.3 Eligibility Requirements for Projects under the Methodology

Individual projects are considered eligible to earn credits if they meet all eligibility requirements of the GHR Registry Standard and all the following conditions are met:

- The livestock population in the farm is managed under confined conditions;
- Manure or the streams obtained after its treatment in digesters are not discharged into natural water resources (e.g., river or estuaries);
- The annual average temperature of baseline site where anaerobic manure treatment facility is located is higher than 5 °C;

- In the baseline scenario, the retention time of manure waste in the anaerobic treatment systems (e.g., lagoons or deep pits) is greater than one month, and if anaerobic lagoons are used in the baseline, their depths are at least 1 meter;
- The amount of methane recovered is increased as a result of the project activities, as described in Section 2.2;
- The residual waste from the animal manure digestion systems (i.e., digestate) is handled aerobically, otherwise the related emissions shall be taken into account as per relevant procedures of *AMS-III.AO Methane recovery through controlled anaerobic digestion*. Proper conditions and procedures (not resulting in methane emissions, e.g., subsurface injection) must be ensured when applying digestate to soils;
- Technical measures and equipment are used (including a flare for exigencies) to ensure that all biogas produced by the digester is used or flared;
- The storage time of the manure after removal from the animal barns, including transportation, does not exceed 45 days before being fed into the anaerobic digester. However, during warmer conditions (e.g., when average daily temperatures exceed 15°C), the storage period shall be reduced to a maximum of 10 days to prevent significant methane emissions during storage. If the project proponent can demonstrate that the dry matter content of the manure when removed from the animal barns is larger than 20%, this time constraint will not apply.
    - For manure removed from compost bedded pack barns, where partial aerobic degradation occurs, the project proponent must demonstrate that conditions in the bedding pack prevent significant methane generation (e.g., regular aeration or sufficient dry matter content). If these conditions are met and methane emissions are controlled, the 45-day limit may remain in place.

2.4 Geographic Scope

Global

3. Materiality, Additionality, Permanence and Secondary Effects

3.1 Materiality

Materiality refers to information that, if omitted, erroneous or misstated, would lead to misrepresentation of radiative forcing (RF) reduction of a project. A materiality assessment is required for projects, with a materiality threshold of +/-5% of RF reductions in a given monitoring period. Materiality will be assessed by the validation and verification body (VVB) as part of validation and verification (see Section 7.5). See further discussion in the GHR Registry Standard.

In this category, errors, omissions, and misrepresentations that could significantly affect the estimation of the RF reduction potential associated with a project include, for example:

- Significant under-estimate or over-estimate of the methane emissions reduced by the project
- Misrepresentation of the project in terms of any eligibility or additionality requirements

3.2 Additionality Considerations

The project proponent must demonstrate additionality for projects that capture and destroy or use biogas, consistent with the Registry Standard. In addition, the following conditions apply:

- The quantity of biogas to be captured and destroyed exceeds any amount of recovery which is required under national or local regulations; and

- Sales of generated biogas are insufficient to financially support the project development and activities.
- If co-digestion of other organic waste (e.g., food waste, agricultural residues) is used, the project proponent must demonstrate that the co-digestion does not detract from the additionality of the project. Specifically, any biogas captured from these additional feedstocks must not already be required by existing regulations or financially viable without carbon credits.

The Project Proponent shall provide clear evidence for additionality in the Project Design Document (see Section 7.1).

3.3 Permanence

The annual methane emissions that would otherwise have been generated by an anaerobic digester system will be permanently reduced by projects under this Methodology. Therefore, there is no risk of non-permanence of RF reductions achieved based on the emissions reductions achieved through this process.

The Project Proponent shall evaluate and report the risk of non-permanence at each monitoring period (see Section 7).

3.4 Risk of Secondary Effects

Secondary effects have the potential to increase greenhouse gas emissions or other contributors to positive RF associated with a project due to material substitutions or changes in activities or operations outside the project boundary.

Secondary effects shall be determined using the latest version of the CDM tool "Project and leakage emissions from anaerobic digesters."[1]

[1] Available at https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-14-v2.pdf

4. Baseline and Project Scenario Descriptions

4.1 Baseline Scenario

The baseline scenario represents a business-as-usual situation, representing what would have occurred in the absence of the project activities (described in Section 4.2). In the baseline scenario, the degradable organic matter in the manure decays during handling and storage within the project boundary and methane and other greenhouse gases (GHGs) are emitted to the atmosphere. Manure or wastewater may be treated anaerobically in common systems such as uncovered lagoons, deep pits, or other anaerobic storage facilities where oxygen is limited, resulting in methane emissions. Baseline emissions shall exclude emissions of methane that would have to be captured, flared, used as fuel, or otherwise gainfully used to comply with national or local safety requirements or legal regulations.

4.2 Project Scenario

The project scenario is a livestock operation in which an anaerobic digester is installed, replaced, or modified for digestion of manure and biogas is generated, captured, and managed on-site.

4.3 Group Project Scenario

It is possible that multiple livestock operations under one management and ownership system may apply for assessment, validation, verification, and credit issuance in an aggregated group. All such operations within the group would be required to individually meet the requirements of the GHR Registry Standard and this methodology.

5. Project Boundaries

5.1 Boundaries for Assessing Radiative Forcing, Radiative Forcing Reduction, Co-benefits, and Trade-offs

The project boundary is the physical, geographical site:

a) Where the manure would have been disposed of and the methane emission occurs in absence of the proposed project activity;
b) In the case of projects co-digesting wastewater, wastewater refers to organic-rich wastewater from agricultural, food processing, or livestock operations, where the wastewater would have been treated anaerobically in the absence of the project activity;
c) Co-digestion of other organic materials, such as food waste or agricultural residues, may be included if these materials contribute to methane recovery. However, the project proponent must ensure that the co-digestion aligns with the additionality requirements outlined in Section 3.2 and that all sources of wastewater or co-digested materials are within the project boundary. For projects including co-digestion, projects must submit calculations of baseline and project emissions that account for the co-digestion to the GHR Registry for approval;
d) Where the treatment of manure through anaerobic digestion takes place;
e) Where the residual waste from biological treatment or products from those treatments, like slurry, are handled, disposed, applied to soil, or treated thermally/mechanically;
f) Where biogas is burned/flared or gainfully used, including biogas sale points, if applicable; and
g) The transportation routes between the above listed cases (a, b, c, d and e), where the transportation of manure, wastewater (where applicable), residual waste after digestion, or biogas occurs.

5.2 Sources, Sinks, and Reservoirs of Radiative Forcing

** NOTE: Delineate sources, sinks, and reservoirs to be analyzed for credits, as described in the **GHR Registry Standard.***

Project proponents shall account for all significant sources of climate forcer emissions and removals, within the project boundary (as described in Section 5.1), to provide an accurate estimation of the project's net impact on climate forcing. The exclusion of emission sources is permissible, provided the exclusions result in conservatively low crediting[2] and have been tested for their significance to total credit amounts. Sources (Table 1) that are considered significant and/or selected for accounting in the baseline scenario shall also be included in the project scenario.

Table 1. Climate forcer emission sources relevant to methane recovery projects

Source	Climate Forcer	Included in Calculation	Justification/Explanation
Uncontrolled anaerobic decay of manure	CH_4	Required	Baseline methane emissions which are avoided under the project scenario.
Operation of anaerobic digester	CO_2, CH_4, N_2O, NO_x, CO, Black Carbon, Organic	Required	Operating an anaerobic digester requires powering pumps and other components. The use of grid electricity or burning of fuels

[2] An exclusion is acceptable if it tends to underestimate net climate forcer emission reductions/removal enhancements.

