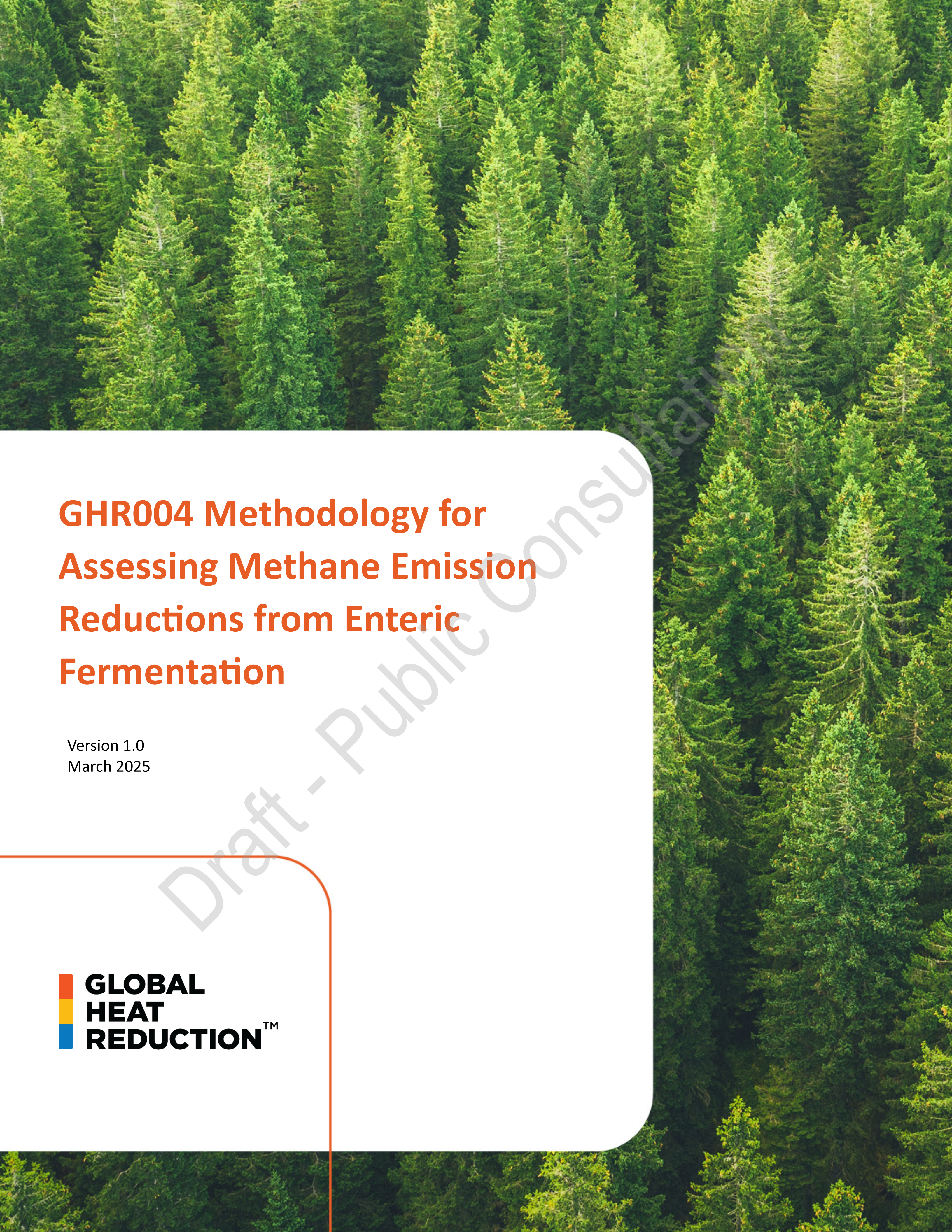

GHR004 Methodology for Assessing Methane Emission Reductions from Enteric Fermentation

Version 1.0
March 2025

GLOBAL HEAT REDUCTION™

GHR004 Methodology for Assessment of Methane Emission Reduction from Enteric Fermentation

Published March 2025 – Version 1.0

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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 GHR Methodology specifically quantifies the abatement of methane emissions from ruminant livestock.

This GHR Methodology utilizes the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (2019)[1] and builds upon the Verra VM0041[2] methodology. The activities within the scope of this methodology involve inclusion of feed additives into the diet of the ruminants to reduce methane emissions from ruminant livestock.

Methane is produced as a byproduct of enteric fermentation, the process where rumen microbes digest feed and release methane (Moss et al., 2000)[3]. This methodology quantifies usage of feed additives that have been scientifically proven to reduce methane emissions without altering the efficiency of livestock production, like fats, oils or tannins (Hristov et al., 2013)[4] and inhibitors such as 3-nitrooxypropanol (3-NOP). Baseline emissions (emissions in the absence of intervention and based on traditional feeding practices) are compared to project scenario emissions, which include methane-reducing interventions. This GHR Methodology follows the IPCC (2019) Guidelines for Greenhouse Gas Inventories, ensuring methodological consistency with international standards.

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

[1] IPCC, 2019: Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol4.html

[2] Verra, VM0041: Methodology for the Reduction of Enteric Methane Emissions from Ruminants through the Use of Feed Ingredients, v2.0, 2019. https://verra.org/methodologies/module-for-vm0041

[3] Moss, A.R., Jouany, J.P., & Newbold, J., 2000: Methane production by ruminants: Its contribution to global warming. *Annales de Zootechnie*, 49(3), 231-253.

[4] Hristov, A.N., et al., 2013: Mitigation of methane and nitrous oxide emissions from animal operations: A review of enteric methane mitigation options. *Journal of Animal Science*, 91(11), 5045-5069.

2.2 Project Type(s) Covered by the Methodology

Projects under this methodology aim to implement dietary interventions in ruminant livestock to reduce enteric methane emissions through the use of feed additives that suppress methanogenesis. Changes in feed composition to enhance digestibility and reduce fermentation losses is outside the scope of this methodology but may be included in future versions. The projects function to promote sustainable agricultural practices, improve livestock productivity, and contribute to climate change mitigation by reducing greenhouse gas (GHG) emissions.

2.3 Eligibility Requirements for Projects under the Methodology

To be eligible to register under this methodology, projects must meet all eligibility requirements of the Registry Standard and the following criteria:

1. Project activities must be within the scope of this methodology.
2. Project proponents must agree to meet all requirements of the Registry Standard and this methodology.
3. Project proponents must provide proof of legal ownership of the project at the designated site(s) and must have legal rights to the credits generated from the project.
4. The project and project proponents must be in compliance with all applicable local, regional, national, and international regulations and laws.
5. The feed additive must be proven safe for ruminant health, with no adverse effects. This safety must be validated through both regulatory approval and credible scientific literature that demonstrates the additive does not negatively impact the health of the animals when used as directed. Project proponents must provide documentation supporting these claims. Emissions reductions that are the result of dietary changes are outside the scope of this methodology.
6. The use of the feed additive must strictly follow the manufacturer's recommended guidelines. These guidelines must specify the correct feeding regimen, dosage per unit of dry matter intake (DMI), and other critical conditions necessary to achieve the expected reduction in methane emissions, such as the timing of feed delivery and the consistency of feed composition.

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 the 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).

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 shall demonstrate additionality for projects that aim to reduce methane emissions from enteric fermentation, consistent with the GHR Registry Standard. This involves proving that the project activities lead to GHG reductions that would not have occurred in the absence of the project. The project proponent shall provide clear evidence of additionality in the Project Design Document (see Section 7.1), and ongoing assessments of additionality will be detailed in the Project Monitoring Reports (see Section 7.3).

3.2.1 Regulatory Surplus Test

The project proponent must demonstrate that the project activities are not required by existing laws, regulations, or any legally binding mandates in the project's jurisdiction. If such regulations do exist, the project proponent must provide evidence that the project's scope exceeds the regulatory requirements. This could involve demonstrating that the intervention goes beyond what is mandated or achieves reductions in a more effective or efficient manner.

3.2.2 Common Practice Analysis

The project proponent must show that the project activities are not common practice within the agricultural sector or region. A thorough analysis must be conducted to confirm that the use of specific feed additives is not widely adopted in the region where the project is implemented. This analysis shall include a review of similar operations in the region surroundings of the project area, supported by reliable data and documented evidence.