	Carbon, Sulfate aerosols		(excluding biogas) to power these components results in climate forcer emissions.
Equipment Leaks	CH_4	Required	Leaks may occur from anaerobic digester tanks or pipes. Regular testing for leaks shall be conducted at least quarterly, or more frequently if local regulations or project-specific conditions (e.g., high methane concentrations or prior leak incidents) warrant it. Leak detection methods may include infrared cameras, gas analyzers, or pressure decay tests. Leaks must be quantified and reported in the Project Monitoring Reports.
Biogas combustion	CO_2, CH_4, N_2O, NO_x, CO, Black Carbon, Organic Carbon, Sulfate aerosols	Required	Combustion of biogas results primarily in CO_2 but can also lead to the release of CH_4, NO_x, CO, and N_2O under suboptimal conditions. Incomplete combustion can emit black carbon and organic carbon.
Flare inefficiency	CO_2, CH_4, N_2O, NO_x, CO, Black Carbon, Organic Carbon, Sulfate aerosols	Required	The efficiency of methane destruction via flaring is variable, therefore residual methane emissions are considered. Flaring has been shown to release other climate forcers which must be considered.
Collection and transport of manure	CO_2, CH_4, N_2O, NO_x, CO, Black Carbon, Organic Carbon, Sulfate aerosols	Optional	Emissions from powered equipment used to collect or transport manure.
Storage of manure	CH_4	Optional	Methane is released from anaerobic manure storage.

6. Quantification

6.1 Types of Data Required, Accepted Data Sources, and Calculation Methods

Information about necessary data and parameters can be found in the calculations and descriptions in Sections 6.2 – 6.4, the tools utilized or mandated in this methodology, and in Section 7.2. A listing of the monitored data and parameters is available in Appendix A.

6.2 Baseline Scenario Climate Forcer Calculation Methods

The project proponent shall calculate the baseline scenario climate forcer emissions using one of the following:

a) Option A – Using the amount of the waste or raw material that would decay anaerobically in the absence of the project activity, with the most recent IPCC Tier 2 approach (please refer to the chapter ‘Emissions from Livestock and Manure Management’ under the volume ‘Agriculture, Forestry and other Land use’ of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories). For the purposes of this methodology, "waste or raw material" refers primarily to animal manure and other organic matter from livestock operations that would naturally undergo anaerobic decay, leading to methane emissions. This may also include other organic substrates that are part of the manure management system, such as agricultural residues or organic-rich wastewater, provided they are included in the baseline scenario. The calculation requires information about the characteristics of the manure and its management systems in the baseline. Manure characteristics include the amount of volatile solids (VS) produced by the livestock and the maximum amount of methane that can be potentially produced from that manure (B_0).

b) Option B – Using the amount of manure that would decay anaerobically in the absence of the project activity based on direct measurement of the quantity of manure treated together with its specific volatile solids (SVS) content.

6.2.1 Option A

If Option A is chosen, baseline methane emissions are determined as follows:

$$BE_y = D_{CH4} \times UF_b \times \sum_{j,LT} (MCF_j \times B_{O,LT} \times N_{LT,y} \times VS_{LT,y} \times MSF_{Bl,j}) \qquad \textbf{Eq. 1}$$

Where:

BE_y	Baseline emissions in year *y* (t CH_4)
D_{CH4}	Density of methane (0.00067 t/m^3 at room temperature (20 °C) and 1 atm)
UF_b	Model correction factor to account for model uncertainties [3] (unitless)
j	Index for animal manure management system
LT	Index for all types of livestock
MCF_j	Annual methane conversion factor for the baseline animal manure management system *j* (unitless)
$B_{O,LT}$	Maximum methane production potential of the volatile solid generated from animal type *LT* (m^3 CH_4/kg-dm)
$N_{LT,y}$	Annual average number of animals of type *LT* in year *y* (numbers)
$VS_{LT,y}$	Volatile solids production/excretion per animal of livestock *LT* in year *y* (on a dry matter weight basis, kg-dm/animal/year)
$MSF_{Bl,j}$	Fraction of manure collected in baseline animal manure management system *j* (unitless: 0-1)

- The maximum methane-production capacity of the manure (B_o) varies by species and diet. The preferred method to obtain B_o measurement values is to use data from country-specific published sources, measured with a standardized method (B_o shall be based on total as-excreted VS). These values shall be compared to the most recent default values of the IPCC and any significant differences shall be explained. If country specific B_o values are not available, default values from tables 10 A-4 to 10 A-9 of *2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4, Chapter 10* can be used, provided that the project participants assess the suitability of those data to the specific situation of the treatment site.

- Volatile solids are the organic material in livestock manure and consist of both biodegradable and non-biodegradable components. For the calculations the total VS excreted by each animal species is required.

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[3] See FCCC/SBSTA/2003/10/Add.2, page 25.

- The preferred method to obtain VS is to use data from nationally published sources. These values shall be compared with IPCC default values and any significant differences shall be explained.
- If data from nationally published sources are not available, country-specific VS excretion rates can be estimated from feed intake levels, via the enhanced characterization method (tier 2) described in section 10.2 in *2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4, Chapter 10*, using Equation 2 below.

$$VS_{LT,y} = \left[GE_{LT} \times \left(1 - \frac{DE_{LT}}{100}\right) + (UE \times GE_{LT})\right] \times [\left(\frac{1-ASH}{ED_{LT}}\right)] \times nd_y \qquad \textbf{Eq. 2}$$

Where:

$VS_{LT,y}$	Annual volatile solid excretions for livestock LT entering all animal waste management systems on a dry matter weight basis (kg-dm/animal/yr)
GE_{LT}	Daily average gross energy intake (MJ/animal/day)
DE_{LT}	Digestible energy of the feed (percent)
UE	Urinary energy (fraction of GE_{LT})
ASH	Ash content of manure (fraction of the dry matter feed intake)
ED_{LT}	Energy density of the feed fed to livestock type *LT* (MJ/kg-dm)
nd_y	Number of days treatment plant was operational in year *y*

If country specific VS values are not available, IPCC default values from *2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4, Chapter 10* table 10 A-4 to 10 A-9 can be used provided that the project proponent and VVB assess the suitability of those data to the specific situation of the treatment site particularly with reference to feed intake levels.

Project proponents may adjust default IPCC values for VS for a site-specific average animal weight. If so, it shall be well explained and documented. The following equation shall be used:

$$VS_{LT,y} = \left(\frac{W_{site}}{W_{default}}\right) \times VS_{default} \times nd_y \qquad \textbf{Eq. 3}$$

Where:

$VS_{LT,y}$	Annual volatile solid excretions for livestock LT entering all animal waste management systems on a dry matter weight basis (kg-dm/animal/yr)
W_{site}	Average animal weight of a defined livestock population at the project site (kg)
$W_{default}$	Default average animal weight of a defined population, this data is sourced from IPCC 2006 (kg)
$VS_{default}$	Default value for the volatile solid excretion rate per day on a dry-matter basis for a defined livestock population (kg-dm/animal/day)
nd_y	Number of days treatment plant was operational in year *y*

B_0 or VS values applicable to developed countries can be used provided the following four conditions are satisfied:

i. The genetic source of the livestock originates from an Annex I Party[4];
ii. The farm uses formulated feed rations (FFR) which are optimized for the various animal(s), stage of growth, category, weight gain/productivity and/or genetics;
iii. The use of FFR can be validated (through on-farm record keeping, feed supplier, etc.); and
iv. The project specific animal weights are within 10% of developed country IPCC default values. If the adjusted VS values deviate by more than 10% from the default developed country IPCC values, the project proponent must provide a detailed justification, including data sources and assumptions used for the adjustments. Any significant deviations should be based on robust, locally relevant data, such as feed composition or animal growth rates, and validated by independent sources.

In the case of sequential treatment stages, the reduction of the volatile solids during a treatment stage is estimated based on referenced data for different treatment types, as described in Equation 4. Emissions from the next treatment stage are then calculated following the approach outlined above, but with volatile solids adjusted for the reduction from the previous treatment stages by multiplying by (1 - RVS), where RVS is the relative reduction of volatile solids from the previous stage. The relative reduction of volatile solids (RVS) depends on the treatment technology and should be estimated in a conservative manner. Default values for different treatment technologies can be found in the table in the Appendix of CDM methodology AMS-III.D[5].

$$BE_y = D_{CH4} \times UF_b \times \sum_{j,LT,ts} \left(MCF_j \times B_{O,LT} \times N_{LT,y} \times VS_{LT,y,ts} \times (1 - RVS_{ts}) \times MSF_{Bl,j} \right) \qquad \text{Eq. 4}$$

Where:

BE_y	Baseline emissions in year *y* (t CH_4)
D_{CH4}	Density of methane (0.00067 t/m^3 at room temperature (20 °C) and 1 atm)
UF_b	Model correction factor to account for model uncertainties [6] (unitless)
j	Index for animal manure management system
LT	Index for all types of livestock
ts	Index for treatment stage
MCF_j	Annual methane conversion factor for the baseline animal manure management system *j* (unitless)
$B_{O,LT}$	Maximum methane production potential of the volatile solid generated from animal type *LT* (m^3 CH_4/kg-dm)
$N_{LT,y}$	Annual average number of animals of type *LT* in year *y* (numbers)
$VS_{LT,y}$	Volatile solids production/excretion per animal of livestock *LT* in year *y* (on a dry matter weight basis, kg-dm/animal/year)
$RVS_{LT,y}$	Relative reduction of volatile solids from the previous stage (fraction 0-1)
$MSF_{Bl,j}$	Fraction of manure collected in baseline animal manure management system *j* (unitless: 0-1)

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[4] Annex I Parties include the industrialized countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States. Retrieved from https://unfccc.int/parties-observers.
[5] https://cdm.unfccc.int/methodologies/DB/H9DVSB24O7GEZQYLYNWUX23YS6G4RC
[6] See FCCC/SBSTA/2003/10/Add.2, page 25.

Methane Conversion Factors (MCF) values are determined for a specific manure management system and represent the degree to which B_0 is achieved. Where available country-specific MCF values that reflect the specific management systems used in particular countries or regions shall be used. Alternatively, the IPCC default values provided in table 10.17 of *2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4, Chapter 10* can be used. The site annual average temperature is taken from official data at the nearest meteorological station, or from data available from historical on-site observations.

The annual average number of animals (N_t) is determined as follows:

$$N_{LT,y} = N_{DA,y}\left(\frac{N_{P,y}}{365}\right) \quad \text{Eq. 5}$$

Where:

$N_{LT,y}$	Annual average number of animals of type *LT* in year *y*
$N_{DA,y}$	Number of days animal is alive in the farm in year *y*
$N_{P,y}$	Number of animals produced annually of type *LT* for the year *y*

6.2.2 Option B

If Option B is chosen, baseline methane emissions are determined based on directly measured quantity of manure and its specific volatile solids content, as follows:

$$BE_y = D_{CH4} \times UF_b \times \sum_{j,LT}(MCF_j \times B_{O,LT} \times Q_{manure,j,LT,y} \times SVS_{j,LT,y}) \quad \text{Eq. 6}$$

Where:

BE_y	Baseline emissions in year *y* (t CH_4)
D_{CH4}	Density of methane (0.00067 t/m^3 at room temperature (20 °C) and 1 atm)
UF_b	Model correction factor to account for model uncertainties [7] (unitless)
MCF_j	Annual methane conversion factor for the baseline animal manure management system *j* (unitless)
$B_{O,LT}$	Maximum methane production potential of the volatile solid generated for animal type *LT* (m^3 CH_4/kg-dm)
$Q_{manure,j,LT,y}$	Quantity of manure from livestock type *LT* that is treated in animal manure management system *j* (tonnes/year, dry basis)
$SVS_{j,LT,y}$	Specific volatile solids content of animal manure from livestock type *LT* and manure management system *j* in year *y* (tonnes/tonnes, dry basis)

[7] See FCCC/SBSTA/2003/10/Add.2, page 25.

6.3 Project Scenario Climate Forcer Calculation Methods

The project scenario climate forcer emissions shall be calculated as follows:

$$PE_{y,f} = PE_{PL,y,f} + PE_{flare,y,f} + PE_{power,y,f} + PE_{transp,y,f} + PE_{storage,y} \qquad \textbf{Eq. 7}$$

Where:

$PE_{y,f}$	Project emissions in year *y*, for climate forcer *f* (tonnes)
$PE_{PL,y,f}$	Emissions due to physical escape of biogas in year *y*, for climate forcer *f* (tonnes). Note, this factor is only required for methane emission calculations.
$PE_{flare,y,f}$	Emissions from flaring or combustion of the biogas stream in year *y*, for climate forcer *f* (tonnes)
$PE_{power,y,f}$	Emissions from the use of fossil fuel or electricity for the operation of the installed facilities in the year *y*, for climate forcer *f* (tonnes)
$PE_{transp,y,f}$	Emissions from incremental transportation in year *y*, for climate forcer *f* (tonnes)
$PE_{storage,y,f}$	Emissions from the storage of manure in year *y*, for climate forcer *f* (tonnes). Note, this factor is only required for methane emission calculations.

- Project emissions due to physical escape of biogas from the animal manure management systems used to produce, collect and transport the biogas to the point of flaring or gainful use are estimated as:
    a) 10% of the maximum methane production potential of the manure fed into the management systems implemented by the project activity:[8]
        i. If Option A is chosen, it is determined as:

$$PE_{PL,y,f} = 0.10 \times D_{CH4} \times \sum_{i} (B_{O,LT} \times N_{LT,y} \times VS_{LT,y} \times MSF_{i,y}) \qquad \textbf{Eq. 8}$$

Where:

$PE_{PL,y,f}$	Emissions due to physical escape of biogas in year *y*, for climate forcer *f* (tonnes)
D_{CH4}	Density of methane (0.00067 t/m^3 at room temperature (20 °C) and 1 atm)
$B_{O,LT}$	Maximum methane production potential of the volatile solid generated for animal type *LT* (m^3 CH_4/kg-dm)
$N_{LT,y}$	Annual average number of animals of type *LT* in year *y*
$VS_{LT,y}$	Volatile solids production/excretion per animal of livestock *LT* in year *y* (on a dry matter weight basis, kg-dm/animal/year)

[8] 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10 guidelines specify a default value of 10% of the maximum methane production potential (Bo) for the physical escape from anaerobic digesters.