3.2.3 Financial Feasibility Test

The project proponent must demonstrate that, without the revenue from carbon credits, the implementation of the project activities would not be financially viable. This can be shown through a financial analysis comparing the project's costs and expected returns with and without the anticipated carbon credit revenue. Additionally, the project proponent must identify and explain any financial barriers, such as high initial costs or lack of access to capital, that would prevent the implementation of the project activities without carbon finance.

3.3 Permanence

As a result of project activities under this methodology, the baseline enteric methane emissions that would otherwise have been released into the atmosphere are reduced. The annual enteric methane emissions in the ruminant population will be permanently lowered for each crediting year through the effective use of feed additives. Consequently, the risk of non-permanence of RF reductions is minimal, given the sustained nature of the emissions reductions achieved through this process.

3.4 Risk of Secondary Effects

In the context of this methodology, secondary effects, also referred to as leakage, are considered minimal and unlikely to impact the overall effectiveness of enteric methane reduction projects. The introduction of specific feed additives to reduce enteric methane emissions is not anticipated to significantly alter livestock performance (strictly complying with the eligibility conditions in Section 2.3. of this methodology), nor is it expected to necessitate changes in livestock populations within or outside the project boundary that would result in leakage. While some studies indicate potential enhancements in productivity due to these dietary interventions by inclusion of feed additives (Kinley et al. 2020)[5], such improvements are not substantial enough to influence market dynamics or cause shifts in livestock numbers to meet demand. Consequently, the risk of secondary effects is deemed negligible, and no adjustments for leakage are required under this methodology.

[5] Kinley, R.D., et al. (2020). Mitigating the carbon footprint and improving productivity of ruminant livestock with dietary additives. *Journal of Cleaner Production*, 259, 120836. DOI: https://doi.org/10.1016/j.jclepro.2020.120836

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. In this methodology, the baseline scenario represents the conditions under which methane emissions from enteric fermentation in ruminant livestock would occur in the absence of the project activities. This baseline scenario assumes that no methane-reducing feed additives are implemented within the project boundary. Additional GHG emissions resulting from manure management are included in the baseline scenario. The baseline is established based on historical data, representing the average methane emissions over at least the three continuous years preceding the project start date based on the number of heads.

The project proponent shall identify and justify the baseline scenario in the PDD, and monitor, and update the scenario as needed in subsequent Project Monitoring Reports.

4.2 Project Scenario

The project scenario is the implementation of improved feedstock through the use of feed additives designed to reduce methane emissions from enteric fermentation in ruminants which otherwise would have been released to the atmosphere. Additional GHG emissions resulting from manure management are included, as well as GHG emissions resulting from feed additive production and project operations are included in the project scenario.

The project proponent shall identify and justify the project scenario in the PDD, and monitor and update the scenario in subsequent Project Monitoring Reports.

4.3 Group Project Scenario

In addition to individual projects, it is possible that multiple operations under one management and ownership system may apply for assessment and credit issuance in an aggregated group. All such individual operations within the group would be required to 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 defined as the physical, geographical site where the following activities occur:

a) Where the ruminant livestock are housed, grazed, and fed, resulting in enteric methane emissions.
b) Where feed additives are administered to reduce methane emissions from enteric fermentation.
c) Where manure from treated livestock is stored, managed, or applied to land, influencing methane and nitrous oxide emissions.
d) Where feed is stored, processed, or handled, within the project boundary, if it contributes significantly to the emissions profile.
e) Where any on-site activities related to the transportation and handling of feed, livestock, and manure occur, impacting the project's emissions.

The project proponent shall describe the project boundaries in the PDD. Any changes to the project boundaries will be reported in subsequent Project Monitoring Reports.

5.2 Sources, Sinks, and Reservoirs of Radiative Forcing

The project proponent shall account for all significant, project-related climate forcer sources, sinks, and reservoirs (SSRs) within the project boundary. The exclusion of emission sources is permissible, provided that such exclusions result in conservatively low crediting and have been tested for their significance to total credit amounts. SSRs (Table 1) that are considered significant and/or have been selected for accounting in the Baseline Scenario shall also be included in the Project Scenario.

Table 1. Potential climate forcer sources, sinks, and reservoirs

Project Type: Use of feed additives to reduce methane emissions from enteric fermentation			
SSR	**Climate Forcer**	**Included in Calculation**	**Justification/Explanation**
Enteric Fermentation in ruminants	CH_4	Required	The primary source of methane (CH_4) emissions, which is directly addressed through dietary modifications in the project scenario.
Feed Additive Production	CO_2, CH_4, N_2O, NO_x, CO, Black Carbon, Organic Carbon, Sulfate aerosols	Required	Emissions from the production of feed additives are included, particularly where they contribute to the overall carbon footprint of the project.
Manure Management	CH_4, N_2O	Required	Emissions from manure are included in the project and baseline scenarios, particularly

			those related to methane and nitrous oxide (N_2O).
Project Operations	CO_2, CH_4, N_2O, NO_x, CO, Black Carbon, Organic Carbon, Sulfate aerosols	Required	Any additional energy use related to the implementation of the project (e.g., machinery, transportation within the project boundary) is accounted for.

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 and non-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 the following:

Total Baseline Emissions (BE_{total})

$$BE_{total,y,f} = BE_{enteric,y,f} + BE_{manure,y,f} \qquad \textit{Eq. 1}$$

Where:

$BE_{total,y,f}$	Baseline emissions in year *y*, for climate forcer *f* (tonnes (t))
$BE_{enteric,f,y}$	Baseline enteric emissions in year *y*, for climate forcer *f* (t CH_4)
$BE_{manure,y,f}$	Baseline manure emissions in year y, for climate forcer *f* (t CH_4 or N_2O)

Option 1 – Default Baseline Enteric Methane Emission Factor Approach ($BE_{entericCH4}$)

This option uses default methane emission factors, which are standard across various livestock types and regions. It is useful for projects without detailed data on feed intake and methane conversion factors.

$$BE_{entericCH4,y} = \sum_{LT}(N_{LT,y} \times EF_{CH4,enteric,LT} \times 0.001 \times 365) \qquad \textit{Eq. 2}$$

Where:

$BE_{entericCH4,y}$	Baseline enteric methane emissions in year *y* (t CH_4)
$N_{LT,y}$	Number of livestock type *LT* in the project boundary in year *y* (head)
$EF_{CH4,enteric,LT}$	Default enteric fermentation emission factor for methane emissions from livestock type *LT* (kg CH_4/head/day) to be referenced from IPCC 2019 or country-specific data if available
0.001	Conversion factor from kg to tonnes
365	Number of days in a year, used to convert daily emissions to annual emissions. For leap years, use 366.

Option 2 – Feed Intake and Methane Conversion Factor Approach

This approach calculates baseline methane emissions using actual feed intake and methane conversion factors.

$$BE_{entericCH4,y} = \sum_{LT}(N_{LT,y} \times FI_{BL,LT,y} \times GE_{feed} \times \frac{Ym_{BL,LT}}{55.65} \times 0.001 \times 365) \qquad \text{Eq. 3}$$

Where:

$BE_{entericCH4,y}$	Baseline enteric methane emissions in year *y* (t CH_4)
$N_{LT,y}$	Number of livestock type *LT* in the project boundary in year *y* (head)
$FI_{BL,LT,y}$	Baseline average daily feed intake per livestock type *LT* in year *y* (kg DM/head/day)
GE_{feed}	Gross energy content of feed (MJ/kg DM), typically 18.45 MJ/kg for many ruminant feeds (IPCC 2019 value)
$Ym_{BL,LT}$	Baseline methane conversion factor for livestock type *LT* (fraction of gross energy intake converted to methane)
55.65	Energy content of methane (MJ/kg methane)
0.001	Conversion factor from kilograms to tonnes
365	Number of days in a year, used to convert daily emissions to annual emissions. For leap years, use 366.

$$N_{LT,y} = N_{DA,LT,y}(\frac{N_{P,y}}{365}) \qquad \text{Eq. 4}$$

Where:

$N_{LT,y}$	Number of livestock type *LT* in the project boundary in year *y* (head)
$N_{DA,y}$	Number of days animal is alive *DA* in the farm of type *LT* in year *y* (days)
$N_{P,y}$	Number of animals produced annually of type *LT* for the year *y* (head)
365	Number of days in a year, used to convert daily emissions to annual emissions. For leap years, use 366.