$MSF_{i,y}$	Fraction of manure treated in system *i* in year *y* (unitless: 0-1) If the project activity involves sequential manure management systems, the procedure specified in Equation 4 in Section 6.2.1 shall be used to estimate the project emissions due to physical escape of biogas from each stage

ii. If Option B is chosen, it is determined as:

$$PE_{PL,y,f} = 0.10 \times D_{CH4} \times \sum_{i} (B_{O,LT} \times Q_{manure,LT,y} \times SVS_{LT,y} \times MSF_{i,y}) \quad \textbf{Eq. 9}$$

Where:

$PE_{PL,y,f}$	Emissions due to physical escape of biogas in year *y*, for climate forcer *f* (tonnes)
D_{CH4}	Density of methane (0.00067 t/m^3 at room temperature (20 °C) and 1 atm)
$B_{O,LT}$	Maximum methane production potential of the volatile solid generated for animal type *LT* (m^3 CH_4/kg-dm)
$Q_{manure,LT,y}$	Quantity of manure treated from livestock type *LT* (tonnes/year, dry basis)
$SVS_{LT,y}$	Specific volatile solids content of animal manure from livestock type *LT* in year *y* (tonnes/tonnes, dry basis)
$MSF_{i,y}$	Fraction of manure handled in system *i* in year *y* (unitless: 0-1) If the project activity involves sequential manure management systems, the procedure specified in Equation 4 in Section 6.2.1 shall be used to estimate the project emissions due to physical escape of biogas in each stage

b) Optionally, the relevant procedure in the methodological tool "Project and leakage emissions from anaerobic digesters" may be followed. In such a case, $PE_{PL,y,CH4}$ for methane is equivalent to $PE_{CH4,y}$ in the tool, excluding conversion to CO_2e.

- The project proponent shall estimate project CO_2 emissions due to leaks from the equipment used to produce, collect, and transport the biogas to the point of use, sale, or flaring using the volume fraction of CO_2 in the biogas and the same default leak factor (10%) as methane, unless a lower value can be justified based on project measurements.

- In the case of flaring of the recovered biogas, the project emissions shall be estimated using the CDM methodological tool "Project emissions from flaring,"[9] with the following modifications:
  a) All CH_4 which is not combusted shall be kept as a quantity of CH_4 and not converted to CO_2e; and
  b) All CH_4 which is combusted shall be considered to be 100% converted to CO_2, and therefore included in the project CO_2 emissions inventory.
     i. If the recovered biogas is combusted for electrical/thermal energy production or for other gainful use, the methane destruction efficiency can be considered as 100%. However, this use of the recovered biogas shall be included in the project boundary and its output shall be monitored in order to ensure that the recovered

[9] Available at https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-06-v4.0.pdf

biogas is actually destroyed. The CO_2 emissions shall be included in the calculation of the project CO_2 emissions inventory.

c) Project emissions from the remaining climate forcers shall be calculated in a similar manner, using the project electricity and fuel use with the appropriate emission factor for each respective climate forcer.

- Project CO_2 emissions from electricity and fossil fuel consumption are determined by following the methodological tool "Project and leakage emissions from anaerobic digesters",[10] where $PE_{power,y,CO2}$ is the sum of $PE_{EC,y}$ and $PE_{FC,y}$ in the tool. Project emissions from the remaining climate forcers shall be calculated in a similar manner, using the project electricity and fuel use with the appropriate emission factor for each respective climate forcer.

- Project emissions due to manure collection and transport ($PE_{transp,y,f}$) are calculated based on the incremental distances between:
  a) The collection points of manure and the digestion site as compared to the baseline solid waste disposal site or manure treatment site; and
  b) When applicable, the collection points of wastewater and treatment site as compared to baseline wastewater treatment site.

Project climate forcer emissions from manure collection and transport are calculated using Equation 10:

- Emissions from transportation-related fuel use include those generated from the use of trucks or other vehicles for transporting manure, wastewater, or residual waste.
- Residual waste refers to the by-products of anaerobic digestion, including digestate, which may be handled, transported, or applied to soil. If the digestate is treated on-site (e.g., for composting or producing other products such as biofertilizers), emissions from transportation of these products must be accounted for in the project scenario as well.

$$PE_{transp,y,f} = \frac{Q_y}{CT_y} \times DAF_w \times EF_{transport,f} + \frac{Q_{resWaste,y}}{CT_{resWaste,y}} \times DAF_{resWaste} \times EF_{transport,f} \quad \text{Eq. 10}$$

Where:

$PE_{transp,y,f}$	Emissions from incremental transportation in year *y*, for climate forcer *f* (tonnes)
Q_y	Quantity of manure treated and/or wastewater co-digested in year *y* (tonnes)
CT_y	Average truck capacity for transportation (tonnes/truck)
DAF_w	Average incremental distance for manure and/or wastewater transportation (km/truck)
$EF_{transport,f}$	Emission factor for climate forcer *f*, from transportation-related fuel use (kg/km, IPCC default values[11] or local values may be used)
$Q_{resWaste,y}$	Quantity of residual waste or other byproducts produced in year y (tonnes)
$CT_{resWaste,y}$	Average truck capacity for residual waste or other byproduct transportation (tonnes/truck)
$DAF_{resWaste}$	Average distance for residual waste transportation (km/truck)

[10] Available at https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-14-v2.pdf

[11] IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1, Chapter 2, and Volume 4, Chapter 10

- Project emissions on account of storage of manure before being fed into the anaerobic digester shall be accounted for if both condition (a) and condition (b) below are satisfied:
    a) The storage time of the manure after removal from the animal barns, including transportation, exceeds 24 hours before being fed into the anaerobic digester;
    b) The dry matter content of the manure when removed from the animal barns is less than 20%.

The following method shall be used to calculate project methane emissions from manure storage:

$$PE_{storage} = D_{CH4} \times \sum_{l}[\frac{365}{AI_l} \times \sum_{d=1}^{AI}(N_{LT} \times VS_{LT,d} \times MSF_l \times (1 - e^{-k(AI_l - d)}) \times MCF_l \times B_{O,LT})] \quad \text{Eq. 11}$$

Where:

$PE_{storage}$	Project emissions on account of manure storage in year *y* (t CH_4)
D_{CH4}	Density of methane (0.00067 t/m^3 at room temperature (20 °C) and 1 atm)
AI_l	Annual average interval between manure collection and delivery for treatment at a given storage device l (days)
N_{LT}	Annual average number of animals of type *LT* (numbers)
$VS_{LT,d}$	Amount of volatile solid production by type of animal LT in a day (kg VS/head/d)
MSF_l	Fraction of volatile solids handled by storage system(s) l (unitless: 0-1)
k	Degradation rate constant (0.069)
d	Days for which cumulative methane emissions are calculated; d can vary from 1 to 45 and to be run from 1 up to AI_l
MCF_l	Annual methane conversion factor for the project manure storage device l from Table 10.17, Chapter 10, Volume 4, 2006 IPCC Guidelines for National Greenhouse Gas Inventories (fraction 0-1)
$B_{O,LT}$	Maximum methane production potential of the volatile solid generated for animal type *LT* (m^3 CH_4/kg-dm)

6.4 Determination of the Project's Climate Impact

The emission reductions achieved by the project activity are calculated as the baseline emissions minus the project emissions using the actual monitored data for the project activity (i.e. $N_{LT,y}$, $MSF_{i,y}$, MSF_l, AI_l, as well as $VS_{LT,y}$ in cases where adjusted values for animal weight are used). The emission reductions achieved in any year are:

$$ER_{y,f} = BE_y - PE_{y,f} \quad \text{Eq. 12}$$

Where:

$ER_{y,f}$	Emission reductions achieved by the project activity based on monitored values for year *y*, for climate forcer *f (tonnes of climate forcer f)*
BE_y	Baseline emissions calculated using Equation 1 (for projects using baseline Option A) using ex post monitored values of $N_{LT,y}$ and, if applicable, $VS_{LT,y}$. For projects using baseline Option B, Equation 6 is used with the ex post monitored values for $Q_{manure,j,LT,y}$ and $SVS_{j,LT,y}$. Methane only unless otherwise noted. (tonnes)

$PE_{y,f}$	Project emissions calculated using Equation 7 using ex post monitored values for year *y* of $N_{LT,y}$, $MSF_{i,y}$, MSF_l, AI_l, and, if applicable, $VS_{LT,y}$ *(tonnes of climate forcer f)*

Biogas flared or combusted (MD_y) shall be determined using the flare efficiency and methane content of biogas.

$$MD_y = BG_{burnt,y} \times w_{CH4,y} \times D_{CH4} \times FE \qquad \text{Eq. 13}$$

Where:

MD_y	Amount of methane captured and destroyed or used gainfully by the project activity in year *y (tonnes)*
$BG_{burnt,y}$	Amount of biogas flared or combusted in year *y* (m^3)
$w_{CH4,y}$	Methane content in the biogas in year *y* (volume fraction)
D_{CH4}	Density of methane (0.00067 t/m^3 at room temperature (20 °C) and 1 atm)
FE	Flare efficiency in the year *y* (fraction)

The method for integration of the terms in Equation 13 to obtain the results for one year of measurements, the confidence levels of those values, as well as the methods and instruments used for metering, recording and processing the data obtained, shall be described in the PDD and monitored during the crediting period.