Of the above two options, Option 2 relies on actual feed intake and methane conversion factors and offers a more tailored calculation of baseline emissions based on each project. It reflects the specific conditions of the livestock population, accounting for variations in feed intake and methane production efficiency.

Option 1 is based on default emission factors, with widely recognized and standardized values across various regions and livestock types. This makes it more accessible for projects where detailed data on feed intake and methane conversion factors may not be readily available and is thus suitable for a broader spectrum of projects ensuring inclusivity, simplicity, and alignment with global accepted standards.

Baseline Manure Emissions (BE_{manure})

The baseline manure emissions equation captures methane and nitrous oxide emissions from manure management.

Baseline emissions of CH_4 from manure management

$$BE_{manure_{CH4,y}} = \sum_{LT,s} (N_{LT,y} \times VS_{LT,y} \times AWM_{S,LT,y} \times EF_{CH4,S,LT,y} \times 0.001) \quad \textit{Eq. 5}$$

Where:

$BE_{manureCH4,y}$	Baseline scenario methane emissions from manure management in year *y* (t CH_4)
$N_{LT,y}$	Number of livestock type *LT* in the project boundary in year *y* (head)
$VS_{LT,y}$	Average excretion of volatile solids by livestock type *LT* in year *y* (kg VS/head)
$AWM_{S,LT,y}$	Fraction of total annual VS managed in manure system *S* for livestock group *LT* in year *y* (dimensionless)
$EF_{CH4,S,LT,y}$	Emission factor for methane emissions from manure management system *S* for livestock type *LT* in year *y* (kg CH_4/kg VS)
0.001	Conversion factor from kg to tonnes

Baseline Excretion of Volatile Solids ($VS_{LT,y}$)

This equation calculates the amount of volatile solids excreted by livestock, which are a key driver of methane emissions from manure.

$$VS_{LT,y} = (FI_{LT,y} \times DM_{LT,y} \times EX_{VS,LT}) \times 365 \quad \textit{Eq. 6}$$

Where:

$VS_{LT,y}$	Annual average excretion of volatile solids by livestock type *LT* in year *y* (kg VS/head)
$FI_{LT,y}$	Average daily feed intake for livestock type *LT* in year *y* (kg DM/day/head)
$DM_{LT,y}$	Dry matter content of the feed consumed by livestock type *LT* in year *y* (dimensionless)
$EX_{VS,LT}$	Excretion factor for volatile solids by livestock type *LT* (kg VS/kg DM)
365	Number of days in a year, used to convert daily emissions to annual emissions. For leap years, use 366.

Fraction of Baseline Volatile Solids Managed ($AWM_{S,LT,y}$)

This equation calculates the fraction of volatile solids that are managed in specific manure systems, influencing the total methane emissions from manure.

$$AWM_{S,LT,y} = \frac{VS_{S,LT,y}}{VS_{LT,y}} \quad \textit{Eq. 7}$$

Where:

$AWM_{S,LT,y}$	Fraction of total annual VS managed in manure system *S* in year *y* (dimensionless).
$VS_{S,LT,y}$	Amount of volatile solids from livestock type *LT* managed in system *S* in year *y* (kg VS)
$VS_{LT,y}$	Total annual excretion of volatile solids by livestock type *LT* in year *y* (kg VS)

Methane Emission Factor for Baseline Manure Management ($EF_{CH4,S,LT,y}$)

This equation calculates the methane emission factor for specific manure management systems, taking into account methane conversion factors and the methane-producing capacity of the manure.

$$EF_{CH4,S,LT,y} = \left(MCF_{S,LT,y} \times B0_{LT}\right) \quad \textit{Eq. 8}$$

Where:

$EF_{CH4,S,LT,y}$	Emission factor for methane emissions from manure management system *S* for livestock type *LT* in year *y* (kg CH_4/kg VS)
$MCF_{S,LT,y}$	Methane conversion factor for manure management system *S* used by livestock type *LT* in year *y* (dimensionless)
$B0_{LT}$	Maximum methane producing capacity of the manure from livestock type *LT* (kg CH_4/kg VS)

Baseline Nitrous Oxide Emissions from manure management

This equation calculates baseline nitrous oxide emissions from manure management. It uses nitrogen excretion rates and emission factors for different manure management systems.

$$BE_{manure,N2O,y} = \sum_{LT,S}\left(\left(N_{LT,y} \times Nex_{LT,y} \times AWM_{S,LT,y} + N_{cdg,S,y}\right) \times EF_{N2O,S,y} \times \frac{44}{28} \times 0.001\right) \quad \textit{Eq. 9}$$

Where:

$BE_{manure,N2O,y}$	Baseline nitrous oxide emissions in year *y* from manure management (t N_2O)
$N_{LT,y}$	Number of livestock type *LT* in the project boundary in year *y* (head)
$Nex_{LT,y}$	Nitrogen excretion per head of livestock type *LT* in year *y* (kg N/head)
$AWM_{S,LT,y}$	Fraction of nitrogen managed in manure system *S* for livestock type *LT* in year *y* (dimensionless)
$N_{cdg,S}$	Nitrogen input via co-digestate in system *S* in year *y* (kg N)
$EF_{N2O,S,y}$	Emission factor for nitrous oxide emissions from manure management system *S* (kg N_2O-N/kg N excreted)
$\frac{44}{28}$	Conversion factor from N_2O-N to N_2O
0.001	Conversion factor from kg to tonnes

Nitrogen Excretion per Head ($Nex_{LT,y}$)

This equation estimates the nitrogen excreted by livestock, a key factor in calculating nitrous oxide emissions from manure.

$$Nex_{LT,y} = (FI_{LT,y} \times CP_{LT,y} \times EX_{N,LT,y}) \times 365 \quad \textit{Eq. 10}$$

Where:

$Nex_{LT,y}$	Nitrogen excretion per head of livestock type *LT* in year *y* (kg N/head)
$FI_{LT,y}$	Average daily feed intake for livestock type *LT* in year *y* (kg DM/day/head)
$CP_{LT,y}$	Crude protein content of the feed consumed by livestock type *LT* in year *y* (kg crude protein/kg DM)
$EX_{N,LT,y}$	Excretion factor for nitrogen by livestock type *LT* in year *y* (kg N/kg crude protein)
365	Number of days in a year, used to convert daily emissions to annual emissions. For leap years, use 366.

Annual Nitrogen Input via Co-Digestate ($N_{cdg,S}$)

This equation calculates the nitrogen added to the manure system through co-digestate, which can affect both methane and nitrous oxide emissions.

$$N_{cdg,S,y} = \sum_{cdg} (FI_{y,S} \times N_{cdg,cont,S} \times CF_N \times FM_{cdg,S} \times 365) \quad \textit{Eq. 11}$$

Where:

$N_{cdg,S,y}$	Nitrogen input via co-digestate *cdg* in system *S* in year *y* (kg N).
$FI_{cdg,S,y}$	Average daily feed intake in system *S* in year *y* (kg DM/day)
$N_{cdg,cont,S}$	Fraction of the co-digestate material *cdg* in system *S* that is nitrogen (dimensionless)
CF_N	Conversion factor to express the nitrogen content per unit dry matter (kg N/kg DM) based on the protein-to-nitrogen ratio specific to the feed as in IPCC 2019
$FM_{cdg,S}$	Fraction of the co-digestate *cdg* material used in system *S* (dimensionless)
365	Number of days in a year, used to convert daily emissions to annual emissions. For leap years, use 366.

6.3 Project Scenario Climate Forcer Calculation Methods

Total Project Emissions (PE_{total})

$$PE_{total,y,f} = PE_{enteric,y,f} + PE_{manure,y,f} + PE_{add\_transport,y,f} + PE_{add\_prod_{y,f}} \quad \textit{Eq. 12}$$

Where:

$PE_{total,y,f}$	Project emissions in year *y*, for climate forcer *f* (t *f*)
$PE_{enteric,y,f}$	Project enteric emissions in year *y,* for climate forcer *f* (t CH_4)
$PE_{manure,y}$	Project manure emissions in year *y*, for climate forcer *f* (t CH_4 or N_2O)
$PE_{feed\_transport_{y,f}}$	Project emissions from feed additive transportation during year *y*, for climate forcer *f* (t *f*)
$PE_{feed\_prod_{y,f}}$	Project emissions from feed additive production during year *y*, for climate forcer *f* (t *f*)

Project Scenario Enteric Methane Emissions ($PE_{entericCH4}$)

This equation calculates methane emissions from enteric fermentation under the project scenario, considering the effects of interventions on feed intake and methane conversion efficiency.

$$PE_{entericCH4,y} = \sum_{LT} (N_{LT,y} \times FI_{PJ,LT,y} \times GE_{add} \times \frac{Ym_{PJ,LT,y}}{55.65} \times 365 \times 0.001) \quad \textit{Eq. 13}$$

Where:

$PE_{entericCH4,y}$	Project scenario enteric methane emissions in year *y* (t CH_4)
$N_{LT,y}$	Number of livestock type *LT* in the project boundary in year *y* (head)
$FI_{PJ,LT,y}$	Project *PJ* scenario average daily feed intake per livestock type *LT* in year *y* (kg DM/day/head)
GE_{add}	Gross energy content of feed with the feed additive (MJ/kg DM)
$Ym_{PJ,LT,y}$	Project *PJ* methane conversion factor for livestock type *LT* in year *y* (fraction of gross energy intake converted to methane)
55.65	Energy content of methane (MJ/kg methane)
365	Number of days in a year, used to convert daily emissions to annual emissions. For leap years, use 366.
0.001	Conversion factor from kg to tonnes

$FI_{PJ,LT,y}$ may differ from $FI_{BL,LT,y}$ based on whether the feed additive improves the efficiency of the total feed, thereby altering the rate of feed consumption. $Ym_{PJ,LT,y}$ may differ from $Ym_{BL,LT,y}$ due to the effect of feed additives. However, this methodology remains focused on the reduction of enteric methane emissions through improved feed incorporation via feed additives.

Project Scenario Manure Emissions (PE_{manure})

The project scenario manure emissions equation captures both methane and nitrous oxide emissions from manure management.

Project emissions of CH_4 from manure management

$$PE_{manure_{CH4,y}} = \sum_{i.LT.s} (N_{LT,y} \times VS_{LT,y} \times AWM_{S,LT,y} \times EF_{CH4,S,LT,y} \times 0.001) \quad \textit{Eq. 14}$$

Where:

$PE_{manureCH4,y}$	Project scenario methane emissions from manure management in year *y* (t CH_4)
$N_{LT,y}$	Number of livestock type *LT* in the project boundary in year *y* (head)
$VS_{LT,y}$	Average excretion of volatile solids by livestock type *LT* in year *y* (kg VS/head)
$AWM_{S,LT,y}$	Fraction of total annual VS managed in manure system *S* in year *y* (dimensionless)
$EF_{CH4,S,LT,y}$	Emission factor for methane emissions from manure management system *S* for livestock type *LT* in year *y* (kg CH_4/kg VS)
0.001	Conversion factor from kg to tonnes

Annual Average Excretion of Volatile Solids ($VS_{LT,y}$)

This equation, adapted from the GHR002 Methodology for Assessing Methane Recovery from Anaerobic Digestion of Manure to Produce Biogas, calculates the amount of volatile solids excreted by livestock, which are a key driver of methane emissions from manure.

$$VS_{LT,y} = (FI_{LT,y} \times DM_{LT,y} \times EX_{VS,LT}) \times 365 \quad \textit{Eq. 15}$$

Where:

$VS_{LT,y}$	Annual average excretion of volatile solids by livestock type *LT* in year *y* (kg VS/head)
$FI_{LT,y}$	Average daily total feed intake for livestock type *LT* in year *y* (kg DM/day/head)
$DM_{LT,y}$	Dry matter content of the feed with additive consumed by livestock type *LT* in year *y* (dimensionless)
$EX_{VS,LT}$	Excretion factor for volatile solids by livestock type *LT* (kg VS/kg DM intake)
365	Number of days in a year, used to convert daily emissions to annual emissions. For leap years, use 366.

Fraction of Volatile Solids Managed ($AWM_{S,L,j,y}$)

This equation calculates the fraction of volatile solids that are managed in specific manure systems, influencing the total methane emissions from manure.

$$AWM_{S,LT,y} = \frac{VS_{S,LT,y}}{VS_{LT,y}} \quad \textit{Eq. 16}$$

Where:

$AWM_{S,LT,y}$	Fraction of total annual VS from livestock type *LT* managed in manure system *S* in year *y* (dimensionless)
$VS_{S,LT,y}$	Amount of volatile solids from livestock type *LT* managed in system *S* in year *y* (kg VS)
$VS_{LT,y}$	Total annual excretion of volatile solids by livestock type *LT* in year *y* (kg VS)

Methane Emission Factor for Manure Management ($EF_{CH4,S,j,y}$)

This equation calculates the methane emission factor for specific manure management systems, taking into account methane conversion factors and the methane-producing capacity of the manure.

$$EF_{CH4,S,LT,y} = \left(MCF_{S,LT,y} \times B0_{LT}\right) \quad \textit{Eq. 17}$$

Where:

$EF_{CH4,S,LT,y}$	Emission factor for methane emissions from manure management system *S* for livestock type *LT* in year *y* (kg CH_4/kg VS)
$MCF_{S,LT,y}$	Methane conversion factor for manure management system *S* used by livestock type *LT* in year *y* (dimensionless)
$B0_{LT}$	Maximum methane producing capacity of the manure from livestock type *LT* (kg CH_4/kg VS)

Project emissions of N_2O from manure management

$$PE_{manure,N2O,y} = \sum_{LT,S}\left(\left(N_{LT,y} \times N_{ex_{LT,y}} \times AWM_{S,LT,y} + N_{cdg,S}\right) \times EF_{N2O,S,y} \times \frac{44}{28} \times 0.001\right) \quad \textit{Eq. 18}$$

Where:

$PE_{manure,N2O,y}$	Project scenario nitrous oxide emissions from manure management in year *y* (t N_2O)
$N_{LT,y}$	Number of livestock type *LT* in the project boundary in year *y*
$Nex_{LT,y}$	Annual average excretion of volatile solids per head of livestock type *LT* in year *y* (kg N/head)
$AWM_{S,LT,y}$	Fraction of total annual VS managed in manure system *S* in year *y*
$N_{cdg,S}$	Nitrogen input via co-digestate in system *S* in year *y* (kg N)
$\frac{44}{28}$	Conversion factor from N_2O-N to N_2O

$EF_{N2O,S}$	Emission factor for nitrous oxide emissions from manure management system *S* (kg N_2O/kg N)
0.001	Conversion factor from kg to tonne

Nitrogen Excretion per Head ($Nex_{LT,y}$)

This equation estimates the nitrogen excreted by livestock, a key factor in calculating nitrous oxide emissions from manure.

$$Nex_{LT,y} = (FI_{LT,y} \times CP_{LT,y} \times EX_{N,LT}) \times 365 \quad \textit{Eq. 19}$$

Where:

$Nex_{LT,y}$	Nitrogen excretion per head of livestock type *LT* in year *y* (kg N/head)
$FI_{LT,y}$	Average daily total feed intake for livestock type *LT* in year *y* (kg DM/day/head)
$CP_{LT,y}$	Crude protein content of the feed with the feed additive consumed by livestock type *LT* in year *y* (kg crude protein/kg DM)
$EX_{N,LT}$	Excretion factor for nitrogen by livestock type *LT* (kg N/kg crude protein)
365	Number of days in a year, used to convert daily emissions to annual emissions. For leap years, use 366.