Alternatively, if project activities utilize the recovered methane for power generation, MD_y may be calculated as follows, based on the amount of monitored electricity generation, without monitoring methane flow and concentration:

$$MD_y = \frac{EG_y \times 3600}{NCV_{CH4} \times EE_y} \times D_{CH4} \qquad \text{Eq. 14}$$

Where:

MD_y	Methane captured and destroyed or used gainfully by the project activity in year *y*
EG_y	Total electricity generated from the recovered biogas in year *y* (MWh)
NCV_{CH4}	NCV of methane (MJ/Nm^3) (use default value: 35.9 MJ/Nm^3)
EE_y	Energy conversion efficiency of the project equipment (manufacturer specification or default value of 40%)
D_{CH4}	Density of methane (0.00067 t/m^3 at room temperature (20 °C) and 1 atm)

The potential credit amount in carbon dioxide equivalents (CO_2e) is calculated as shown in Equation 15:

$$R_{CO_2e,y} = ER_{y,CO_2} + \sum_{y,f} ER_{y,f} \times GWP_f \qquad \text{Eq. 15}$$

Where:

$R_{CO_2e,t}$	Reduction in CO_2e due to project activities in year *y (t CO_2e)*
ER_{y,CO_2}	Net CO_2 emissions in year *y* (t CO_2e)
$ER_{y,f}$	Net emissions in year *y* for climate forcer *f* (tonnes)
GWP_f	Global warming potential over 100 years (GWP 100) for climate forcer *f* (use latest IPCC values)[12]

The RF reduction (CO_2fe or W/m^2) in a given year is calculated as follows:

$$R_{CO_2fe,y} = \sum RF(ER_{y,f}) \qquad \text{Eq. 16}$$

Where:

$R_{CO_2fe,y}$	Climate forcer reduction due to project activities in year y (t CO_2fe)
$ER_{y,f}$	Net emissions in year *y* for climate forcer *f* (tonnes)
$RF(ER_{y,f})$	RF of net climate forcer emissions in year *y. The function calculating RF for a given climate forcer (in CO_2fe, W/m^2, or derivative unit) is described in Appendix A of the Registry Standard.*

Additional details for calculating radiative forcing can be found in Appendix A of the Registry Standard. Radiative forcing shall also be calculated in W/m^2, or derivative unit (e.g., nanowatts per square meter, or nW/m^2) as described in the GHR Registry Standard. Accumulated RF reductions shall be calculated annually using the first year of the project as t_0.

6.5 Conservative Assumptions and Estimates

For manure management systems using sequential treatment stages, an estimation of the VS during a treatment stage is made based on referenced data for different treatment types. The approach from Equation 3 is used to calculate emissions from subsequent treatment stages, with the VS term adjusted down to account for the reduction in volatile solids in the previous treatment stage(s), using a conservative estimate for the relative VS reduction based on the treatment technology. The Appendix of CDM methodology AMS-III.D contains default values for different treatment technologies.

Project activities where a portion of the biogas is destroyed through flaring and the other portion is used for energy must apply the flare efficiency to the portion of the biogas used for energy, if separate measurements of the respective flows are not performed. When the amount of methane that is combusted for energy and that is flared is separately monitored, or when only the biogas flow to the flare is monitored and the biogas used for energy is calculated based on electricity generation, a destruction efficiency of 100% can be used for the amount that is combusted for energy.

[12] See IPCC AR6 Table 7.SM.7 | Greenhouse gas lifetimes, radiative efficiencies, global warming potentials (GWPs), global temperature potentials (GTPs) and cumulative global temperature potentials (CGTPs). Available at https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter07_SM.pdf.

Emissions of methane and CO_2 from project equipment leaks are estimated to be 10% of the maximum potential methane production and 10% of the total CO_2 production (based on mole fraction in the biogas), respectively, unless a lower value can be justified based on project measurements.

In addition, as noted above, a factor (UF_b) of 0.94 is used in the Equation for Baseline Option A to account for model uncertainties.

6.6 Methods of Determining Uncertainty

Uncertainties may originate from estimated values and limitations in the accuracy of the systems used to measure the methane recovery and management processes. These uncertainties affect the baseline scenario, the measurement of methane recovery, the factors considered in the whole project emissions calculations, and the methane utilization or destruction processes. Each parameter used in the quantification (Sections 6.2- 6.4) must have its uncertainty calculated from calibration checks, determined from relevant peer-reviewed scientific literature, or conservatively estimated with clear documentation, as applicable.

The degradation rate of methane in the atmosphere is well established in the literature and will be used for calculation purposes. Conservative assumptions listed in Section 6.5 may be used without uncertainty estimation requirements. Credit issuance will be discounted on a conservative basis reflecting on the variability in these parameters, as described in Section 8.

6.7 Potential co-benefits, trade-offs, and Sustainable Development Goals (SDGs)

The project proponent shall, at minimum, make a qualitative assessment of co-benefits and trade-offs associated with the project activities. The Project Proponent may self-report applicable SDGs using the GHR SDG Contributions Reporting Tool. Self-reported SDGs must include justifications for each and will be made publicly available in the GHR Registry.

Alternatively, for verified claims, the latest Methodology Standard for Stressor-Effects Life Cycle Assessment (SCS-002) standard[13] may be used to make a quantitative assessment of any co-benefits and trade-offs. Verified claims related to co-benefits, trade-offs, and SDGs are only permissible when the project has undergone a quantitative assessment for the relevant impact category.

Table 2 shows a list of potential co-benefits and trade-offs relevant to this methodology. In the table, a "Yes" indicates that a co-benefit or trade-off may be applicable to the project, while a "No" indicates a lack of applicability.

Table 2. List of Impact Categories for determining Potential Co-benefits and Trade-offs

Impact Group	Impact Category	Potential Co-benefits relevant to Project Scenario	Potential Trade-off relevant to Project Scenario
Resource Depletion Group	Non-Renewable Energy Resource Depletion	Yes	No
	Net Freshwater Consumption	No	No
	Biotic Resource Depletion	No	No

[13] **Methodology Standard for Stressor-Effects Life Cycle Assessment Version 2.0**.

Ocean Ecosystem Impacts Group	Ocean Acidification	No	No
	Marine Biome Disturbance	No	No
	Marine Eutrophication	No	No
	Key Species Loss	No	No
	Persistent Eco Toxic Chemical Loading	No	No
	Marine Plastic Loading	No	No
Terrestrial Ecosystem Impacts Group (impacts from Emissions)	Regional Acidification	No	No
	Stratospheric Ozone Depletion	No	No
	Freshwater Ecotoxic Exposure Risks	No	No
	Freshwater Eutrophication	No	No
	Terrestrial Eutrophication	No	No
Terrestrial Ecosystem Impacts Group (impacts from Land Use and Land Conversion)	Terrestrial Disturbance	Yes	No
	Freshwater Disturbance	Yes	No
	Threatened Species Impacts	No	No
Human Health Impacts (from Chronic Exposures to Hazardous Substances)	Ground Level Ozone Exposure Impacts	Project Dependent	
	PM2.5 Exposure Impacts	Project Dependent	
	Hazardous Ambient Air Contaminant Exposure Impacts	Yes	No
	Hazardous Indoor Air Contaminant Exposure Impacts	No	No
	Hazardous Food or Water Contaminant Exposure Impacts	No	No
	Hazardous Dermal Contaminant Impacts	No	No
Risks from Hazardous Wastes	Risks from Radioactive Wastes	No	No
	Risks from Untreated Hazardous Wastes	No	No

Projects which undergo a quantitative co-benefit and trade-off assessment may be eligible to make verified claims about the following SDGs and targets (determined using the GHR SDG Contributions Reporting Tool, pending assessment results:

Table 3. Potentially Verifiable SDGs and Targets

Sustainable Development Goal	Target Number	Target
3. Ensure healthy lives and promote well-being for all at all ages	3.9	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination
6. Ensure availability and sustainable management of water and sanitation for all	6.6	By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
	7.2	By 2030, increase substantially the share of renewable energy in the global energy mix

7. Ensure access to affordable, reliable, sustainable and modern energy for all	7.b	By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programs of support
11. Make cities and human settlements inclusive, safe, resilient and sustainable	11.3	By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
	11.4	Strengthen efforts to protect and safeguard the world's cultural and natural heritage
	11.6	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
12. Ensure sustainable consumption and production patterns	12.a	Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production
13. Take urgent action to combat climate change and its impacts	13.2	Integrate climate change measures into national policies, strategies and planning
15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.1	By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements
	15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally
	15.3	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

7. Reporting Requirements

7.1 Project Design Document (PDD)

A Project Design Document (PDD) is required to be developed by the Project Proponent under the Registry Standard at the outset of the project prior to validation and verification. It is subject to approval by GHR prior to registration in the GHR Registry.

The PDD will be published and publicly available in the GHR Registry. A Project Proponent may request redactions to some information in the PDD to protect intellectual property and other business confidential information (e.g., proof of eligibility information, the specific terms of legal agreements, and intellectual property detailed in life cycle assessments). Redaction will be at the sole choice of GHR but such permission will not be unreasonably withheld. However, all information will be subject to validation and verification requirements.

Specifications for the content of the Project Design Document can be found in the GHR Project Design Document Template.

7.2 Documentation and Monitoring

The project proponent must submit a detailed project monitoring plan as part of the Project Design Document (PDD). The monitoring plan should facilitate the gathering of all pertinent data needed for:

- Confirming the fulfilment of the eligibility requirements
- Confirming the emissions associated with the project and any emissions from secondary effects

The data gathered shall be kept on record for a minimum of five years following the conclusion of the project activity's final crediting period.

Details shall be provided and documented in the project monitoring plan to confirm that best practices are being utilized, as specified in the GHR Project Design Document. In cases where such methods and procedures are not known or accessible, the project will establish, document, and apply standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) processes for inventory tasks, including field data gathering and data management. It is advisable to use or modify SOPs obtained from published manuals.

Project proponents shall provide evidence to a validating VVB that only the biogas recovered through the project manure management system is used for power generation; no other gas or fuels except a start-up fuel representing no more than 1% of total fuel utilized on an energy basis are used.

The monitoring plan shall include on-site inspections for each individual farm included in the project boundary where the project activity is implemented for each verification period. Where applicable, proper soil application (not resulting in methane emissions) of the residual waste shall be monitored.

If Option A is chosen for baseline emission determination:

- The project monitoring plan shall describe the system used for monitoring the fraction of the manure handled in the animal manure management system ($MSP_{i,t}$), the average weight of the livestock (W_{site}) and the livestock population (N_t) taking into account the average number of days the animals are alive in the farm in a specific year. The consistency between these values and indirect information (records of sales, records of food purchases) shall be assessed by the VVB. Significant changes in livestock population and average weight shall be explained.

- If developed country VS values are being used the following shall be monitored:
  - Genetic source of the production operations livestock originates from an Annex I Party;
  - The formulated feed rations (FFR). If Equation 3 is used to estimate the value $VS_{default}$ (kg-dm/animal/day), the default average animal weight of a defined population (kg) shall be recorded and archived.

Monitoring Reports for the project must be submitted as specified in Section 7.3, using the GHR Monitoring Report Template. Monitoring Reports must contain updated data, calculations, and attestations as specified in the project monitoring plan and the Monitoring Report Template. Any deviations from the project monitoring plan must be reported and justified within the Monitoring Reports.

7.3 Monitoring Report

The Project Proponent shall generate a Monitoring Report to describe ongoing project activities addressed in the monitoring plan. Each Monitoring Report must cover the period from the last report to present, and will be published and publicly available in the GHR Registry.

Project Proponents may request redactions to some information in updated Monitoring Reports to protect intellectual property (IP). Redaction will be at the sole discretion of the GHR Registry, however, such permission will not be unreasonably withheld. All information will be subject to validation and verification requirements.

Content requirements for the Monitoring Reports are provided in the GHR Monitoring Report Template.

7.4 Monitoring Period

The monitoring period is the timespan over which the VVB assesses and confirms the Project's climate mitigation activities and resulting *ex-poste* GHG emission reductions/removals and other RF reductions per vintage year.

The monitoring period for projects assessed under this methodology shall be at most 5 years from the project start date or last date of verification.

During the monitoring period, the Project Proponent shall file an Incident Report if changes in processes, materials or activities are observed that could alter the level of RF reduction, describing the nature, timing, scale, and likely permanence of the change. An incident report must also be submitted to the Registry if actual RF reduction levels are shown to fall short of projections, whether due to a known loss event (i.e., a planned or unplanned change in process or activity) or due to any other cause describing the nature, extent, scope and expected permanence of the shortfall, and provide a root cause analysis of the source of the shortfall.

7.5 Project Validation and Verification

The Project shall be validated consistent with the requirements of Registry Standard Section 6.3.2.

The Project shall undergo verification within the monitoring period as defined above (Section 7.4).

Project validation and verification reports shall be provided to the GHR Registry by the VVB. Project validation and verification reports shall clearly describe the process of the assessment as well as the findings from the assessment. Specifications for the content of the validation and verification reports can be found in the GHR Validation and Verification Report Template.

8. CREDITING

8.1 Credit Issuance

Credits will be issued after independent validation and verification that the requirements of this methodology have been met for biogas capture and management. Credit issuance will be adjusted to reflect inherent uncertainties in measuring and monitoring the project activities. The adjustment will be based on the uncertainty assessment conducted as part of the project's quantification process and reported in the Monitoring Reports. Credit issuance will be adjusted to reach a 90% or greater certainty in the quantified CO_2e.

Once issued, the credits will be registered and tracked in the GHR Registry. The registry will record the details of each credit, including the project it was issued for, the date it was issued, the retirement date and retirement location, the amount of net CO_2e it represents, and associated documentation. All GHR Registry credits may be retired for carbon accounting only once, and all retirements are recorded in the GHR Registry.

8.2 Crediting Period

The crediting period for projects under this methodology is 5 years. The project may be renewed up to two times and must be re-validated for each crediting period.