Annual Nitrogen Input via Co-Digestate ($N_{cdg,S}$)

This equation[6] calculates the nitrogen added to the manure system through co-digestate, which can affect both methane and nitrous oxide emissions.

$$N_{cdg,S,y} = \sum_{cdg} (FI_{cdg,y} \times N_{cdg,cont} \times CF_N \times FM_{cdg} \times 365) \quad \textit{Eq. 20}$$

Where:

$N_{cdg,S,y}$	Nitrogen input via co-digestate in system *S* in year *y* (kg N)
$FI_{cdg,y}$	Average daily total feed intake via co-digestate in year *y* (kg DM/day)
$N_{cdg,cont}$	Fraction of the co-digestate material (cdg) that is nitrogen (dimensionless)
CF_N	Conversion factor to express the nitrogen content per unit dry matter (kg N/kg DM) based on the protein-to-nitrogen ratio specific to the feed as in IPCC 2019
FM_{cdg}	Fraction of the co-digestate material used in system *S* (dimensionless)
365	Number of days in a year, used to convert daily emissions to annual emissions. For leap years, use 366.

Project emissions from feed additive transport

[6] IPCC, 2019: Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol4.html

$$PE_{add\_transport,y,k,f} = \sum_{i=1}^{n} D_{k,y} \times TM_{add\_transport,y} \times EF_{k,y,f}$$ **Eq. 21**

Where:

$PE_{add\_transport,y,k,f}$	Project emission from feed additive transportation during year, *y*, for climate forcer *f* (t *f*)
$D_{k,y}$	Distance travelled in vehicle type *k* while transporting feed additive from a storage/aggregation facility to a project region during year *y* (distance unit)
$TM_{add\_transport,y}$	Mass of transported feed, including the container mass, in year *y* (t or other mass unit)
$EF_{k,y,f}$	Emission factor of transportation in vehicle type *k*, during year *y*, for climate forcer *f* (t/mass and distance unit)

Project emissions from Feed production (PE_{feed_prod})

$$PE_{add\_prod\ y,f} = \sum_{i} (EF_{prod,i,f} \times FI_{add,i,y})$$ **Eq. 22**

Where:

$PE_{add\_prod,y,f}$	Project emissions from feed additive production in year *y* (t *f*)
$EF_{prod,i,f}$	Emission factor for the production of feed additive ingredient *i* in year *y* (t *f*/kg feed additive)
$FI_{feed,i,y}$	Feed intake for feed additive *i* under project conditions in year *y* (kg)

6.4 Determination of the Project's Climate Impact

The project proponent shall provide the projected levels of reduction or removal of climate forcers in the Project Design Document and shall provide actual levels of reduction or removal of climate forcers in the Monitoring Report.

First, the difference in emission reductions or removals between the baseline and project scenarios is calculated separately for each climate forcer (see Table 1):

$$ER_{y,f} = BE_{total,y,f} - PE_{total,y,f}$$ **Eq. 23**

Where:

$ER_{y,f}$	Emission reductions in year *y*, for climate forcer *f* (t *f*)
$BE_{total,y,f}$	Total Baseline emissions in year *y*, for climate forcer *f* (t *f*)
$PE_{total,y,f}$	Total Project emissions in year *y*, for climate forcer *f* (t *f*)

The potential credit amount in carbon dioxide equivalents (CO_2e) based on GWP-100 is calculated and summed across all climate forcers as follows:

$$R_{CO_2e,y} = ER_{y,CO_2} + \sum ER_{y,f} \times GWP_f \quad \textit{Eq. 24}$$

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_2)
$ER_{y,f}$	Net emissions in year *y* for climate forcer *f* (t *f*)
GWP_f	Global warming potential over 100 years (GWP 100) for climate forcer *f* (t CO_2e/t *f*, use IPCC AR6 values)[7]

The RF reduction over time horizon is calculated as follows:

$$R_{CO_2fe,y} = \sum RF(ER_{y,f}) \quad \textit{Eq. 25}$$

Where:

$R_{CO_2fe,y}$	Climate forcer *f* reduction due to project activities in year *y* (t CO_2fe)
$ER_{y,f}$	Net emissions in year *y* for climate forcer *f* (t *f*)
$RF(ER_{y,f})$	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.*

NOTE: The function for determining RF is described in Appendix A of the Registry Standard.
NOTE: This equation accounts for accumulated GHG reductions over the time horizon.

Additional details for calculating radiative forcing can be found in the Registry Standard. Radiative forcing shall also be calculated in W/m^2 or a derivative unit, as described in GHR Registry Standard Section 4.1.3.

6.5 Conservative Assumptions and Estimates

For projects implementing dietary modifications, the estimation of methane reduction is based on referenced data specific to the feed types and additives used. When calculating baseline and project emissions, conservative values for feed conversion efficiency and methane yield shall be applied,

[7] 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.

particularly where feed quality or livestock response may vary. The IPCC (2019)[8], provides default values for methane yield under different feeding regimes.

In scenarios where multiple feed additives or changes in diet composition are introduced, the cumulative impact on methane emissions is estimated conservatively by applying the lower end of methane reduction efficiency for each feed additive administered, unless robust scientific evidence is available to demonstrate an additive or synergistic effect between them. This approach accounts for potential variability in livestock response to feed additives and ensures that the emission reductions are not overstated.

For project activities involving the use of specific feed additives known to reduce methane production, emissions of residual methane to account for potential trade-offs or uncertainties when implementing feed additives and associated greenhouse gases (e.g., CO_2) from inefficiencies in feed utilization are estimated to be 10% of the maximum potential methane production reduction. This default value may be adjusted based on the project's specific conditions and available data. If project-specific measurements indicate a lower inefficiency, this value may be adjusted accordingly, provided the adjustment is justified with robust evidence.

6.6 Methods of Determining Uncertainty

Uncertainties may originate from estimated values and limitations in the accuracy of the systems used to monitor the enteric methane produced from the fermentation processes within the ruminants. These uncertainties affect the baseline scenario, the quantification of enteric methane released, and the factors considered in the project emissions calculations. 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 RF 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 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 make a quantitative assessment of any co-benefits and trade-offs using the *Methodology Standard for Stressor-Effects Life Cycle Assessment (SCS-002)* or an alternative ISO-14044-compliant life-cycle assessment standard. Verified claims related to co-benefits, trade-offs, and

[8] **IPCC (2019)**. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4, Agriculture, Forestry and Other Land Use, Chapter 10: Emissions from Livestock and Manure Management*.

corresponding United Nations Sustainable Development Goals (SDGs) are only permissible when the project has undergone a quantitative assessment for each relevant impact category.

Table 2 contains a list of potential co-benefit and trade-off impact categories relevant to this Methodology. Table 3 provides a list of specific SDG targets related to these impact categories.

Table 2. Potential Co-benefits and Trade-offs

Impact Group	Impact Category	Enter Yes if applicable, No if not applicable	
		Potential Co-benefits	Potential Trade-off
Resource Depletion Group	Non-Renewable Energy Resource Depletion	No	No
	Net Freshwater Consumption	No	No
	Biotic Resource Depletion	No	No
Ocean Ecosystem Impacts Group	Ocean Acidification	Yes	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 (from Land Use and Conversion)	Terrestrial Disturbance	No	No
	Freshwater Disturbance	No	No
	Threatened Species Impacts	No	No
Human Health Impacts (from Chronic Exposures to Hazardous Substances)	Ground Level Ozone Exposure Impacts	Yes	No
	PM2.5 Exposure Impacts	No	No
	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

Table 3. Associated Sustainable Development Goals 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
9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities
13. Take urgent action to combat climate change and its impacts	13.2	Integrate climate change measures into national policies, strategies and planning
14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.3	Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

7 Reporting Requirements

7.1 Project Design Document

A Project Design Document (PDD) is required to be developed by the project proponent prior to validation and verification. PDDs must meet the requirements of the Registry Standard and this methodology, using GHR's PDD Template. PDDs are subject to approval by GHR prior to registration in the GHR Registry.

The PDD shall 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 LCAs). Redaction shall be at the sole choice of GHR, but such permission will not be unreasonably withheld. However, all information is subject to validation and verification requirements.

7.2 Documentation and Monitoring

The project proponent shall submit a detailed Project Monitoring Plan as part of the PDD. The monitoring plan facilitates the gathering of pertinent data needed for:

Confirming the fulfilment of the eligibility requirements

- Confirming the climate forcer emissions or amounts associated with the project and baseline scenarios

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. In cases where such methods and procedures are not known or accessible, the project proponent shall 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.

The monitoring plan must include the on-site inspections for each of the individual farms included in the project boundary where the project activity is/will be implemented for each verification period.

If Option 1 is chosen for baseline emission determination:

- The project monitoring plan must detail the system used for monitoring the livestock population (N_{LT}) and the type of livestock involved in the project. The Project Monitoring Plan must include records of the specific breeds or genetic sources of the livestock, ensuring consistency with the emission factors ($EF_{CH4,LT}$) applied.

- The feed types and quality used during the baseline scenario must be documented, with attention to any changes in feed composition that could affect methane emissions. The consistency between these feed records (minimum of previous 3 years of data to be submitted) and indirect data (such as records of feed purchases, feed formulations, and animal health reports) must be evaluated. Significant deviations in feed quality or livestock type shall be explained and justified.

- If default emission factors from the IPCC or other recognized bodies are used, the monitoring plan must ensure that these factors are applicable to the specific conditions of the project. This includes verifying that the emission factors align with the type of feed, livestock, and management practices in the region.

If Option 2 is chosen for baseline emission determination:

- The Project Monitoring Plan must describe the system used for monitoring daily feed intake ($FI_{BL,LT}$ and $FI_{PJ,LT}$) and the specific feed composition provided to the livestock. Detailed records of feed types, amounts, and feeding schedules must be maintained, ensuring that the recorded data accurately reflects the baseline scenario.

- The methane conversion factor ($Ym_{BL,LT}$) used in the baseline calculations must be monitored by documenting the energy content of the feed (MJ/kg DM) and any changes in feed efficiency or livestock health that could influence methane production. The Project Monitoring Plan should include a procedure for cross-referencing these values with independent data sources, such as feed analysis reports or livestock performance metrics.

- Significant changes in livestock population (N_{LT}), feed intake, or feed quality must be recorded and explained. If the livestock population or feeding practices change significantly during the project, these changes must be reflected in the monitoring records, with adjustments made to ensure the baseline scenario remains representative of the original conditions to ensure calculation of baseline emissions on a per-animal basis. Additionally, for feedyards, where herd occupancy (head-days) fluctuates due to market conditions, proponents must transparently document variations in the PDD. The methodology ensures reductions are calculated proportionally to the actual population and feed-additive implementation, thereby preventing overestimation of emission reduction credits.

- In cases where specific feed additives used for methane emission reduction during the enteric fermentation in the ruminants are introduced during the project, the monitoring plan must include a method for quantifying the impact of these changes on methane emissions, ensuring that the emission reductions claimed are based on actual measurements rather than estimates wherever active measurement of data points are feasible.

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. Redaction shall be at the sole discretion of GHR; however, such permission will not be unreasonably withheld. All information is 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-post* GHG emission reductions/removals and other RF reductions per vintage year.

The monitoring period for projects assessed under this methodology shall be at most two 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.

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 Crediting Issuance

Credits shall be issued after independent validation and verification that the requirements of this Methodology have been met. Credit issuance shall 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 shall 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 Registry. The Registry will record the details of each credit, including the project for which it was issued, the date it was issued, the retirement date and retirement location, the amount of net CO_2e it represents, CO_2e+ information (e.g., scope of analysis, co-benefit and trade-off information, climate benefits over various time horizons), and associated documentation.

All 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 6 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 reduction 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

A comprehensive list of GHR Registry-related terms and definitions can be found in the *GHR Glossary of Terms.* Additional terms and definitions pertaining to specific aspects of this Methodology are provided here.

Enteric Fermentation: The process by which methane is produced as a byproduct of digestion in the stomachs (rumen) of ruminant animals (e.g., cattle, sheep, goats). Microorganisms in the rumen break down feed, resulting in the production of methane, which is emitted primarily through eructation.

Baseline Scenario: The business-as-usual scenario representing the typical emissions from enteric fermentation in the livestock population in the absence of the project. It serves as the reference point against which the project's methane and other GHG emission reductions are measured.

Methane (CH_4): A potent greenhouse gas primarily produced through enteric fermentation in ruminants. Methane has a global warming potential (GWP) significantly higher than carbon dioxide (CO_2) and is a key climate forcer considered in this methodology.

Feed Conversion Efficiency: The efficiency with which livestock converts feed into body mass or production output (e.g., milk, meat). Improved feed conversion efficiency can lead to reduced methane and other GHG emissions per unit of livestock productivity.

Dietary/Feed Additives: Substances added to livestock feed that can influence the digestive process, often used to reduce methane production in ruminants. Common additives include fats, oils, tannins, and specific feed supplements designed to inhibit methane-producing microorganisms.

Methane Conversion Factor (Ym): A percentage that represents the portion of the gross energy intake from feed that is converted into methane during enteric fermentation. This factor varies depending on the type of feed.

Project Area: The area within the project boundary where livestock management and feed additives are implemented. This area includes all locations where the project's activities, such as feeding, housing, and monitoring of livestock, take place.

Climate Forcer: Any external driver of climate change that causes a positive or negative change in radiative forcing (RF). In the context of enteric fermentation, methane (CH_4) is the primary climate forcer, given its significant impact on global warming.

Livestock Population (N_{LT}): The total number of livestock within the project boundary, categorized by livestock type (e.g., cattle, sheep). Monitoring changes in livestock population is critical for accurate baseline and project emissions calculations.

Acronyms and Abbreviations:

3-NOP: 3-nitrooxypropanol

BE: Baseline Emissions

CH_4: Methane

CO_2: Carbon Dioxide

CO_2e: Carbon Dioxide Equivalents

EF: Emission Factor

GHG: Greenhouse Gas

GHR: Global Heat Reduction

GWP: Global Warming Potential

IPCC: Intergovernmental Panel on Climate Change

kg DM: Kilograms Dry Matter

LT: Livestock Type

N_2O: Nitrous oxide

PDD: Project Design Document

PE: Project Emissions

QA/QC: Quality Control/Quality Assurance

RF: Radiative Forcing

Registry: Global Heat Reduction Registry

SDG: United Nations Sustainable Development Goal

SOP: Standard Operating Procedure

SSR: Sources, Sinks, and Reservoir

t: tonne

VVB: Validation and Verification Body

VS: Volatile Solids

Appendix A: Data and Parameters

1. Monitored Data and Parameters

The information provided below is consistent with the Registry Standard, including Normative Appendix A, *Calculating Project-Related Radiative Forcing Values*.

Data/Parameter:	$N_{LT,y}$
Data Unit:	Number (Head)
Description:	Total number of animals in each livestock type *LT* in year *y* within the project boundary
Source(s) of data:	Livestock management system in the project area
Description of measurement methods and procedures to be applied:	Annual headcount audits and ongoing livestock inventory management
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	Verification through on-site inspections and livestock logs
Comments:	Essential for calculating the emissions based on livestock population

Data/Parameter:	$FI_{BL,LT,y}$
Data Unit:	Kilograms dry matter per head per day
Description:	Average daily feed intake per livestock type *LT* in year *y* in the baseline *BL* scenario
Source(s) of data:	Feed delivery logs and consumption records
Description of measurement methods and procedures to be applied:	Monitoring of feed delivery and consumption recorded daily
Frequency of monitoring/ recording:	Daily monitoring, aggregated monthly
QA/QC procedures to be applied:	Cross-checking feed log entries with physical inventory
Comments:	Directly influences calculations for methane emissions from enteric fermentation

Data/Parameter:	$VS_{LT,y}$
Data Unit:	kg of volatile solids per head
Description:	Annual average excretion of volatile solids by each livestock type *LT* in year *y*, used for manure management calculations
Source(s) of data:	Manure management records, laboratory analysis, IPCC 2019
Description of measurement methods and procedures to be applied:	Collection of manure samples for laboratory analysis to determine volatile solid content
Frequency of monitoring/ recording:	Annually