8.3 Buffer Pool Requirements

Methane capture and combustion projects are not reversible and therefore are subject to the GHR Registry Standard's lower minimum buffer pool contribution requirement of 2% of the total credits issued. However, this buffer pool contribution percentage is subject to review on a project-by-project basis, based on the parameters identified in Appendix B, and may be increased as warranted.

Glossary

The definitions in this section apply to the terminology used in this methodology. A more comprehensive list of definitions can be found in the GHR Glossary of Terms.

Anaerobic digestion: The process by which biodegradable organic matter is converted to methane-rich biogas using microorganisms in a complex biological process.

Baseline Scenario: The business-as-usual scenario representing the project area environment and emissions in the absence of the project.

Biogas: The gaseous product of anaerobic digestion, comprised mainly of methane and carbon dioxide, with trace amounts of hydrogen sulfide and ammonia.

Climate forcer: any external driver of climate change that causes a positive or negative change in RF (e.g., an emission, substance, process, activity or change in state). *Source: Radiative Forcing Protocol.*

Manure management system: The system by which manure and its derivatives are collected, stored, treated, and used.

Project area: The area within the project boundary where project activities take place. The project area may be contiguous or be comprised of multiple areas within a larger defined boundary.

Secondary effects: Often termed "leakage", an increase in greenhouse gas emissions or other contributors to positive RF associated with a project due to material substitutions or changes in activities or operations outside the project boundary.

Acronyms and Abbreviations:
CDM: Clean Development Mechanism
FFR: Formulated feed rations
GHG: Greenhouse gas
GWP: Global Warming Potential
Kg-dm: Kilograms dry matter
IPCC: Intergovernmental Panel on Climate Change
PDD: Project Design Document
RF: Radiative forcing
SOP: Standard Operating Procedure
UNFCCC: United Nations Framework Convention on Climate Change
VS: Volatile solids

Appendix A: Monitored Data and Parameters

Data/Parameter:	$VS_{LT,y}$
Data Unit:	kg dry matter/animal/year
Description:	Volatile solids for livestock *LT* entering the animal manure management system in year *y*
Source of data:	Farm measurements or published value from national source or IPCC
Description of measurement methods and procedures to be applied:	Only required when data from national published source are not available or IPCC default value from 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10 table 10 A-4 to 10 A-9 are not used. When country-specific excretion rates are to be estimated from feed intake levels as indicated on page 11, via the enhanced characterization method (Tier 2) described in section 10.2 in 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 chapter 10, parameters of GELT, DELT, UE, ASH and EDLT shall be monitored as detailed below to derive this value. When developed country values are to be used in the project, relevant parameters specified on page 12 shall be monitored/documented. If IPCC default values are to be adjusted for a site-specific average animal weight as specified on page 11, the average animal weight of a defined livestock population at the project site (W_{site}) shall be monitored as detailed below.
Frequency of monitoring/ recording:	
QA/QC procedures to be applied:	All measurements should be conducted with calibrated measurement equipment according to relevant industry standards (refer to Section 7.2 of this methodology “Documentation and Monitoring”)
Comments:	

Data/Parameter:	$N_{DA,y}$
Data Unit:	Number
Description:	Number of days animal is alive in the farm in the year *y*
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	The PDD should describe the system for monitoring the number of livestock population. The consistency between the value and indirect information (records of sales, records of food purchases) should be assessed sales, records of food purchases) should be assessed
Frequency of monitoring/ recording:	Annually, based on monthly records
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	$N_{P,y}$

Data Unit:	Number
Description:	Number of animals produced annually of type *LT* for the year *y*
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	The PDD should describe the system on monitoring the number of livestock population. The consistency between the value and indirect information (records of sales, records of food purchases) should be assessed
Frequency of monitoring/ recording:	Annually, based on monthly records
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	W_{site}
Data Unit:	kg
Description:	Average animal weight of a defined livestock population at the project site
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	When IPCC values of VS are adjusted for site specific animal weight as per Equation 3, sampling procedures can be used to estimate this variable as per the "Standard for sampling and surveys for CDM project activities and Programmes of Activities"
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	--
Comments:	For a non-binding best practice example, see Box 2 in AMS-III.D

Data/Parameter:	$BG_{burnt,y}$
Data Unit:	m^3
Description:	Biogas volume in year *y*
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	The amount of biogas recovered and fueled, flared or used gainfully shall be monitored ex post, using flow meters. If the biogas flared and fueled (or utilized) is continuously monitored separately, the two fractions can be added to determine the biogas recovered. In that case, recovered biogas need not be monitored separately. The system should be built and operated to ensure that there is no air ingress into the biogas pipeline. The methane content measurement shall be carried out close to a location in the system where a biogas flow measurement takes place, and on the same basis (wet or dry)
Frequency of monitoring/ recording:	Annually, based on continuous flow measurement with accumulated volume recording (e.g. hourly/daily accumulated reading)
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	$w_{CH4,y}$
Data Unit:	%
Description:	Methane content in biogas in the year *y*
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	The fraction of methane in the biogas should be measured with a continuous analyzer (values are recorded with the same frequency as the flow) or, with periodical measurements at a 90/10 confidence/precision level by following the "Standard for sampling and surveys for CDM project activities and Programme of Activities", or, alternatively a default value of 60% methane content can be used. The method chosen should be clearly specified in the PDD. 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, and on the same basis (wet or dry)
Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	For a nonbinding best practice example of the application of the default value of methane content in biogas, see Box 3 in AMS-III.D

Data/Parameter:	*T*
Data Unit:	°C
Description:	Temperature of the biogas at the flow measurement site
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	As per the relevant procedure in AMS-III.H, if used
Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	For a nonbinding best practice example of temperature measurement, see Box 4 in AMS-III.D

Data/Parameter:	*P*
Data Unit:	Pa
Description:	Pressure of the biogas at the flow measurement site
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	As per the relevant procedure in AMS-III.H, if used

Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	For a nonbinding best practice example of pressure measurement, see Box 4 in AMS-III.D

Data/Parameter:	*FE*
Data Unit:	%
Description:	The flare efficiency
Source of data:	Farm records or default value
Description of measurement methods and procedures to be applied:	As per the tool "Project emissions from flaring". Regular maintenance shall be carried out to ensure optimal operation of flares
Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	$Q_{manure,j,LT,y}$
Data Unit:	Tonnes-dm/year
Description:	Quantity of manure treated from livestock type *LT* at animal manure management system *j*
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	As the case on page 13, manure weight shall be directly measured or alternatively manure volume can be measured together with the density determined from representative sample (90/10 precision). The quantity of animal manure from different farms and different animal types shall be recorded separately for crosscheck. Recording of the baseline animal manure management system where the animal manure would have been treated anaerobically is also required
Frequency of monitoring/ recording:	Annually, based on daily measurement and monthly aggregation
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	$SVS_{j,LT,y}$
Data Unit:	tonnes VS/tonnes--dm
Description:	Specific volatile solids content of animal manure from livestock type *LT* and animal manure management system *j* in year *y*
Source of data:	Farm records
Description of measurement methods	If animal manure is treated in a centralized plant, as in the case on page 13, testing shall be performed according to the guideline in annex 2 of

and procedures to be applied:	AM0073. It can be on sample basis by following the "Standard for sampling and surveys for CDM project activities and programme of activities", with a maximum margin of error of 10% at a 90% confidence level
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	Q_y
Data Unit:	tonnes
Description:	Quantity of manure treated and/or wastewater co-digested in year *y*
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	On-site data sheets recorded monthly using weigh bridge.
Frequency of monitoring/ recording:	Monthly
QA/QC procedures to be applied:	Weighbridge will be subject to periodic calibration (in accordance with stipulation of the weighbridge supplier)
Comments:	--