QA/QC procedures to be applied:	Laboratory analysis of manure samples for volatile solid content using periodic sampling or composite samples from multiple feed batches to reflect conditions
Comments:	To calculate methane and nitrous oxide emissions from manure management systems

Data/Parameter:	$AWM_{S,LT,y}$
Data Unit:	Percentage (%)
Description:	Fraction of total annual volatile solids excreted that is managed in each specific manure management system *S* for livestock group *LT* in year *y*
Source(s) of data:	Manure management plan and operational records
Description of measurement methods and procedures to be applied:	Review of manure management practices and systems in place
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	Review of manure management practices and systems in place
Comments:	To accurately calculate emissions from different manure management systems

Data/Parameter:	$Nex_{LT,y}$
Data Unit:	kg of nitrogen per head
Description:	Total nitrogen excreted per head for livestock type *LT* in year *y*, critical for calculating nitrogen-related emissions from manure
Source(s) of data:	Livestock feeding records and nutritional analyses
Description of measurement methods and procedures to be applied:	Nutritional analysis of feed and excretion rates based on livestock type and diet
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	Regular nutritional analysis of livestock feed and verification of calculation models
Comments:	Used for determining the nitrogen load in manure management calculations

Data/Parameter:	FM_{cdg}
Data Unit:	Percentage (%)
Description:	Fraction of the co-digestate material used in a specific manure management system, affecting nutrient management and emission calculations
Source(s) of data:	Biogas plant operation logs and manure management records
Description of measurement methods and procedures to be applied:	Tracking and recording the usage and distribution of co-digestate from biogas plants
Frequency of monitoring/ recording:	As each batch of co-digestate is produced and used

QA/QC procedures to be applied:	Monitoring and verification of co-digestate volumes and distribution records
Comments:	Key parameter for managing nutrient flows and emissions in biogas-driven manure management systems

Data/Parameter:	$VS_{S,LT,y}$
Data Unit:	kg of volatile solids
Description:	Annual excretion of volatile solids by livestock type *LT* using manure management system *S* in year *y*, aggregated across the entire herd or project boundary for reporting purposes
Source(s) of data:	Manure management system records and animal health monitoring
Description of measurement methods and procedures to be applied:	Collection and analysis of manure samples to quantify volatile solids content, and references from IPCC 2019.
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	Periodic sampling and laboratory testing for volatile solids content
Comments:	Critical for calculating emissions from specific manure management systems

Data/Parameter:	$FI_{S,y}$
Data Unit:	Kg DM per day
Description:	Daily feed intake for animals producing manure that results in biogas in system *S* during year *y*
Source(s) of data:	Biogas production and livestock feeding records
Description of measurement methods and procedures to be applied:	Monitoring the quantity fed to livestock as part of their daily ration
Frequency of monitoring/ recording:	Daily
QA/QC procedures to be applied:	Calibration of feeding equipment and regular audits of feeding records
Comments:	Important for assessing the impact of co-digestate on livestock diet and subsequent methane production

Data/Parameter:	$TM_{add\_transport,y}$
Data Unit:	Tonnes (t) or other mass unit as appropriate
Description:	Total mass of feed additive transported to the project site during year *y*
Source(s) of data:	Supply chain records and transportation invoices
Description of measurement methods and procedures to be applied:	Verification of delivery receipts and cross-referencing with supply orders
Frequency of monitoring/ recording:	Recorded with each delivery; aggregated annually

QA/QC procedures to be applied:	Audit of supply chain records and confirmation with feed additive suppliers
Comments:	Used to estimate emissions from the transportation of feed additive, an important factor in overall project emissions.

Data/Parameter:	$D_{k,y}$
Data Unit:	Km or other distance unit as appropriate
Description:	Total distance covered by transport vehicle *k* during year *y*, related to project activities
Source(s) of data:	Vehicle logs and fleet management software
Description of measurement methods and procedures to be applied:	Tracking of all vehicle movements via onboard GPS systems
Frequency of monitoring/ recording:	Continuously recorded; summarized annually
QA/QC procedures to be applied:	Regular maintenance of tracking systems and audit of vehicle logs
Comments:	Crucial for calculating transportation-related emissions for the project

Data/Parameter:	$FI_{PJ,LT,y}$
Data Unit:	Kg DM per head per day
Description:	Average daily total feed intake for livestock group *LT* during year *y*, critical for calculating nutrient intake and associated project emissions
Source(s) of data:	Feed distribution logs, farm management software
Description of measurement methods and procedures to be applied:	Daily monitoring of feed allocation and consumption recorded by farm staff
Frequency of monitoring/ recording:	Daily tracking, summarized monthly and annually
QA/QC procedures to be applied:	Verification of feed measurements and calibration of feed scales
Comments:	Accurate tracking ensures precise calculation of emissions from enteric fermentation and nutrient management

Data/Parameter:	$Ex_{N,LT,y}$
Data Unit:	kg of nitrogen per kg crude protein
Description:	Total nitrogen *N* excreted per kg of crude protein intake by each animal in group *LT* in year *y*, important for nutrient management and emission calculations from manure, aggregated across all livestock types and the project boundary for reporting purposes
Source(s) of data:	Livestock dietary and excretion studies, on-farm measurements. If unavailable, then IPCC Tier 2 equations and NASEM equations can be utilized.

Description of measurement methods and procedures to be applied:	Analysis of dietary intake and waste output, using standardized coefficients for nitrogen excretion based on animal type and diet
Frequency of monitoring/ recording:	Annually, with periodic reviews during dietary changes or shifts in livestock composition
QA/QC procedures to be applied:	Cross-referencing data with nutritional analyses and empirical waste assessments
Comments:	Provides foundational data for managing nitrogen flows and calculating related emissions in manure management systems

Data/Parameter:	$EX_{VS,LT,y}$
Data Unit:	kg of VS per kg crude protein
Description:	Total kilogram of volatile solids excreted per kilogram of crude protein intake by each animal in group *LT* in year *y*
Source(s) of data:	Manure management system records and animal health monitoring
Description of measurement methods and procedures to be applied:	Collection and analysis of manure samples to quantify volatile solids content, and references from IPCC 2019
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	Periodic sampling and laboratory testing for volatile solids content
Comments:	Critical for calculating emissions from specific manure management systems

Data/Parameter:	$N_{DA,LT,y}$
Data Unit:	Days
Description:	Number of days alive *DA* of animals in group *LT* and fed a specific diet during the year *y*, important for calculations involving dietary changes and their impact on emissions
Source(s) of data:	Farm feeding logs and diet management systems
Description of measurement methods and procedures to be applied:	Daily logging of animal diets and duration of each diet regimen
Frequency of monitoring/ recording:	Continuously tracked throughout the year
QA/QC procedures to be applied:	Routine audits of feeding records and verification against delivery receipts of diet components
Comments:	Vital for tracking the effectiveness of diet-based emission reduction strategies in livestock management

Data/Parameter:	$N_{cdg,cont}$
Data Unit:	Percentage (%)

Description:	Percentage of nitrogen content in the co-digestate *cdg* material produced from biogas operations, essential for nutrient management in agriculture
Source(s) of data:	Biogas production facility reports and laboratory analysis
Description of measurement methods and procedures to be applied:	Laboratory analysis of co-digestate samples to determine nitrogen content
Frequency of monitoring/ recording:	Sampled with each batch of co-digestate produced
QA/QC procedures to be applied:	Regular calibration of laboratory equipment and cross-checking results with established standards
Comments:	Critical for adjusting fertilizer use and managing soil health effectively in agricultural applications of co-digestate

Data/Parameter:	$AWM_{S,LT,y}$
Data Unit:	Percentage (%)
Description:	Fraction of nitrogen excreted by livestock type *LT* that is managed in manure management system *S* during year *y*
Source(s) of data:	Manure management records and nitrogen balance studies sourced from credible peer-reviewed literature or internationally recognized guidelines, such as the IPCC 2019 guidelines
Description of measurement methods and procedures to be applied:	Analysis of nitrogen flow within manure systems based on livestock type and management practices
Frequency of monitoring/ recording:	Annually
QA/QC procedures to be applied:	Verification of nitrogen management practices and cross-checking with nutrient management plans
Comments:	Essential for calculating nitrogen emissions from manure management systems and compliance with nutrient management regulations

Data/Parameter:	$FI_{add,i,y}$
Data Unit:	Kg feed additive i
Description:	Feed intake for feed additive *i* under project conditions in the year *y*
Source(s) of data:	Farm feeding logs and diet management systems
Description of measurement methods and procedures to be applied:	Daily logging of animal diets and duration of each diet regimen
Frequency of monitoring/ recording:	Continuously tracked throughout the year
QA/QC procedures to be applied:	Routine audits of feeding records and verification against delivery receipts of diet components
Comments:	Vital for tracking the effectiveness of diet-based emission reduction strategies in livestock management

2. Non-Monitored Data and Parameters

The information provided below is consistent with the Registry Standard, including Normative Appendix A, Calculating Project-Related Radiative Forcing Values.