Data/Parameter:	$Q_{resWaste,y}$
Data Unit:	tonnes
Description:	Quantity of residual waste produced in year *y*
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	On-site data sheets recorded monthly using weigh bridge.
Frequency of monitoring/ recording:	Monthly
QA/QC procedures to be applied:	Weighbridge will be subject to periodic calibration (in accordance with stipulation of the weighbridge supplier)
Comments:	--

Data/Parameter:	CT_y
Data Unit:	tonnes/truck
Description:	Average truck capacity for transportation
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	On site measurement

Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	$CT_{resWaste,y}$
Data Unit:	tonnes/truck
Description:	Average truck capacity for residual waste transportation
Source of data:	Transport records
Description of measurement methods and procedures to be applied:	On-site measurement
Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	DAF_w
Data Unit:	km/truck
Description:	Average incremental distance for manure and/or wastewater transportation
Source of data:	Transport records
Description of measurement methods and procedures to be applied:	On-site measurement, assumption to be approved by VVB
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	$DAF_{resWaste}$
Data Unit:	km/truck
Description:	Average distance for residual waste transportation
Source of data:	Transport records
Description of measurement methods and procedures to be applied:	On-site measurement, assumption to be approved by VVB
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	--

Comments:	--

Data/Parameter:	$MSF_{i,y}$
Data Unit:	unitless
Description:	Fraction of manure handled in system *i* in project activity in year *y*
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	If animal manure is treated in different treatment systems manure weight delivered to each system shall be directly measured or alternatively manure volume can be measured together with the density determined from representative sample (90/10 precision). The quantity of animal manure from different farms and different animal types shall be recorded separately for cross-check. Recording of the baseline animal manure management system where the animal manure would have been treated anaerobically is also required
Frequency of monitoring/ recording:	Annually, based on daily measurement and monthly aggregation
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	AL_l
Data Unit:	Days
Description:	Annual average interval between manure collection and delivery for treatment at a given storage device *l*
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	It is to be used to calculate possible project emissions due the storage of animal manure, as per page 16
Frequency of monitoring/ recording:	Annually, based on monthly records
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	nd_y
Data Unit:	Days
Description:	Number of days that the animal manure management system was operational
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	If any farm has no operations on a given day it needs to be documented (e.g. logbook) and taken into account for the calculation of $BE_{ex\ post}$
Frequency of monitoring/ recording:	Annually, based on daily records and monthly aggregation

QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	MSF_l
Data Unit:	unitless
Description:	Fraction of volatile solids handled by storage device *l*
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	It is to be used to calculate possible project emissions due the storage of animal manure, as per page 16
Frequency of monitoring/ recording:	Monthly
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	$B_{O,LT}$
Data Unit:	m^3 CH_4/kg-dm
Description:	Maximum methane production potential of the volatile solid generated for animal type *LT*
Source of data:	Published country values
Description of measurement methods and procedures to be applied:	Only when developed country values are to be used in the project, in such a case relevant parameters specified on page 12 shall be monitored/documented
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	GE_{LT}
Data Unit:	MJ/day
Description:	Daily average gross energy intake
Source of data:	IPCC
Description of measurement methods and procedures to be applied:	Only when country-specific excretion rates are to be estimated from feed intake levels as indicated on page 11, via the enhanced characterization method (Tier 2) described in section 10.2 in 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Chapter 10
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	DE_{LT}
Data Unit:	%
Description:	Digestible energy of the feed
Source of data:	Farm records or IPCC
Description of measurement methods and procedures to be applied:	If IPCC Tier 2 is used for VS determination. IPCC 2006 Table 10.2, Chapter 10, Volume 4
Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	*UE*
Data Unit:	Fraction of GE
Description:	Urinary energy, expressed as fraction of GE
Source of data:	Country-specific values or IPCC
Description of measurement methods and procedures to be applied:	If IPCC Tier 2 is used for VS determination. Typically, 0.04GE can be considered urinary energy excretion by most ruminants (reduce to 0.02 for ruminants fed with 85% or more grain in the diet or for swine). Use country-specific values where available
Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	*ASH*
Data Unit:	Fraction of the dry matter feed intake
Description:	Ash content of the manure calculated as a fraction of the dry matter feed intake
Source of data:	Country-specific values or IPCC
Description of measurement methods and procedures to be applied:	If IPCC Tier 2 is used for VS determination. Use country-specific values where available
Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	ED_{LT}
Data Unit:	MJ/kg-dm
Description:	Energy density of the feed in MJ/kg fed to livestock type *LT*
Source of data:	Farm records

Description of measurement methods and procedures to be applied:	If IPCC Tier 2 is used for VS determination. IPCC notes the energy density of feed, ED, is typically 18.45 MJ/kg-dm, which is relatively constant across a wide variety of grain-based feeds. The project proponent will record the composition of the feed to enable the VVB to verify the energy density of the feed
Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	EG_y
Data Unit:	MWh
Description:	Total electricity generated from the recovered biogas in year *y*
Source of data:	Farm records
Description of measurement methods and procedures to be applied:	Only required for project activities that utilize the recovered methane for power generation as per Equation 14
Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	EE_y
Data Unit:	%
Description:	Energy Conversion Efficiency of the project equipment
Source of data:	Equipment manufacturer
Description of measurement methods and procedures to be applied:	As per Equation 14 Specification provided by the equipment manufacturer. The equipment shall be designed to utilize biogas as fuel, and the efficiency specification is for this fuel. If the specification provides a range of efficiency values, the highest value of the range shall be used for the calculation
Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	--

Data/Parameter:	UF_b
Data Unit:	unitless
Description:	Model correction factor to account for model uncertainties in baseline emissions calculation
Source of data:	FCCC/SBSTA/2003/10/Add.2, page 25

Description of measurement methods and procedures to be applied:	--
Frequency of monitoring/ recording:	--
QA/QC procedures to be applied:	--
Comments:	--

Appendix B. Project Risks for Consideration When Establishing Buffer Pool Contributions

The following is a list of potential events that could affect the validity of credits issued for projects in any given specific project category. Methodologies representing specific project types provide additional guidance where applicable.

Reversal Risks

Environmental Events that result in the release of sequestered carbon, including:

- Fire
- Drought
- Disease/Pests
- Flood
- Earthquake
- Storms
- Heatwaves
- Avalanche

Human activity that unintentionally or deliberately result in the release of sequestered carbon

- Land-use changes (e.g., deforestation, urban development)
- Project site abandonment (due to inadequate management, financial failure, socio-political instability, economic crises, community opposition, etc.)
- Failure of maintenance or oversight

Regulatory, Legal, and Compliance Risks

Regulatory Changes

- Alterations in national or regional regulations that invalidate or require re-evaluation of credit validity.
- Introduction of new performance or safety standards that retroactively affect previously verified projects.

Legal Disputes

- Litigation challenging the validity of credits.
- Ownership disputes over land or resources related to the project.

Compliance Failures

- Failure to adhere to regulatory requirements after credit issuance.

- Non-compliance with ongoing monitoring and reporting obligations.

Project Implementation and Verification Risks

Inadequate technical capacity of the VVB, VVB contractor, or project proponent

- Unintentional or deliberate misrepresentation of project outcomes by the VVB, VVB contractor, or project proponents
- Inaccurate or incomplete Measurement, Reporting, and Verification processes leading to issuance of credits that do not reflect actual carbon reductions or removals
- Inaccurate data collection methods or issues related to the security, accuracy, and storage of data over time

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