Data/Parameter:	$Ym_{BL,LT}$
Data Unit:	Percentage (%)
Description:	Baseline *BL* methane conversion factor for each livestock type *LT*, indicating the proportion of feed energy converted into methane
Source(s) of data:	IPCC 2019 guidelines, research publications with country-specific values
QA/QC procedures to be applied:	Validation against contemporary research and recalibration with controlled feeding trials
Comments:	Essential for accurate methane emission calculations from enteric fermentation

Data/Parameter:	$EF_{CH4,S,LT,y}$
Data Unit:	kg CH_4 per kg volatile solids
Description:	Emission factor for methane emissions from manure management system *S* for livestock type *LT* in year *y*
Source(s) of data:	IPCC 2019 guidelines, research publications with country-specific values
QA/QC procedures to be applied:	Validation against sector-specific studies and emission reporting guidelines
Comments:	Used to estimate methane emissions from manure management systems

Data/Parameter:	GE_{feed}
Data Unit:	MJ/kg DM
Description:	Gross energy content of the feed consumed per unit of dry matter, as per published default values
Source(s) of data:	Default values published in IPCC 2019 Guidelines (e.g., 18.45 MJ/kg DM for standard ruminant feed)
Description of measurement methods and procedures to be applied:	Document the type of feed and its source clearly to match the corresponding IPCC value.
Frequency of monitoring/ recording:	Reviewed annually or updated whenever significant changes to feed composition occur.
QA/QC procedures to be applied:	Verify that the chosen values align with IPCC 2019 or other peer-reviewed literature. Retain records of feed types and corresponding gross energy values for audit purposes.

Comments:	Default IPCC 2019 values to be applied to ensure consistency and avoid measurement discrepancies. No laboratory analysis is required.

Data/Parameter:	GE_{add}
Data Unit:	MJ/kg DM
Description:	Gross energy content of the feed with feed additive
Source(s) of data:	Default values published in IPCC 2019 Guidelines (e.g., 18.45 MJ/kg DM for standard ruminant feed) and scientific literature for feed additives
Description of measurement methods and procedures to be applied:	Document the type of feed additive introduced with the feed, and its source clearly to match the corresponding IPCC value
Frequency of monitoring/ recording:	Reviewed annually or updated whenever significant changes to feed composition or additives occur
QA/QC procedures to be applied:	Verify that the chosen values align with IPCC 2019 or other peer-reviewed literature. Retain records of feed types and corresponding gross energy values for audit purposes.
Comments:	Default IPCC 2019 values corresponding the feed and feed additive to be applied to ensure consistency and avoid measurement discrepancies. No laboratory analysis is required.

Data/Parameter:	$DM_{LT,y}$
Data Unit:	Dimensionless
Description:	Dry matter content of the feed for livestock type *LT* in year *y*
Source(s) of data:	IPCC 2019
QA/QC procedures to be applied:	Verify that the chosen values align with other peer-reviewed literature if available. Retain records of feed types and corresponding gross energy values for audit purposes.
Comments:	

Data/Parameter:	CF_N
Data Unit:	kgN per kg DM
Description:	Conversion factor to express the nitrogen content per unit dry matter (kg N/kg DM) based on the protein-to-nitrogen ratio specific to the feed as in IPCC 2019
Source(s) of data:	IPCC 2019
QA/QC procedures to be applied:	Cross verification with existing peer reviewed literature
Comments:	-

Data/Parameter:	$CP_{LT,y}$
Data Unit:	Kg crude protein per kg dry matter
Description:	Crude protein content of the feed consumed by livestock type *LT* in year *y*
Source(s) of data:	IPCC 2019 Refinement and related agricultural guidelines that provide typical ranges or default values for various feed categories.
QA/QC procedures to be applied:	Cross verification with existing peer reviewed literature
Comments:	

Data/Parameter:	$MCF_{S,LT,y}$
Data Unit:	Percentage (%)
Description:	Methane conversion factor from manure management system *S* for each livestock type *LT* in year *y*, indicating the proportion of feed energy converted into methane
Source(s) of data:	IPCC 2019 guidelines, research publications with country-specific values
QA/QC procedures to be applied:	Validation against contemporary research and recalibration with controlled feeding trials
Comments:	Essential for accurate methane emission calculations from enteric fermentation

Data/Parameter:	$EF_{k,y,f}$
Data Unit:	tF *f* per ton-km (or mass and distance unit as appropriate)
Description:	Emission factor for climate forcer *f*, for transport vehicle *k* used in year *y*
Source(s) of data:	Transportation sector studies and regulatory emissions data
QA/QC procedures to be applied:	Validation against national emissions standards and updates in transportation regulations
Comments:	Necessary for accurate emissions accounting for different types of transportation involved in the project

Data/Parameter:	$B0_{LT}$
Data Unit:	kg CH_4 per tonne of volatile solids
Description:	Maximum potential of methane production per kg of volatile solid available from the waste of livestock type *LT*
Source(s) of data:	IPCC 2019 guidelines, research publications with country-specific values and empirical data from similar waste management settings

QA/QC procedures to be applied:	Peer review of adopted values and comparison with industry benchmarks
Comments:	Essential for the calculation of theoretical maximum methane emissions from managed waste

Data/Parameter:	$EF_{N2O, S,y}$
Data Unit:	kg N_2O-N per kg of nitrogen excreted
Description:	Nitrous oxide emission factor from manure management system *S* in year *Y*, used to calculate emissions from manure nitrogen content
Source(s) of data:	IPCC 2019 guidelines, research publications with country-specific values manure management studies
QA/QC procedures to be applied:	Cross-referencing IPCC values with project-specific conditions and manure management practices
Comments:	Essential for calculating N_2O emissions from manure management systems based on nitrogen flows

Data/Parameter:	$EF_{prod,i,f}$
Data Unit:	t *f* per kg of feed additive
Description:	The emission factor for climate forcer *f* for the production of feed ingredient *i*, including emissions from agricultural activities, processing, and any associated energy use
Source(s) of data:	Lifecycle assessments, agricultural emissions databases
QA/QC procedures to be applied:	Verification through LCA reports and periodic review of feed sourcing changes
Comments:	Important for estimating the GHG footprint of feed used in livestock production

Data/Parameter:	$Ym_{PJ,LT}$
Data Unit:	Percentage (%)
Description:	Project *PJ* methane conversion factor for each livestock type *LT*, indicating the proportion of feed energy converted into methane
Source(s) of data:	IPCC 2019 guidelines, research publications with country-specific values
QA/QC procedures to be applied:	Validation against contemporary research and recalibration with controlled feeding trials
Comments:	Essential for accurate methane emission calculations from enteric fermentation

Data/Parameter:	GWP_f

Data Unit:	t CO_2e/t *f*
Description:	The 100 year global warming potential (GWP) of climate forcer *f* (e.g., CH_4, N_2O, CO_2), used to convert different GHGs into CO_2 equivalents
Source(s) of data:	IPCC AR6 reports
QA/QC procedures to be applied:	Ensuring use of the most up-to-date GWP values as stipulated by relevant regulatory bodies
Comments:	Essential for converting emissions from different GHGs into a common unit (CO_2e) for reporting purposes

Appendix B: Project Risks for Consideration When Establishing Buffer Pool

The following is a list of potential events that could affect the validity of credits issued for projects in any given specific project category.

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

Version 1.0 (March 2025)